DIGITAL 2021

Advances on Societal Digital Transformation

ISBN: 978-1-61208-927-0

November 14 - 18, 2021

Athens, Greece

DIGITAL 2021 Editors

Wanwan Li, University of South Florida-Tampa, USA
Manuela Popescu, IARIA, USA/EU

DIGITAL 2021

Forward

Advances on Societal Digital Transformation (DIGITAL 2021), held between November 14 and November 18, 2021, initiated a series of international events covering a large spectrum of topics related to the digital transformation of our society.

The society is continuously changing with a rapid pace under digital transformation. Taking advantage of a solid transformation of digital communications and infrastructures and with great progress in AI (Artificial Intelligence), IoT (Internet of Thinks), ML (Machine Learning), Deep Learning, Big Data, Knowledge acquisition and Cognitive technologies, almost all societal areas were redefined. Transportation, Buildings, Factories, and Agriculture are now a combination of traditional and advanced technological features. Digital citizen-centric services, including health, well-being, community participation, learning and culture are now well-established and set to advance further on. As counter-effects of digital transformation, notably fake news, digital identity risks and the digital divide are also progressing in a dangerous rhythm, there is a major need for digital education, fake news awareness, and legal aspects mitigating sensitive cases.

We take here the opportunity to warmly thank all the members of the DIGITAL 2021 technical program committee, as well as all the reviewers. The creation of such a high-quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and effort to contribute to DIGITAL 2021. We truly believe that, thanks to all these efforts, the final conference program consisted of top-quality contributions. We also thank the members of the DIGITAL 2021 organizing committee for their help in handling the logistics of this event.

DIGITAL 2021 Chairs

DIGITAL 2021 Steering Committee

Adel Aneiba, Department of Networks and Cybersecurity (NCS), School of Computing and Digital Technology, Birmingham City University, UK
Fernando Joaquim Lopes Moreira, Universidade Portucalense, Portugal
Yunpeng (Jack) Zhang, University of Houston, USA
Wanwan Li, University of South Florida, USA

DIGITAL 2021 Publicity Chairs

Sandra Viciano Tudela, Universitat Politecnica de Valencia, Spain
Mar Parra Boronat, Universitat Politecnica de Valencia, Spain

DIGITAL 2021
Committee

DIGITAL 2021 Steering Committee
Adel Aneiba, Department of Networks and Cybersecurity (NCS), School of Computing and Digital Technology, Birmingham City University, UK
Fernando Joaquim Lopes Moreira, Universidade Portucalense, Portugal
Yunpeng (Jack) Zhang, University of Houston, USA
Wanwan Li, University of South Florida, USA

DIGITAL 2021 Publicity Chairs
Sandra Viciano Tudela, Universitat Politecnica de Valencia, Spain
Mar Parra Boronat, Universitat Politecnica de Valencia, Spain

DIGITAL 2021 Technical Program Committee
Qammer Abbasi, University of Glasgow, UK
Aaroud Abdessadek, Chouaib Doukkali University, Morocco
Kawiwat Amnatchotiphan, Rangsit University, Thailand
Daniel Amo Filvà, La Salle, Ramon Llull University, Spain
Mariia Andriyiivna Nazarkevych, Lviv Polytechnic National University, Ukraine
Adel Aneiba, Birmingham City University, UK
Mohamed Basel Almourad, Zayed University, United Arab Emirates
Louiza Bouallouche-Medjkoune, University of Bejaia, Algeria
An Braeken, Vrije Universiteit Brussel, Belgium
Roberta Calegari, University of Bologna, Italy
Jundong Chen, Dickinson State University, USA
Siming Chen, Fudan University, China
Marta Chinnici, ENEA, Rome, Italy
Mohamed Dahmane, CRIM – Computer Research Institute of Montreal, Canada
Babu R. Dawadi, Tribhuvan University, Nepal
Zakaria Abou El Houda, University of Montreal, Canada
Nikos Fakotakis, University of Patras, Greece
Fadi Farha, University of Science and Technology Beijing, China / Aleppo University, Syria
Nasim Ferdosian, Cergy Paris University, France
Ali Mohsen Frihida, University of Tunis El Manar, Tunisia
Andrea Gentili, University in Rome, Italy
Jing Gong, Uppsala University, Sweden
Teresa Guarda, CIST Research and Innovation Center | UPSE, Ecuador / ALGORITMI Research Centre of Minho University, Portugal
A S M Touhidul Hasan, University of Asia Pacific, Dhaka, Bangladesh
Kuan He, Apple Inc., USA
Md Shafaeat Hossain, Southern Connecticut State University, USA
Waheb A. Jabbar Al-Areeqi, UniversityMalaysia Pahang, Malaysia
Hassan A. Karimi, University of Pittsburgh, USA
Michał Kawulok, Silesian University of Technology, Poland
Sebastian Lawrenz, Institute for Software and Systems Engineering | TU Clausthal, Germany
Ahmed Lbath, Université Grenoble Alpes, France

Copyright Information

Table of Contents

Dimensions of Fake News

Paulina Schindler
Chair of Business Informatics,
Friedrich Schiller University Jena
Jena, Germany
e-mail: paulina.schindler@uni-jena.de

Marek Opuszko
Department of Business Administration, Ernst-Abbe Hochschule Jena, University of Applied Sciences
Jena, Germany
e-mail: marek.opuszko@eah-jena.de

Meena Stöbesand
Department of Business Administration, Ernst-Abbe Hochschule Jena, University of Applied Sciences
Jena, Germany
e-mail: meena.stoebesand@eah-jena.de

Abstract **- "Fake news" has become a common buzzword in public, political, and scientific debates. Whereas the definition of the term and its political consequences are often highlighted, this paper seeks to provide an overview of the development, the most common dimensions of fake news, and their mode of action. Research shows that fake news can trigger and act in conjunction with numerous effects that influence recipients. A comprehensive overview of these effects is given in this paper.**

Keywords - fake news; social media; misinformation; disinformation.

I. INTRODUCTION

In 1835, the New York Sun published a story by Richard Adam Locke saying that the renowned astronomer Sir John Herschel discovered life on the moon. The story was published for of a few days with new information about the discovery including the geography, lunar vegetation, and the inhabitants: bat-people. The story was reprinted by other papers and the New York Sun's circulation increased from about 4.000 daily sales to 19.000 [1]. Of course, the Great Moon Hoax was made up by Locke without the knowledge of Herschel who was not amused to see his name used [2]. Locke later explained that he intended to write a satire and never meant it to be a hoax; his goal was to mock the gullibility of Americans and their belief in extraterrestrial life [2]. Locke's famous news stunt would probably be called fake news today. In recent history, the term "fake news" is heavily associated with the emergence of social media or the role it played in the 2016 US general election [3]. Since the incident at a press conference in the White House on February 16, 2017, when the then President Donald Trump called CNN media representatives "fake news", refusing to allow any questions, the term has become a hot topic in the scientific discussion about modern and social media [4]. However, the frequent use and popularity of the term led to a more and more blurred understanding and vastly different interpretations among scholars and the general population, leaving it unclear as to what is considered fake news [5]. It is further unclear what mechanisms of action of fake news are prevalent in social media.

In order to grasp fake news as a whole, a comprehensive understanding of the associated mechanisms and dissemination methods is important. Above all, this is necessary to recognize all aspects and occurrences of false and misinformation in social media. This work aims to provide a uniform view and to deliver a basic systematization of all dimensions of fake news and its prevalence in modern media.

The rest of the paper is structured as follows. In order to classify the fuzzy concept of fake news, we will present the historical development of the term fake news in Section 2. In Section 3, we will discuss the methodology used to capture all dimensions of the phenomenon of fake news. We will present the results of a comprehensive literature and study analysis and characterize a total of 28 dimensions of fake news. In the final section, we evaluate the dangers of fake news, classify the results of this study, and provide an outlook for future studies.

II. THE DEVELOPMENT OF FAKE NEWS

The term "fake news" was recorded in lexicons in the USA as early as the late 19th century. Prior to that, the term "false news" was used [6]. Originally used to refer to made-up or false news [7], today the term "fake news" is also used to refer to false news on social media, to undermine work by news outlets [8] [9] or to describe fabricated news in satirical contributions [10]. Fake news is often described as intentionally deceptive [3][11]. Other sources also acknowledge the possibility that the dissemination of fake news may also happen unintentionally [6][12]. Apart from the pure intention to deceive, other motivations, such as political ideologies or financial goals, are sometimes also attributed to creators of fake news [3]. Similarly, some sources define fake news as being written in a way that has news characteristics [9][13]. For some authors, online dissemination is an important aspect of fake news [14] or even a characteristic of it [15], while other sources do not pay particular attention to it [6]. Some definitions require fake news to be completely false, i.e., to have no basis of fact underneath [3][16], which raises the issue of classifying half-truths and manipulating the context with a "core of truth". Tandoc et al. address this problem by distinguishing high and low levels of "facticity" [9]. Another approach to the argument is to call something "fake news" only if the intended deception has succeeded, otherwise, it is just fiction [9]. In a contrasting theory, fake news does not necessarily have to be believed in order to be considered as such [17]. In contrast to lies, fake news has less socially motivated purposes, such as protecting oneself or avoiding harm, but rather serves those who create it to achieve financial or political goals or to promote themselves [18].

It becomes clear that the definition of the term determines the time of recognition and what is counted as fake news; therefore, historical examples or its different types and sub-categories vary. In this work, the term fake news refers to the deliberate dissemination of erroneous information by the creator with the intent to deceive.

Examples of fake news could be documented in the pre-printing press era. While the invention of the printing press and the spread of literacy helped the spread of knowledge, it also resulted in its monetization [19]. Information became a commodity that could be produced, published, and sold in a high number of copies. Through the 17th century in France, false stories became very popular on printed broadsides: the so-called "canards" [19]. Progressing in history, mass media and the press have had an important role in the spread of hoaxes.

Fake news today differs from the historical examples due to the instant and global distribution through the new media and the "systemic ways in which fake news mobilizes our cognitive biases and heuristics" [20]. The motivations did not change, but they increased on a global level: young Macedonian people spreading fake news for the US election 2016 with no other interest than money, Donald Trump defining established mainstream media as "fake news" or the famous so-called "pizzagate" conspiracy theory which culminated in a shooting [10][20][21]. Spreading real or fake news through online media and social networks led to an enormous amount of information, making it more difficult to classify its validity. In addition, producers of fake news make use of the design of established news sources disguising their origin and intent [8]. Therefore, the consequences of fake news combined with social media are toxic and explosive because they make it possible for the creator to target an audience specifically and manipulate cognitive biases [20][22]. These dimensions of fake news, which can be direct effects of fake news or work in conjunction with them, are described next.

III. THE DIMENSIONS OF FAKE NEWS

To obtain information on the development and impact of fake news, first, a broad literature search was conducted via Google Scholar using the search terms "fake news" and "fake news effects". Since this search term delivers over half a million search results, the search was further narrowed down to results that deal with fake news and its effects on people. After reviewing over 500 articles, 28 different effects or mechanisms of action could be identified. To examine these more closely, a snowball and depth-first search was then carried out for each effect.

The creators of fake news often use various mechanisms or effects that work in conjunction with fake news and can make false information more effective for the recipient, amplify existing effects or immunize against counterarguments. These dimensions can be used by the creators of fake news. However, some dimensions that can play a significant role in the effectiveness of fake news are not necessarily used purposefully. Instead, these can result from the recipient's environment or handling of fake news. In TABLE I, common influential dimensions and effects in conjunction with fake news are listed and explained in alphabetical order according to their most common name (if available).

TABLE I. DIMENSIONS OF "FAKE NEWS".

Dimension	Explanation
Astroturfing	Astroturfing is an attempt to convey an incorrect impression of public opinion, e.g. by feigning that a large majority of people is in favor of a certain decision. In contrast to a "grassroots movement", however, the population is not actually behind it, but it is organized by a covert initiator [23]–[27]. Even though it is not a new phenomenon [28], astroturfing can spread more effectively by means of the Internet [29][30].
Availability Cascade	Individuals tend to adopt the views of others when those views gain popularity in their social environment [31]–[33]. Informational cascades and reputational cascades can make this possible through different motivations and may occur together [32].
Availability heuristic	The probability of events is measured by how available a similar event is in memory. So a recent or frequent reporting of certain events ensures that they are considered more likely [34]–[40]. This also applies if these reports are purely thought-provoking [41].
Backfire effect	It was found that subjects believed even more strongly in the original, incorrect information after it had been corrected [42][43]. It is assumed that this effect only occurs in specific situations, since it could not be proven with another experimental setup [44]–[47]. If judgements are formed immediately during reception, backfire effects can be reduced [48]. Research suggests that emotions may be relevant in this process [49]. Additional research is needed [50]. This can also be called "boomerang effect" [51][52].
Bandwagon effect	This refers to the assumption that if other people perceive something as good, it will also be judged good by oneself [53]–[55]. Own opinions are formed on the basis of other people's opinions. This phenomenon has also been observed in online reviews, for example [55][56].
Clickbait	Information gaps created by news titles arouse the potential reader's curiosity for the rest of the article. Often a forward reference is used, which refers to further information in the article [57]–[59]. This may increase the readership of an article but does not necessarily have further negative effects [60].
Confirmation bias	People unconsciously prefer information that coincides with their own opinion. If it does, they consider it more credible [61]–[66]. It is suspected that this contributes to the emergence of echo chambers and filter bubbles [67].
Conservatism bias	This refers to the tendency of individuals to inadequately adjust their attitudes when

	confronted with new information [64][68]–[70]. Thus, if a person already believes in fake news, their beliefs are difficult to correct.
Continued influence effect	Even the negation and correction of incorrect original information usually cannot completely reverse its effect. It continues to influence the recipient [71]–[76], even when warnings are given [77]. This effect is weakened if instead of a simple correction a suitable alternative explanation for a scenario is offered [78]. Partly this may be because recipients do not accept a correction [79]. This is also called "belief perseverance" [70][80].
Echo chamber effect	If users mainly interact with other users or institutions that have a similar opinion to their own, an echo chamber is created. The users thus reinforce each other's opinions [81]–[83]. The confirmation bias works in a similar way. Often, however, users are not completely isolated, but continue to be confronted with opposing content, especially online [84]–[87]. Thus, this effect may not be as strong as initially perceived.
Emotional memory enhancement	Emotionally charged information is better retained than neutral information [88]–[92]. Suggestion has an even stronger effect than pure emotionality [92].
Filter bubble	This term refers to information bubbles that are created in social media in particular and in which algorithms select or pre-filter content that is then displayed to the user. This content often corresponds to existing interests. Users are often unaware of the filter bubble [93]–[97]. Thus, no contrary opinions are displayed that could invalidate fake news. This effect is similar to echo chambers. It is still debated whether filter bubbles exist and are problematic as some evidence points against it [87][95][98][99].
Framing effect	Small changes in context or in the way information is conveyed can lead to a major change in decision-making behavior [100]–[102]. Emotions may be an important aspect of this [103][104]. The effect of framing can be reduced through warnings [105][106].
Google effect	People tend not to remember information in itself, but instead where it can be found when needed [107][108]. Thus, insufficient background knowledge of a person might not be enough to counter fake news.
Hostile media effect	Biased subjects feel disadvantaged by media coverage, even if a large proportion of recipients perceive it as appropriate [109]–[114]. The disadvantage is perceived to be unfavorable of one's own opinion. This may reduce belief in the correction of fake news by major news outlets.
Illusory truth effect	Statements that are heard several times are attributed a higher truth value than statements that are heard for the first time [115]–[118]. This means that repetition increases the probability that a statement will be considered true. This is true even if the plausibility of the statement is low [119] or in the case of warnings against it [120]. This effect is also referred to as the "validity effect" [121].
Implied truth effect	If other news is recognized or labeled as fake news, but one is not, it is more likely to be considered true [122]. However, this effect may be small [123].
Informational cascade	People who lack complete information on a subject may rely on the perceived beliefs of others [32][124]–[126]. A decision is made based on the decisions of others, even ignoring personal knowledge, expecting the crowd to be right. This is called an “informational cascade” or “information cascade”. This way, fake news can be propagated through a network. The strength of ties of a person to the other people in their group may influence their decision-making behavior [127]. Self-corrections by further cascades are possible [128].
Misdirecting	Misdirecting is employed when contextual hashtags are used in social media, but a completely different topic is being reported on [129]. To do this en masse, social bots can be used. This distracts from the actual topic and actual information is lost in the amount of news [130]. In another study, this could not be detected [131].
Misinformation effect	Untruthful reporting following an event damages the correct memory of that event [132]–[137]. Later corrections may be able to reduce that effect [138].
Negativity bias	People have a tendency to give more weight to negative information than to positive information [66][139]–[144].
Primacy effect & Recency effect	Information that a recipient takes in first has a stronger impact on them than the information that follows (primacy effect). Likewise, the information received last remains in the memory longer (recency effect) [145]–[149]. The primacy effect may be stronger than the recency effect [147]–[150].
Reputational cascade	Like with the informational cascade, people base their decisions on the decisions of their peers. However, here they do so regardless of their own thoughts because they are motivated to earn social approval and avoid disapproval [32][151][152]. Because of the perceived social pressure, this cascade may be more resilient than informational cascades [153].
Reputation heuristic	Instead of checking the content of a source’s information, the source itself is checked for credibility. If the source has a good reputation or is considered credible, the information is more likely to be believed [73][154]–[157]. If fake news creators succeed in imitating a credible source, their credibility increases.
Rumor refutation	Rumors on social media that are incorrect take longer to be resolved than true rumors. Unverified rumors are often shared earlier and reach a larger user base than resolved rumors [158][159].
Smoke screening	Smoke screening works like misdirecting with the difference that at least similar content to a hashtag is posted [129]–[131].
Tainted truth effect	Warnings of false information issued erroneously in relation to truthful content can damage the credibility of the truthful information [137][160][161].

Third person effect	People tend to believe that mass media influence other people more strongly than they influence themselves [162]–[167]. As a result, the influence of fake news on oneself can be underestimated.

Human memory can be affected by internal and external influences and is not infallible [92]. The effects of fake news that operate in this context are presented in this paper. Fake news can initially be an external influence with numerous associated effects on a person's perception. How strong the impact of these effects ultimately turns out also depends on the internal circumstances of this person. While some personal characteristics may support the effect of fake news, others weaken it. The susceptibility to fake news can be influenced, for example, by a tendency toward analytical thinking [168], skeptical attitudes [168], emotions [169], frequency of media use [3], conditions of one's own networks [3][168][173], age [170], and the culture from which someone comes [171][172]. Some effects may bypass some of these factors by operating at a low cognitive level [168].

Numerous other, even previously undiscovered or unexplored internal possibilities of influence by a subject's personality or attitude may exist. Thus, in addition to further investigation of the effects of fake news, a closer look at the recipients of fake news and their circumstances also offers research potential for the future.

IV. Conclusion

Fake news has been with mankind for a long time and has made multiple appearances in the past. Although the phenomenon of fake news may not be new, it is crucial to understand that the latest developments are a danger to democratic societies. In this work, the basis for the understanding of various phenomena in the field of fake news is laid in order to ensure a holistic view of the topic for future research projects. Fake news can be spread particularly easily and quickly through modern technologies such as social media. Furthermore, it is evident that fake news and its impact should be considered within the respective cultural, social and political contexts [10]. This makes the dimensions with which fake news works even more relevant for current discussions, even more so when emotions are considered more valuable than facts [21]. Since it has been shown that fake news can influence a person's opinion formation in numerous ways, a danger to opinion formation in society as a whole is possible. Therefore, especially regarding the aspects of opinion formation and freedom of expression, attention should be paid to fake news and, if necessary, its spread should be curbed. The dimensions of fake news presented in this paper can be used in further work and serve as a reference standard to better classify and categorize fake news effects in social media, but also beyond. In this way, further studies could investigate which effects are particularly prevalent in the various social media.

References

[1] B. Thornton, “The Moon Hoax: Debates About Ethics in 1835 New York Newspapers”, Journal of Mass Media Ethics, vol. 15, no. 2, pp. 89–100, 2000, doi: 10.1207/S15327728JMME1502.

[2] S. W. Ruskin, “A Newly-Discovered Letter of J.F.W. Herschel concerning the ‘Great Moon Hoax’,” Journal for the History of Astronomy, vol. 33, no. 1, pp. 71–74, 2002, doi: 10.1177/002182860203300108.

[3] H. Allcott and M. Gentzkow, “Social Media and Fake News in the 2016 Election,” Journal of Economic Perspectives, vol. 31, no. 2, pp. 211–236, 2017, doi: 10.1257/jep.31.2.211.

[4] J. Acosta, “How Trumps's 'fake news' rhetoric has gotten out of control”. [Online]. Available: https://edition.cnn.com/2019/06/11/politics/enemy-of-the-people-jim-acosta-donald-trump/index.html (retrieved: October, 2021).

[5] T. Quandt, L. Frischlich, S. Boberg, and T. Schatto-Eckrodt, “Fake News,” in The International Encyclopedia of Journalism Studies, T. P. Vos, F. Hanusch, D. Dimitrakopoulou, M. Geertsema-Sligh, and A. Sehl, Eds.: Wiley, 2019, pp. 1–6.

[6] C. McManus and C. Michaud, “Never Mind the Buzzwords: Defining Fake News and Post-Truth,” in Fake News - A Roadmap, King’s Centre for Strategic Communications and NATO Strategic Communications Centre of Excellence, Eds., Riga, London: King’s Centre for Strategic Communications; NATO Strategic Communications Centre of Excellence, 2018, pp. 14–20.

[7] C. Borchers, “‘Fake News’ Has Now Lost All Meaning”. [Online]. Available: https://www.washingtonpost.com/news/the-fix/wp/2017/02/09/fake-news-has-now-lost-all-meaning/?utm_term=.70fa3df16f17 (retrieved: August, 2020).

[8] I. Stavre and M. Puntí, “Fake News, Something New?,” Sociology and Anthropology, vol. 7, no. 5, pp. 212–219, 2019, doi: 10.13189/sa.2019.070504.

[9] E. C. Tandoc, Z. W. Lim, and R. Ling, “Defining ‘Fake News’,” Digital Journalism, vol. 6, no. 2, pp. 137–153, 2018, doi: 10.1080/21670811.2017.1360143.

[10] H. Wasserman, “Fake news from Africa: Panics, politics and paradigms,” Journalism, vol. 21, no. 1, pp. 3–16, 2020, doi: 10.1177/1464884917746861.

[11] M. Sullivan, “It’s time to retire the tainted term ‘fake news’”. [Online]. Available: https://www.washingtonpost.com/lifestyle/style/its-time-to-retire-the-tainted-term-fake-news/2017/01/06/a5a7516c-d375-11e6-945a-76f69a399dd5_story.html (retrieved: September, 2020).

[12] C. Wardle and H. Derakhshan, Information Disorder: Toward an Interdisciplinary Framework for Research and Policy Making: Council of Europe report DGI(2017)09. [Online]. Available: https://rm.coe.int/information-disorder-toward-an-interdisciplinary-framework-for-researc/168076277c (retrieved: August, 2020).

[13] B. D. Horne and S. Adali, “This Just In: Fake News Packs a Lot in Title, Uses Simpler, Repetitive Content in Text Body, More Similar to Satire than Real News,” Mar. 2017. [Online]. Available: http://arxiv.org/pdf/1703.09398v1 (retrieved: October, 2021).

[14] D. Klein and J. Wueller, “Fake News: A Legal Perspective,” Journal of Internet Law, vol. 20, no. 10, 1, 6-13, 2017.

[15] L. Bounegru, J. Gray, T. Venturini, and M. Mauri, A Field Guide To "Fake News" And Other Information Disorders: Zenodo, 2018.

[16] D. Paskin, “Real or Fake News: Who Knows?,” The Journal of Social Media in Society, vol. 7, no. 2, pp. 252–273, 2018.

[17] D. Fallis, “What Is Disinformation?,” Library Trends, vol. 63, no. 3, pp. 401–426, 2015, doi: 10.1353/lib.2015.0014.

[18] V. Perez-Rosas, B. Kleinberg, A. Lefevre, and R. Mihalcea, “Automatic Detection of Fake News,” Proceedings of the 27th International Conference on Computational Linguistics, pp. 3391–3401, 2018.

[19] J. M. Burkhardt, Combating fake news in the digital age. Chicago IL: ALA TechSource, 2017.

[20] A. Gelfert, “Fake News: A Definition,” Informal Logic, vol. 38, no. 1, pp. 84–117, 2018, doi: 10.22329/il.v38i1.5068.

[21] R. Jaster and D. Lanius, Die Wahrheit schafft sich ab: Wie Fake News Politik machen. Ditzingen: Reclam, 2019.

[22] J. Gorbach, “Not Your Grandpa’s Hoax: A Comparative History of Fake News,” American Journalism, vol. 35, no. 2, pp. 236–249, 2018, doi: 10.1080/08821127.2018.1457915.

[23] C. H. Cho, M. L. Martens, H. Kim, and M. Rodrigue, “Astroturfing Global Warming: It Isn’t Always Greener on the Other Side of the Fence,” J Bus Ethics, vol. 104, no. 4, pp. 571–587, 2011, doi: 10.1007/s10551-011-0950-6.

[24] F. B. Keller, D. Schoch, S. Stier, and J. Yang, “Political Astroturfing on Twitter: How to Coordinate a Disinformation Campaign,” Political Communication, vol. 37, no. 2, pp. 256–280, 2020, doi: 10.1080/10584609.2019.1661888.

[25] M. Kovic, A. Rauchfleisch, M. Sele, and C. Caspar, “Digital astroturfing in politics: Definition, typology, and countermeasures,” SComS, vol. 18, no. 1, 2018, doi: 10.24434/j.scoms.2018.01.005.

[26] K. Voss, “Grassrootscampaigning und Chancen durch neue Medien,” Aus Politik und Zeitgeschichte, vol. 19, pp. 28–33, 2010. [Online]. Available: https://www.bpb.de/apuz/32777/grassrootscampaigning-und-chancen- durch-neue-medien (retrieved: October, 2021).

[27] T. Zerback, F. Töpfl, and M. Knöpfle, “The disconcerting potential of online disinformation: Persuasive effects of astroturfing comments and three strategies for inoculation against them,” New Media & Society, vol. 23, no. 5, pp. 1080–1098, 2021, doi: 10.1177/1461444820908530.

[28] C. W. Lee, “The Roots of Astroturfing,” Contexts, vol. 9, no. 1, pp. 73–75, 2010, doi: 10.1525/ctx.2010.9.1.73.

[29] T. Chen et al., “A Hidden Astroturfing Detection Approach Base on Emotion Analysis,” in vol. 10412, Knowledge Science, Engineering and Management, G. Li, Y. Ge, Z. Zhang, Z. Jin, and M. Blumenstein, Eds., Cham: Springer International Publishing, 2017, pp. 55–66.

[30] K. Henrie and C. Gilde, “An Examination of the Impact of Astroturfing on Nationalism: A Persuasion Knowledge Perspective,” Social Sciences, vol. 8, no. 2, p. 38, 2019, doi: 10.3390/socsci8020038.

[31] . B. Barr, “An evidence based approach to sports concussion: confronting the availability cascade,” Neuropsychology review, vol. 23, no. 4, pp. 271–272, 2013, doi: 10.1007/s11065-013-9244-3.

[32] T. Kuran and C. R. Sunstein, “Availability Cascades and Risk Regulation,” Stanford Law Review, vol. 51, no. 4, p. 683, 1999, doi: 10.2307/1229439.

[33] T. Nogami, “Negative misconceptions about disaster behaviour through availability cascades: An examination of secondhand information and the moderating effect of trait anxiety on disaster myths,” J Community Appl Soc Psychol, vol. 30, no. 4, pp. 369–380, 2020, doi: 10.1002/casp.2441.

[34] J. Bos, M. Frömmel, and M. Lamers, “FDI, terrorism and the availability heuristic for U.S. investors before and after 9/11,” Maastricht University School of Business and Economics Research Memoranda. Maastricht University School of Business and Economics, 2013.

[35] V. S. Folkes, “The Availability Heuristic and Perceived Risk,” Journal of Consumer Research, vol. 15, no. 1, p. 13, 1988, doi: 10.1086/209141.

[36] M. Geurten, S. Willems, S. Germain, and T. Meulemans, “Less is more: The availability heuristic in early childhood,” The British journal of developmental psychology, vol. 33, no. 4, pp. 405–410, 2015, doi: 10.1111/bjdp.12114.

[37] L. H. Rubel, “The Availability Heuristic: A Redux,” Journal of Statistics Education, vol. 15, no. 2, 2007, doi: 10.1080/10691898.2007.11889467.

[38] N. Schwarz, H. Bless, F. Strack, G. Klumpp, H. Rittenauer-Schatka, A. Simons, “Ease of retrieval as information: Another look at the availability heuristic,” Journal of Personality and Social Psychology, vol. 61, no. 2, pp. 195–202, 1991, doi: 10.1037/0022-3514.61.2.195.

[39] A. Tversky and D. Kahneman, “Availability: A heuristic for judging frequency and probability,” Cognitive Psychology, vol. 5, no. 2, pp. 207–232, 1973, doi: 10.1016/0010-0285(73)90033-9.

[40] H. Yin, J. Chen, and E. Michel-Kerjan, “Availability Heuristic and Gambler's Fallacy over Time in a Natural Disaster Insurance Choice Setting,” SSRN Journal, 2016, doi: 10.2139/ssrn.2798371.

[41] J. S. Carroll, “The effect of imagining an event on expectations for the event: An interpretation in terms of the availability heuristic,” Journal of Experimental Social Psychology, vol. 14, no. 1, pp. 88–96, 1978, doi: 10.1016/0022-1031(78)90062-8.

[42] A. Cook, J. Arndt, and J. D. Lieberman, “Firing back at the backfire effect: the influence of mortality salience and nullification beliefs on reactions to inadmissible evidence,” Law and human behavior, vol. 28, no. 4, pp. 389–410, 2004, doi: 10.1023/B:LAHU.0000039332.21386.f4.

[43] B. Nyhan and J. Reifler, “When Corrections Fail: The Persistence of Political Misperceptions,” Polit Behav, vol. 32, no. 2, pp. 303–330, 2010, doi: 10.1007/s11109-010-9112-2.

[44] U. K. H. Ecker, S. Lewandowsky, and M. Chadwick, “Can corrections spread misinformation to new audiences? Testing for the elusive familiarity backfire effect,” Cognitive research: principles and implications, vol. 5, no. 1, p. 41, 2020, doi: 10.1186/s41235-020-00241-6.

[45] B. Swire, A. J. Berinsky, S. Lewandowsky, and U. K. H. Ecker, “Processing political misinformation: comprehending

the Trump phenomenon," Royal Society open science, vol. 4, no. 3, p. 160802, 2017, doi: 10.1098/rsos.160802.

[46] T. Wood and E. Porter, "The Elusive Backfire Effect: Mass Attitudes' Steadfast Factual Adherence," Polit Behav, vol. 41, no. 1, pp. 135–163, 2019, doi: 10.1007/s11109-018-9443-y.

[47] K. Haglin, "The limitations of the backfire effect," Research & Politics, vol. 4, no. 3, 205316801771654, 2017, doi: 10.1177/2053168017716547.

[48] C. Peter and T. Koch, "When Debunking Scientific Myths Fails (and When It Does Not)," Science Communication, vol. 38, no. 1, pp. 3–25, 2016, doi: 10.1177/1075547015613523.

[49] G. J. Trevors, K. R. Muis, R. Pekrun, G. M. Sinatra, and P. H. Winne, "Identity and Epistemic Emotions During Knowledge Revision: A Potential Account for the Backfire Effect," Discourse Processes, vol. 53, 5-6, pp. 339–370, 2016, doi: 10.1080/0163853X.2015.1136507.

[50] B. Swire-Thompson, J. DeGutis, and D. Lazer, "Searching for the Backfire Effect: Measurement and Design Considerations," Journal of applied research in memory and cognition, vol. 9, no. 3, pp. 286–299, 2020, doi: 10.1016/j.jarmac.2020.06.006.

[51] P. S. Hart and E. C. Nisbet, "Boomerang Effects in Science Communication," Communication Research, vol. 39, no. 6, pp. 701–723, 2012, doi: 10.1177/0093650211416646.

[52] D. J. Ringold, "Boomerang Effects in Response to Public Health Interventions: Some Unintended Consequences in the Alcoholic Beverage Market," Journal of Consumer Policy, vol. 25, no. 1, pp. 27–63, 2002, doi: 10.1023/A:1014588126336.

[53] R. Nadeau, E. Cloutier, and J.-H. Guay, "New Evidence About the Existence of a Bandwagon Effect in the Opinion Formation Process," International Political Science Review, vol. 14, no. 2, pp. 203–213, 1993, doi: 10.1177/019251219301400204.

[54] C. Marsh, "Back on the Bandwagon: The Effect of Opinion Polls on Public Opinion," Brit. J. Polit. Sci., vol. 15, no. 1, pp. 51–74, 1985, doi: 10.1017/S0007123400004063.

[55] S. S. Sundar, A. Oeldorf-Hirsch, and Q. Xu, "The bandwagon effect of collaborative filtering technology," in Proceeding of the twenty-sixth annual CHI conference extended abstracts on Human factors in computing systems - CHI '08, Florence, Italy, 2008, p. 3453.

[56] S. Knobloch-Westerwick, N. Sharma, D. L. Hansen, and S. Alter, "Impact of Popularity Indications on Readers' Selective Exposure to Online News," Journal of Broadcasting & Electronic Media, vol. 49, no. 3, pp. 296–313, 2005, doi: 10.1207/s15506878jobem4903_3.

[57] J. N. Blom and K. R. Hansen, "Click bait: Forward-reference as lure in online news headlines," Journal of Pragmatics, vol. 76, pp. 87–100, 2015, doi: 10.1016/j.pragma.2014.11.010.

[58] Y. Chen, N. J. Conroy, and V. L. Rubin, "Misleading Online Content," in Proceedings of the 2015 ACM on Workshop on Multimodal Deception Detection, Seattle Washington USA, 2015, pp. 15–19.

[59] M. Potthast, S. Köpsel, B. Stein, and M. Hagen, "Clickbait Detection," in Lecture Notes in Computer Science, Advances in Information Retrieval, N. Ferro et al., Eds., Cham: Springer International Publishing, 2016, pp. 810–817.

[60] K. Munger, M. Luca, J. Nagler, and J. Tucker, "The (Null) Effects of Clickbait Headlines on Polarization, Trust, and Learning," Public Opinion Quarterly, vol. 84, no. 1, pp. 49–73, 2020, doi: 10.1093/poq/nfaa008.

[61] M. Jones and R. Sugden, "Positive confirmation bias in the acquisition of information," Theory and Decision, vol. 50, no. 1, pp. 59–99, 2001, doi: 10.1023/A:1005296023424.

[62] C. S. Meppelink, E. G. Smit, M. L. Fransen, and N. Diviani, ""I was Right about Vaccination": Confirmation Bias and Health Literacy in Online Health Information Seeking," Journal of health communication, vol. 24, no. 2, pp. 129–140, 2019, doi: 10.1080/10810730.2019.1583701.

[63] H. Mercier and D. Sperber, "Why do humans reason? Arguments for an argumentative theory," The Behavioral and brain sciences, vol. 34, no. 2, 57-74; discussion 74-111, 2011, doi: 10.1017/S0140525X10000968.

[64] R. S. Nickerson, "Confirmation Bias: A Ubiquitous Phenomenon in Many Guises," Review of General Psychology, vol. 2, no. 2, pp. 175–220, 1998, doi: 10.1037/1089-2680.2.2.175.

[65] S. Schweiger, A. Oeberst, and U. Cress, "Confirmation bias in web-based search: a randomized online study on the effects of expert information and social tags on information search and evaluation," Journal of medical Internet research, vol. 16, no. 3, e94, 2014, doi: 10.2196/jmir.3044.

[66] T. G. L. A. van der Meer, M. Hameleers, and A. C. Kroon, "Crafting Our Own Biased Media Diets: The Effects of Confirmation, Source, and Negativity Bias on Selective Attendance to Online News," Mass Communication and Society, vol. 23, no. 6, pp. 937–967, 2020, doi: 10.1080/15205436.2020.1782432.

[67] D. Lazer et al., Combating Fake News: An Agenda for Research and Action. [Online]. Available: https:// shorensteincenter.org/wp-content/uploads/2017/05/ Combating-Fake-News-Agenda-for-Research-1.pdf (retrieved: October, 2021).

[68] W. Edwards, "Conservatism in Human Information Processing," in Judgment under uncertainty: heuristics and biases, D. Kahneman, P. SLOVIC, and A. Tversky, Eds., Cambridge: Cambridge University Press, 2001, pp. 359–369.

[69] M. Hilbert, "Toward a synthesis of cognitive biases: how noisy information processing can bias human decision making," Psychological bulletin, vol. 138, no. 2, pp. 211–237, 2012, doi: 10.1037/a0025940.

[70] D. S. Soper, "Informational Social Influence, Belief Perseverance, and Conservatism Bias in Web Interface Design Evaluations," IEEE Access, vol. 8, pp. 218765–218776, 2020, doi: 10.1109/ACCESS.2020.3042777.

[71] C. R. Brydges, G. E. Gignac, and U. K. Ecker, "Working memory capacity, short-term memory capacity, and the continued influence effect: A latent-variable analysis," Intelligence, vol. 69, pp. 117–122, 2018, doi: 10.1016/j.intell.2018.03.009.

[72] S. Connor Desai and S. Reimers, "Comparing the use of open and closed questions for Web-based measures of the continued-influence effect," Behavior research methods, vol. 51, no. 3, pp. 1426–1440, 2019, doi: 10.3758/s13428-018-1066-z.

[73] U. K. H. Ecker and L. M. Antonio, “Can you believe it? An investigation into the impact of retraction source credibility on the continued influence effect,” Memory & cognition, vol. 49, no. 4, pp. 631–644, 2021, doi: 10.3758/s13421-020-01129-y.

[74] U. K. H. Ecker, S. Lewandowsky, O. Fenton, and K. Martin, “Do people keep believing because they want to? Preexisting attitudes and the continued influence of misinformation,” Memory & cognition, vol. 42, no. 2, pp. 292–304, 2014, doi: 10.3758/s13421-013-0358-x.

[75] S. Lewandowsky, U. K. H. Ecker, C. M. Seifert, N. Schwarz, and J. Cook, “Misinformation and Its Correction: Continued Influence and Successful Debiasing,” Psychological science in the public interest : a journal of the American Psychological Society, vol. 13, no. 3, pp. 106–131, 2012, doi: 10.1177/1529100612451018.

[76] L. Ross, M. R. Lepper, and M. Hubbard, “Perseverance in self-perception and social perception: Biased attributional processes in the debriefing paradigm,” Journal of Personality and Social Psychology, vol. 32, no. 5, pp. 880–892, 1975, doi: 10.1037/0022-3514.32.5.880.

[77] U. K. H. Ecker, S. Lewandowsky, and D. T. W. Tang, “Explicit warnings reduce but do not eliminate the continued influence of misinformation,” Memory & cognition, vol. 38, no. 8, pp. 1087–1100, 2010, doi: 10.3758/MC.38.8.1087.

[78] H. M. Johnson and C. M. Seifert, “Sources of the continued influence effect: When misinformation in memory affects later inferences,” Journal of Experimental Psychology: Learning, Memory, and Cognition, vol. 20, no. 6, pp. 1420–1436, 1994, doi: 10.1037/0278-7393.20.6.1420.

[79] A. E. O'Rear and G. A. Radvansky, “Failure to accept retractions: A contribution to the continued influence effect,” Memory & cognition, vol. 48, no. 1, pp. 127–144, 2020, doi: 10.3758/s13421-019-00967-9.

[80] M. D. Cobb, B. Nyhan, and J. Reifler, “Beliefs Don't Always Persevere: How Political Figures Are Punished When Positive Information about Them Is Discredited,” Political Psychology, vol. 34, no. 3, pp. 307–326, 2013, doi: 10.1111/j.1467-9221.2012.00935.x.

[81] M. Cinelli, G. de Francisci Morales, A. Galeazzi, W. Quattrociocchi, and M. Starnini, “The echo chamber effect on social media,” Proceedings of the National Academy of Sciences of the United States of America, vol. 118, no. 9, 2021, doi: 10.1073/pnas.2023301118.

[82] E. Colleoni, A. Rozza, and A. Arvidsson, “Echo Chamber or Public Sphere? Predicting Political Orientation and Measuring Political Homophily in Twitter Using Big Data,” J Commun, vol. 64, no. 2, pp. 317–332, 2014, doi: 10.1111/jcom.12084.

[83] D. Goldie, M. Linick, H. Jabbar, and C. Lubienski, “Using Bibliometric and Social Media Analyses to Explore the “Echo Chamber” Hypothesis,” Educational Policy, vol. 28, no. 2, pp. 281–305, 2014, doi: 10.1177/0895904813515330.

[84] P. Barberá, J. T. Jost, J. Nagler, J. A. Tucker, and R. Bonneau, “Tweeting From Left to Right: Is Online Political Communication More Than an Echo Chamber?,” Psychological science, vol. 26, no. 10, pp. 1531–1542, 2015, doi: 10.1177/0956797615594620.

[85] E. Dubois and G. Blank, “The echo chamber is overstated: the moderating effect of political interest and diverse media,” Information, Communication & Society, vol. 21, no. 5, pp. 729–745, 2018, doi: 10.1080/1369118X.2018.1428656.

[86] R. K. Garrett, “The “Echo Chamber” Distraction: Disinformation Campaigns are the Problem, Not Audience Fragmentation,” Journal of applied research in memory and cognition, vol. 6, no. 4, pp. 370–376, 2017, doi: 10.1016/J.JARMAC.2017.09.011.

[87] F. J. Zuiderveen Borgesius, D. Trilling, J. Möller, B. Bodó, C. H. de Vreese, and N. Helberger, “Should we worry about filter bubbles?,” Internet Policy Review, vol. 5, no. 1, 2016, doi: 10.14763/2016.1.401.

[88] E. A. Kensinger and S. Corkin, “Memory enhancement for emotional words: are emotional words more vividly remembered than neutral words?,” Memory & cognition, vol. 31, no. 8, pp. 1169–1180, 2003, doi: 10.3758/BF03195800.

[89] T. Sommer, J. Gläscher, S. Moritz, and C. Büchel, “Emotional enhancement effect of memory: removing the influence of cognitive factors,” Learning & memory (Cold Spring Harbor, N.Y.), vol. 15, no. 8, pp. 569–573, 2008, doi: 10.1101/lm.995108.

[90] D. Talmi, “Enhanced Emotional Memory,” Curr Dir Psychol Sci, vol. 22, no. 6, pp. 430–436, 2013, doi: 10.1177/0963721413498893.

[91] D. Talmi and L. M. McGarry, “Accounting for immediate emotional memory enhancement,” Journal of Memory and Language, vol. 66, no. 1, pp. 93–108, 2012, doi: 10.1016/j.jml.2011.07.009.

[92] I. van Damme and K. Smets, “The power of emotion versus the power of suggestion: memory for emotional events in the misinformation paradigm,” Emotion (Washington, D.C.), vol. 14, no. 2, pp. 310–320, 2014, doi: 10.1037/a0034629.

[93] D. DiFranzo and K. Gloria-Garcia, “Filter bubbles and fake news,” XRDS, vol. 23, no. 3, pp. 32–35, 2017, doi: 10.1145/3055153.

[94] M. Emmer and C. Strippel, “Stichprobenziehung für Online-Inhaltsanalysen: Suchmaschinen und Filter Bubbles,” 2015.

[95] S. Flaxman, S. Goel, and J. M. Rao, “Filter Bubbles, Echo Chambers, and Online News Consumption,” Public Opinion Quarterly, vol. 80, S1, pp. 298–320, 2016, doi: 10.1093/poq/nfw006.

[96] T. T. Nguyen, P.-M. Hui, F. M. Harper, L. Terveen, and J. A. Konstan, “Exploring the filter bubble,” in Proceedings of the 23rd international conference on World wide web - WWW '14, Seoul, Korea, 2014, pp. 677–686.

[97] E. Pariser, Filter Bubble: Wie wir im Internet entmündigt werden. München: Hanser, Carl, 2012.

[98] A. Bruns, Are filter bubbles real? Cambridge, UK, Medford, USA: Polity, 2019.

[99] M. Haim, A. Graefe, and H.-B. Brosius, “Burst of the Filter Bubble?,” Digital Journalism, vol. 6, no. 3, pp. 330–343, 2018, doi: 10.1080/21670811.2017.1338145.

[100] S. Almashat, B. Ayotte, B. Edelstein, and J. Margrett, “Framing effect debiasing in medical decision making,” Patient education and counseling, vol. 71, no. 1, pp. 102–107, 2008, doi: 10.1016/j.pec.2007.11.004.

[101] H. Bless, T. Betsch, and A. Franzen, “Framing the framing effect: the impact of context cues on solutions to the ‘Asian disease’ problem,” Eur. J. Soc. Psychol., vol. 28, no. 2, pp.

287–291, 1998, doi: 10.1002/(SICI)1099-0992(199803/04)28:2%3C287::AID-EJSP861%3E3.0.CO;2-U.

[102] V. Stocké, Framing und Rationalität: Die Bedeutung der Informationsdarstellung für das Entscheidungsverhalten. Zugl.: Mannheim, Univ., Dissertationsschrift, 2000. München: De Gruyter Oldenbourg, 2002. [Online]. Available: http://www.degruyter.com/search?f_0=isbnissn&q_0=9783486833263&searchTitles=true (retrieved: October, 2021).

[103] C. J. Gosling and S. Moutier, "Is the framing effect a framing affect?," Quarterly journal of experimental psychology (2006), vol. 72, no. 6, pp. 1412–1421, 2019, doi: 10.1177/1747021818796016.

[104] S. Lecheler, A. R. T. Schuck, and C. H. de Vreese, "Dealing with feelings: Positive and negative discrete emotions as mediators of news framing effects," Communications - The European Journal of Communication Research, vol. 38, no. 2, 2013, doi: 10.1515/commun-2013-0011.

[105] F.F. Cheng and C.S. Wu, "Debiasing the framing effect: The effect of warning and involvement," Decision Support Systems, vol. 49, no. 3, pp. 328–334, 2010, doi: 10.1016/j.dss.2010.04.002.

[106] R. L. Nabi et al., "Can Emotions Capture the Elusive Gain-Loss Framing Effect? A Meta-Analysis," Communication Research, vol. 47, no. 8, pp. 1107–1130, 2020, doi: 10.1177/0093650219861256.

[107] B. Sparrow, J. Liu, and D. M. Wegner, "Google effects on memory: cognitive consequences of having information at our fingertips," Science (New York, N.Y.), vol. 333, no. 6043, pp. 776–778, 2011, doi: 10.1126/science.1207745.

[108] D. M. Wegner and A. F. Ward, "How Google is changing your brain," Scientific American, vol. 309, no. 6, pp. 58–61, 2013, doi: 10.1038/scientificamerican1213-58.

[109] L. M. Arpan and A. A. Raney, "An Experimental Investigation of News Source and the Hostile Media Effect," Journalism & Mass Communication Quarterly, vol. 80, no. 2, pp. 265–281, 2003, doi: 10.1177/107769900308000203.

[110] L. Feldman, "Partisan Differences in Opinionated News Perceptions: A Test of the Hostile Media Effect," Polit Behav, vol. 33, no. 3, pp. 407–432, 2011, doi: 10.1007/s11109-010-9139-4.

[111] A. C. Gunther and J. L. Liebhart, "Broad Reach or Biased Source? Decomposing the Hostile Media Effect," Journal of Communication, vol. 56, no. 3, pp. 449–466, 2006, doi: 10.1111/j.1460-2466.2006.00295.x.

[112] A. C. Gunther and K. Schmitt, "Mapping Boundaries of the Hostile Media Effect," Journal of Communication, vol. 54, no. 1, pp. 55–70, 2004, doi: 10.1111/j.1460-2466.2004.tb02613.x.

[113] S. A. Reid, "A Self-Categorization Explanation for the Hostile Media Effect," vol. 62, no. 3, pp. 381–399, 2012, doi: 10.1111/j.1460-2466.2012.01647.x.

[114] R. P. Vallone, L. Ross, and M. R. Lepper, "The hostile media phenomenon: Biased perception and perceptions of media bias in coverage of the Beirut massacre," Journal of Personality and Social Psychology, vol. 49, no. 3, pp. 577–585, 1985, doi: 10.1037/0022-3514.49.3.577.

[115] N. M. Brashier, E. D. Eliseev, and E. J. Marsh, "An initial accuracy focus prevents illusory truth," Cognition, vol. 194, p. 104054, 2020, doi: 10.1016/j.cognition.2019.104054.

[116] A. Hassan and S. J. Barber, "The effects of repetition frequency on the illusory truth effect," Cognitive research: principles and implications, vol. 6, no. 1, p. 38, 2021, doi: 10.1186/s41235-021-00301-5.

[117] J. de Keersmaecker et al., "Investigating the Robustness of the Illusory Truth Effect Across Individual Differences in Cognitive Ability, Need for Cognitive Closure, and Cognitive Style," Personality & social psychology bulletin, vol. 46, no. 2, pp. 204–215, 2020, doi: 10.1177/0146167219853844.

[118] E. J. Newman, M. C. Jalbert, N. Schwarz, and D. P. Ly, "Truthiness, the illusory truth effect, and the role of need for cognition," Consciousness and cognition, vol. 78, p. 102866, 2020, doi: 10.1016/j.concog.2019.102866.

[119] L. K. Fazio, D. G. Rand, and G. Pennycook, "Repetition increases perceived truth equally for plausible and implausible statements," Psychonomic bulletin & review, vol. 26, no. 5, pp. 1705–1710, 2019, doi: 10.3758/s13423-019-01651-4.

[120] G. Pennycook and D. G. Rand, "Who falls for fake news? The roles of bullshit receptivity, overclaiming, familiarity, and analytic thinking," Journal of personality, vol. 88, no. 2, pp. 185–200, 2020, doi: 10.1111/jopy.12476.

[121] L. E. Boehm, "The Validity Effect: A Search for Mediating Variables," Pers Soc Psychol Bull, vol. 20, no. 3, pp. 285–293, 1994, doi: 10.1177/0146167294203006.

[122] G. Pennycook, A. Bear, E. T. Collins, and D. G. Rand, "The Implied Truth Effect: Attaching Warnings to a Subset of Fake News Headlines Increases Perceived Accuracy of Headlines Without Warnings," Management Science, 2020, doi: 10.1287/mnsc.2019.3478.

[123] K. Clayton et al., "Real Solutions for Fake News? Measuring the Effectiveness of General Warnings and Fact-Check Tags in Reducing Belief in False Stories on Social Media," Polit Behav, vol. 42, no. 4, pp. 1073–1095, 2020, doi: 10.1007/s11109-019-09533-0.

[124] L. R. Anderson and C. A. Holt, "Information cascades in the laboratory," The American Economic Review, vol. 87, no. 5, pp. 847–862, 1997.

[125] S. Bikhchandani, D. Hirshleifer, and I. Welch, "A Theory of Fads, Fashion, Custom, and Cultural Change as Informational Cascades," Journal of Political Economy, vol. 100, no. 5, pp. 992–1026, 1992, doi: 10.1086/261849.

[126] M. Jalili and M. Perc, "Information cascades in complex networks," Journal of Complex Networks, 2017, doi: 10.1093/comnet/cnx019.

[127] F. Wang, J. Wei, and D. Zhao, "A Quantifiable Risky Decision Model: Incorporating Individual Memory into Informational Cascade," Syst. Res., vol. 31, no. 4, pp. 537–553, 2014, doi: 10.1002/sres.2294.

[128] J. K. Goeree, T. R. Palfrey, B. W. Rogers, and R. D. McKelvey, "Self-correcting information cascades," The review of economic studies, vol. 74, no. 3, pp. 733–762, 2007.

[129] Akademische Gesellschaft, How powerful are Social Bots? [Online]. Available: https://www.akademische-gesellschaft.com/fileadmin/webcontent/Publikationen/Communication_Snapshots/AGUK_

CommunicationSnapshot_SocialBots_June2018.pdf (retrieved: October, 2021).

[130] N. Abokhodair, D. Yoo, and D. W. McDonald, "Dissecting a Social Botnet," in Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing, Vancouver BC Canada, 2015, pp. 839–851.

[131] F. Brachten, S. Stieglitz, L. Hofeditz, K. Kloppenborg, and A. Reimann, "Strategies and Influence of Social Bots in a 2017 German state election - A case study on Twitter," Oct. 2017. [Online]. Available: http://arxiv.org/pdf/1710.07562v1 (retrieved: October, 2021).

[132] M. S. Ayers and L. M. Reder, "A theoretical review of the misinformation effect: Predictions from an activation-based memory model," Psychon Bull Rev, vol. 5, no. 1, pp. 1–21, 1998, doi: 10.3758/BF03209454.

[133] H. Blank and C. Launay, "How to protect eyewitness memory against the misinformation effect: A meta-analysis of post-warning studies," Journal of applied research in memory and cognition, vol. 3, no. 2, pp. 77–88, 2014, doi: 10.1016/j.jarmac.2014.03.005.

[134] K. A. Braun and E. F. Loftus, "Advertising's misinformation effect," Appl. Cognit. Psychol., vol. 12, no. 6, pp. 569–591, 1998, doi: 10.1002/(SICI)1099-0720(1998120)12:6%3C569::AID-ACP539%3E3.0.CO;2-E.

[135] E. Cowley and E. Janus, "Not Necessarily Better, but Certainly Different: A Limit to the Advertising Misinformation Effect on Memory," J CONSUM RES, vol. 31, no. 1, pp. 229–235, 2004, doi: 10.1086/383438..

[136] K. Lee, "Age, neuropsychological, and social cognitive measures as predictors of individual differences in susceptibility to the misinformation effect," Appl. Cognit. Psychol., vol. 18, no. 8, pp. 997–1019, 2004, doi: 10.1002/acp.1075.

[137] M. Szpitalak and R. Polczyk, "Warning against warnings: Alerted subjects may perform worse. Misinformation, involvement and warning as determinants of witness testimony," Polish Psychological Bulletin, vol. 41, no. 3, pp. 105–112, 2010, doi: 10.2478/v10059-010-0014-2.

[138] W. E. Crozier and D. Strange, "Correcting the misinformation effect," Appl. Cognit. Psychol., 2018, doi: 10.1002/acp.3499.

[139] R. F. Baumeister, E. Bratslavsky, C. Finkenauer, and K. D. Vohs, "Bad is Stronger than Good," Review of General Psychology, vol. 5, no. 4, pp. 323–370, 2001, doi: 10.1037/1089-2680.5.4.323.

[140] Y.-X. Huang and Y.-J. Luo, "Temporal course of emotional negativity bias: an ERP study," Neuroscience letters, vol. 398, 1-2, pp. 91–96, 2006, doi: 10.1016/j.neulet.2005.12.074.

[141] T. Ito and J. Cacioppo, "Variations on a human universal: Individual differences in positivity offset and negativity bias," Cognition & Emotion, vol. 19, no. 1, pp. 1–26, 2005, doi: 10.1080/02699930441000120.

[142] P. Rozin and E. B. Royzman, "Negativity Bias, Negativity Dominance, and Contagion," Pers Soc Psychol Rev, vol. 5, no. 4, pp. 296–320, 2001, doi: 10.1207/S15327957PSPR0504_2.

[143] S. Soroka and S. McAdams, "News, Politics, and Negativity," Political Communication, vol. 32, no. 1, pp. 1–22, 2015, doi: 10.1080/10584609.2014.881942.

[144] B. Wojciszke, H. Brycz, and P. Borkenau, "Effects of information content and evaluative extremity on positivity and negativity biases," Journal of Personality and Social Psychology, vol. 64, no. 3, pp. 327–335, 1993.

[145] H. A. Demaree, B. V. Shenal, D. E. Everhart, and J. L. Robinson, "Primacy and recency effects found using affective word lists," Cognitive and Behavioral Neurology: Official Journal of the Society for Behavioral and Cognitive Neurology, vol. 17, no. 2, pp. 102–108, 2004, doi: 10.1097/01.wnn.0000117861.44205.31.

[146] J. A. Krosnick and D. F. Alwin, "An Evaluation of a Cognitive Theory of Response-Order Effects in Survey Measurement," Public Opinion Quarterly, vol. 51, no. 2, p. 201, 1987, doi: 10.1086/269029.

[147] A. B. Morrison, A. R. A. Conway, and J. M. Chein, "Primacy and recency effects as indices of the focus of attention," Frontiers in human neuroscience, vol. 8, p. 6, 2014, doi: 10.3389/fnhum.2014.00006.

[148] J. Murphy, C. Hofacker, and R. Mizerski, "Primacy and Recency Effects on Clicking Behavior," J Comp Mediated Comm, vol. 11, no. 2, pp. 522–535, 2006, doi: 10.1111/j.1083-6101.2006.00025.x.

[149] C. Li, "Primacy effect or recency effect? A long-term memory test of Super Bowl commercials," Journal of Consumer Behaviour, n/a-n/a, 2009, doi: 10.1002/cb.291.

[150] P. H. Marshall and P. R. Werder, "The effects of the elimination of rehearsal on primacy and recency," Journal of Verbal Learning and Verbal Behavior, vol. 11, no. 5, pp. 649–653, 1972, doi: 10.1016/S0022-5371(72)80049-5.

[151] R. C. Ellickson, "The market for social norms," American Law and Economics Review: The Journal of the American Law and Economics Association, vol. 3, no. 1, pp. 1–49, 2001.

[152] C. R. Sunstein and R. Hastie, "Making dumb groups smarter," Harvard business review : HBR, vol. 92, no. 12, pp. 90–98, 2014. [Online]. Available: https://hbr.org/2014/12/making-dumb-groups-smarter (retrieved: October, 2021).

[153] P. Lemieux, "Following the Herd: Why do some ideas suddenly become popular, and then die out just as quickly?," Regulation : the Cato review of business and government, vol. 26, no. 4, pp. 16–21, 2003.

[154] R. Blom, "Believing false political headlines and discrediting truthful political headlines: The interaction between news source trust and news content expectancy," Journalism, vol. 22, no. 3, pp. 821–837, 2021, doi: 10.1177/1464884918765316.

[155] T. Buchanan and V. Benson, "Spreading Disinformation on Facebook: Do Trust in Message Source, Risk Propensity, or Personality Affect the Organic Reach of "Fake News"?," Social Media + Society, vol. 5, no. 4, 205630511988865, 2019, doi: 10.1177/2056305119888654.

[156] A. Kim, P. L. Moravec, and A. R. Dennis, "Combating Fake News on Social Media with Source Ratings: The Effects of User and Expert Reputation Ratings," Journal of Management Information Systems, vol. 36, no. 3, pp. 931–968, 2019, doi: 10.1080/07421222.2019.1628921.

[157] M. J. Metzger, A. J. Flanagin, and R. B. Medders, "Social and Heuristic Approaches to Credibility Evaluation Online," J

Commun, vol. 60, no. 3, pp. 413–439, 2010, doi: 10.1111/j.1460-2466.2010.01488.x.

[158] S. Vosoughi, D. Roy, and S. Aral, “The spread of true and false news online,” Science (New York, N.Y.), vol. 359, no. 6380, pp. 1146–1151, 2018, doi: 10.1126/science.aap9559.

[159] A. Zubiaga, M. Liakata, R. Procter, G. Wong Sak Hoi, and P. Tolmie, “Analysing How People Orient to and Spread Rumours in Social Media by Looking at Conversational Threads,” PloS one, vol. 11, no. 3, e0150989, 2016, doi: 10.1371/journal.pone.0150989.

[160] G. Echterhoff, S. Groll, and W. Hirst, “Tainted Truth: Overcorrection for Misinformation Influence on Eyewitness Memory,” Social Cognition, vol. 25, no. 3, pp. 367–409, 2007, doi: 10.1521/soco.2007.25.3.367.

[161] M. Freeze et al., “Fake Claims of Fake News: Political Misinformation, Warnings, and the Tainted Truth Effect,” Polit Behav, 2020, doi: 10.1007/s11109-020-09597-3.

[162] W. P. Davison, “The Third-Person Effect in Communication,” Public Opinion Quarterly, vol. 47, no. 1, p. 1, 1983, doi: 10.1086/268763.

[163] A. C. Gunther and P. Mundy, “Biased Optimism and the Third-Person Effect,” Journalism Quarterly, vol. 70, no. 1, pp. 58–67, 1993, doi: 10.1177/107769909307000107.

[164] A. Lev-On, “The third-person effect on Facebook: The significance of perceived proficiency,” Telematics and Informatics, vol. 34, no. 4, pp. 252–260, 2017, doi: 10.1016/j.tele.2016.07.002.

[165] R. M. Perloff, “Third-person effect research 1983–1992: A Review and Synthesis,” International Journal of Public Opinion Research, vol. 5, no. 2, pp. 167–184, 1993, doi: 10.1093/ijpor/5.2.167.

[166] H. Rojas, D. V. Shah, and R. J. Faber, “For the good of others: Censorship and the third-person effect,” International Journal of Public Opinion Research, vol. 8, no. 2, pp. 163–186, 1996, doi: 10.1093/ijpor/8.2.163.

[167] Y. Sun, L. Shen, and Z. Pan, “On the Behavioral Component of the Third-Person Effect,” Communication Research, vol. 35, no. 2, pp. 257–278, 2008, doi: 10.1177/0093650207313167.

[168] G. Pennycook and D. G. Rand, “Lazy, not biased: Susceptibility to partisan fake news is better explained by lack of reasoning than by motivated reasoning,” Cognition, vol. 188, pp. 39–50, 2019, doi: 10.1016/j.cognition.2018.06.011.

[169] B. E. Weeks, “Emotions, Partisanship, and Misperceptions: How Anger and Anxiety Moderate the Effect of Partisan Bias on Susceptibility to Political Misinformation,” J Commun, vol. 65, no. 4, pp. 699–719, 2015, doi: 10.1111/jcom.12164.

[170] A. Guess, J. Nagler, and J. Tucker, “Less than you think: Prevalence and predictors of fake news dissemination on Facebook,” Science advances, vol. 5, no. 1, eaau4586, 2019, doi: 10.1126/sciadv.aau4586.

[171] J. Yang, S. Counts, M. R. Morris, and A. Hoff, “Microblog credibility perceptions,” in Proceedings of the 2013 conference on Computer supported cooperative work - CSCW '13, San Antonio, Texas, USA, 2013, p. 575.

[172] S. M. Shariff, X. Zhang, and M. Sanderson, “On the credibility perception of news on Twitter: Readers, topics and features,” Computers in Human Behavior, vol. 75, pp. 785–796, 2017, doi: 10.1016/j.chb.2017.06.026.

[173] M. Opuszko, S. Gehrke, and S. Niemz,. "Peer Influence and Centrality in Online Social Networks." In 2019 International Conference on Computational Science and Computational Intelligence (CSCI), pp. 1377-1382. IEEE, 2019, doi: 10.1109/CSCI49370.2019.0025

An Agent-based Model for Simulating Travel Patterns of Stroke Patients

Abdulrahman Alassadi, Fabian Lorig, Johan Holmgren
Department of Computer Science and Media Technology
Faculty of Technology and Society, Malmö University
Malmö, Sweden
e-mail: alassadi@live.com, fabian.lorig@mau.se, johan.holmgren@mau.se

Abstract—**For patients suffering from a stroke, the time until the start of the treatment is a crucial factor with respect to the recovery from this condition. In rural regions, transporting the patient to an adequate hospital typically delays the diagnosis and treatment of a stroke, worsening its prognosis. To reduce the time to treatment, different policies can be applied. This includes, for instance, the use of Mobile Stroke Units (MSUs), which are specialized ambulances that can provide adequate care closer to where the stroke occurred. To simulate and assess different stroke logistics policies, such as the use of MSUs, a major challenge is the realistic modeling of the patients. In this article, we present an approach for generating an artificial population of stroke patients to simulate when and where strokes occur. We apply the model to the region of Skåne, where we investigated the relevance of travel behavior on the spatial distribution of stroke patients.**

Keywords-Agent-based Social Simulation; Synthetic Population; Population Generation; Mobile Stroke Unit.

I. INTRODUCTION

Every year, more than 1 million people in the European Union suffer from a stroke and the one-month case-fatality is up to 35% [1]. The occurrence of strokes is associated with the age of the individual and most of those suffering from a stroke are 70 years of age or older. Hence, as the number of people that are older than 70 years will increase, the number of strokes is also expected to increase [2][3].

There are two types of acute strokes, acute ischemic strokes (AIS), where a clot or narrowed blood vessel blocks the flow of blood to the brain, and hemorrhagic strokes, caused by a burst blood vessel [4]. Both types of strokes require immediate treatment and delays negatively affect the patients' outcomes. Yet, the treatment of these two kinds of strokes differs greatly. To dissolve the blood clot and to restore the blood flow, an AIS needs to be treated with thrombolytic medication as quickly as possible. In case of hemorrhagic strokes, however, there is a contraindication for thrombolysis as it might kill the patient. Instead, the effect of blood thinners must be counteracted to control and stop the bleeding. Hence, making the right diagnosis is a vital first step for the efficient treatment of strokes.

Imaging of the brain, e.g., through CT or MRI scans, and specific laboratory tests are required to adequately diagnose the cause of a stroke. However, especially in urban areas, the access to such scanners and laboratories is limited and the patient needs to be transported to a suitable hospital, causing valuable time to pass. A stroke logistics policy that can be applied to address this challenge is the deployment of Mobile Stroke Units (MSUs), which are specialized ambulances with all equipment required to diagnose stroke patients. Through this, the time between the onset of symptoms and the beginning of treatment of the stroke can be shortened, which significantly can improve the prognosis of the patients. The feasibility of this concept and its capability to prevent brain damage of stroke patients was demonstrated by Walter et al. [5].

To investigate the suitability and effects of stroke logistics policies for a specific region, computer simulation can be used. This allows for investigating different policies under realistic conditions without jeopardizing the health of the patients as they can be analyzed and compared in an artificial system. The use of simulation in healthcare is well established. Barnes et al. [6], for instance, provide a comprehensive overview of how simulation can be applied in healthcare operations management and underline the successful application of simulation for evaluating policy alternatives. An increasing application of simulation in healthcare has also been identified by Almagooshi [7], e.g., for the analysis of patient flows, emergency departments, and treatment of, e.g., stroke.

A major challenge when simulating stroke logistics is the modeling of the patients' whereabouts. For instance, in terms of MSUs, where the number of vehicles is limited, the locations of the MSUs should be determined such that the time to treatment can be reduced for all inhabitants of the region. To this end, Amouzad Mahdiraji et al. [8] studied the average time to treatment for different distributions of MSUs and showed that a small number of MSUs can indeed significantly reduce the time to treatment for most inhabitants in the region. For their study, the authors used demographic data on the inhabitants' place of residence for determining where the demand for emergency care occurs. However, this does not consider that individuals travel and might not be at home when having a stroke, for instance, due to leisure activities, shopping, or work. Yet, the spatial distribution of strokes potentially affects the suitability of different stroke logistics policies and, thus, might need to be considered when assessing their suitability.

In this article, we present an agent-based model for generating a synthetic population of stroke patients and to simulate their travel behavior. This allows for testing different policies without jeopardizing the health of the patients. We apply this model to the region of Skåne in southern Sweden to investigate how travel behavior is expected to affect the spatial distribution of stroke patients. Moreover, the generated synthetic population of stroke patients can be used to assess different stroke logistics

 ISBN: 978-1-61208-927-0

policies, e.g., to compare different placements of MSUs and to assess how this affects the time to treatment.

The rest of the article is structured as follows. Section II presents related work on the use of agent-based modeling and simulation in healthcare, on policy making for treatment of acute strokes, and on methods for population generation. In Section III, the model for generating a population of stroke patients with travel behavior is presented. Section IV presents and discusses the results of the case study in Skåne, Sweden, and in Section V, conclusions are drawn, and future work is presented.

II. BACKGROUND

Diagnosis and treatment processes in healthcare often include multiple consecutive steps and involve different specialists and caregivers. Planning and optimizing such complex processes are challenging and requires the comparison of potential configurations under different circumstances. Evaluating these processes in the real-world prior to their implementation might not only be costly and time consuming but also pose a danger to the patients' well-being. To overcome this, simulation can be used. By building a virtual model of the real-world, an artificial system can be created to investigate different scenarios and to observe the effects different measures and decisions might have on the process of care provision.

A. Agent-based modeling and simulation in healthcare

There exist different simulation paradigms, i.e., approaches for modeling and simulating phenomena or systems. In healthcare, as well as in other domains where humans are the object of investigation, individual-based simulation paradigms are often applied. An example is agent-based simulation (ABS), a form of microsimulation, which consists of the simulation of states and behavior of individuals over time [9]. Here, each individual is represented by an agent, an autonomous entity that, for example, imitates human-like behavior and reasoning. This includes the subjective perception of the environment but also the individual decision making based on the personal traits and characteristics of each individual, which leads to individual actions and behavior.

In logistics and production, for instance, the use of simulation is well established [10]. But also in healthcare, for instance in terms of the ongoing Covid-19 pandemic, the use of simulation is feasible [11]. Cabrera et al. [12] use simulation for designing a decision support system that can provide management support for emergency departments. This is achieved by analyzing the optimal staff configuration to minimize patients' waiting time and maximize patient throughput. A more extensive simulation model of hospital processes has been proposed by Djanatliev & German [13]. It combines individual-based simulation with system dynamics for analyzing different innovative workflows prior to their implementation, e.g., prostate cancer screening and effects of MSUs on onset-to-treatment times.

Simulations of stroke treatment were presented by, for instance, Monks et al. [14] and Chemweno et al. [15]. Monks et al. investigate clinical benefits of reducing delays in thrombolysis (alteplase) of AIS patients. They propose a discrete-event simulation model of stroke patients arriving at a large district hospital, where measures can be adopted to reduce in-hospital delays (e.g., prealert of paramedics) and where certain limitations of alteplase treatment (i.e., extension of treatment deadline from 3 to 4.5 hours and patient age over 80 years) can be relaxed. To assess and compare the benefits of policies for reducing waiting times, the authors model two treatment paths, the traditional treatment and one that takes measures into account for reducing in-hospital delays. The results show that an extension of the time window in combination with reduced delays can lead to 5-times increased thrombolysis rates. Chemweno et al. present a discrete-event simulation of the diagnostic path of patients in a stroke unit to investigate the effect of different test capacities. This is to overcome shortcomings of traditional queuing theory models, which cannot predict waiting times due to the complexity of treatment pathways and interrelationships between required resources. This allows for the assessment of policy changes in capacity profiles and test resources. The study outlines the effects different policies might have on waiting times, e.g., adding extra timeslots, shifting from MR to CT scans, and implementing joint timeslots.

B. Policies for Treatment of Acute Strokes

For the treatment of acute ischemic strokes, intravenous thrombolysis to dissolve the blood clot is the only approved reperfusion treatment [16]. However, according to Fassbender et al. [17], only less than 5% of the stroke patients receive this therapy. One potential explanation is that the critical time window of 3 hours is exceeded due to the transport to the hospital. To reduce the time to treatment, the use of Mobile Stroke Units (MSUs) was proposed, i.e., specialized vehicles that are equipped with devices required for adequately diagnosing and treating stroke patients. Walter et al. [5] compared the use of MSUs to hospital treatment and found that the time from alarm to therapy could be reduced from 76 to 35 minutes. Calderon et al. [18] analyzed the worldwide status of MSUs and compared different services outlining the success of the approach. The economic viability of MSU treatment was analyzed by Kim et al. [19], underlining its cost-effectiveness due to earlier provision of therapy.

The success of MSUs and their effect on treatment times also depends on where they are located. Rhudy et al. [20] visually analyzed data of MSU dispatches and the occurrence of strokes to optimize service provision. For Sydney, Australia, Phan et al. [21] searched for optimal locations for MSUs by investigating travel times from suburbs to each potential MSU hub. For a similar purpose, Amouzad Mahdiraji et al. [8] developed an agent-based model that allows for analyzing the benefits of different MSU configurations. In their study, Amouzad Mahdiraji et al. investigated the average time to treatment for different distributions of MSUs and showed that a small number of MSUs can significantly reduce the time to treatment for most inhabitants in the region. Moreover, agent-based simulation can also be used to assess other stroke logistics policies, e.g., whether patients should be brought to the closest hospital or to a specialized thrombectomy center [22]. To assess this, Al Fatah et al. developed a simulation model of logistical operations of stroke patients, i.e., whether patients should be transported to the closest hospital or towards a stroke center. The results showed that those patients that require special treatment indeed benefit from being transported in the direction of a stroke center whereas those who do not require specialist treatment benefit from being transported to the closest hospital.

None of the presented approaches takes travel behavior into consideration when investigating and optimizing locations and service designs of MSUs. Instead, individuals are assumed to stay at their home location, which can be derived from census data or randomly selected using Monte Carlo approaches [22].

C. Population Generation

To generate realistic results when applying agent-based simulation, individuals and their behavior must be modeled in a realistic way. Especially when modeling a larger population of individuals, it is important that the relevant features of the artificial population, e.g., age distribution or employment status, correspond to those of the original population. However, due to privacy reasons, data on each individual's properties is usually not available. The challenge associated with synthetic population generation is that aggregated data, e.g., census data, and disaggregated personal data need to be combined to model each individual, such that the characteristics of the modeled population correspond to the used input data [23][24]. In transportation, for instance, population generation is used to model individual demand for mobility services [25][26].

III. An Agent-based Model for Generating a Population of Stroke Patients with Travel Behavior

To allow for a more dynamic and realistic assessment of stroke logistics policies, we developed an agent-based model that takes travel behavior of individuals into account. To this end, we generate a synthetic population of potential stroke patients, combining socio-demographic census data, data on real strokes cases from a healthcare provider, and travel data from a transport service provider. This allows for the simulation of the dynamical spatial and the temporal component of stroke occurrence and treatment.

For the study, we selected Skåne, a region in southern Sweden. Skåne consists of approximately 1.4 million inhabitants, that live in 33 municipalities with a total area of nearly 11 000 km^2. In Skåne, there are 9 hospitals with emergency departments that can treat acute strokes. In 2015, there were 3 973 stroke incidents recorded in Skåne out of which 3 830 patients also live in Skåne. Moreover, 12 patients that have their place of residence in Skåne were treated in the neighboring counties Kronoberg, Blekinge, or Halland and most of the patients are 45 years of age and older. Based on data from the regional healthcare provider, *Södra Sjukvårdsregionen* (Southern Health Care Region; SHR), we derived the daily distribution of strokes per hour (see Figure 1). Most strokes are reported during the afternoon with most of the incidents occurring around 4 p.m.

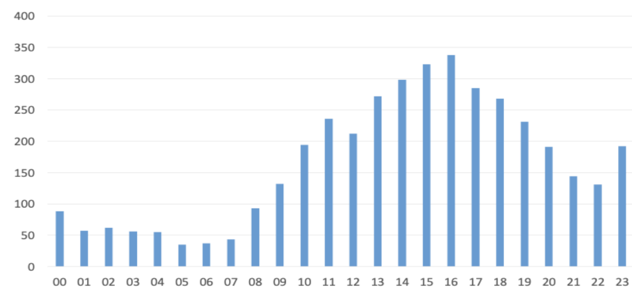


Figure 1. Total number of strokes per hour extracted from data of the regional healthcare provider.

To model travel behavior, we used data from a regional travel survey (*Resvaneundersökning för Skåne; RVU*) that was conducted in Skåne in 2013 [27]. As part of this study, travelers were asked about their traveling habits and the resulting dataset contains information on approximately 56 000 distinct trips. This includes, for instance, the origin, destination, duration, and purpose of the trip but also socio-demographic data on the travellers, e.g., age, gender, and place of residence.

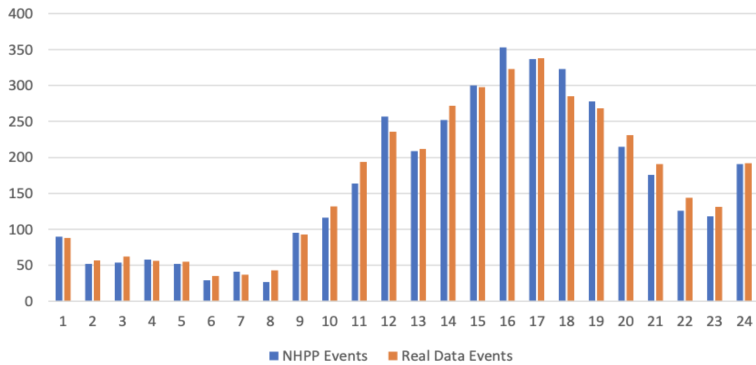
Finally, for generating a realistic population, we used a census dataset from *Statistiska centralbyrån* (Statistics Sweden; SCB), the Swedish government agency for statistics. The SCB dataset includes, for instance, information of the density and age of the population of Skåne. Yet, this data only provides information on the permanent residence of individuals and not on their actual location. To allocate the anonymized trips of the RVU dataset to actual individuals from the SCB dataset, we randomly match the datasets based on the individuals' age group and home municipality.

For modeling the inter-arrival time of stroke incidents, we used a non-homogeneous Poisson process (NHPP) [28]. In contrast to ordinary Poisson processes, that are used to model events that occur with a fixed average rate of arrivals (λ), the rate of arrivals can vary over time in an NHPP where $\lambda(t)$ is the rate function for time segment t for all $t \in [0, t_0]$ and $\lambda_u(t)$ is the maximum number of actions in a time series with $0 \leq \lambda(t) \leq \lambda_u(t)$. By this means, we can explicitly model the accumulation of stroke events during the afternoon. In our NHPP, we divide each day into 24 time segments, each equipped with a specific probability that a stroke occurs during this hour in relation to the number of strokes occurring per day.

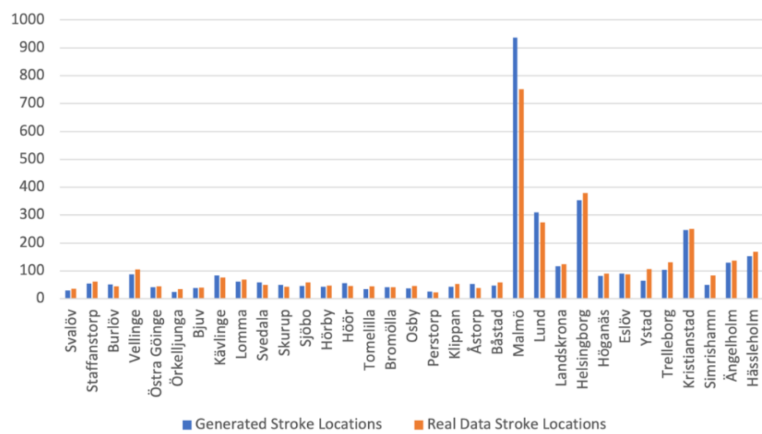
Based on the generated number of daily stroke incidents, we define two probability mass functions to distribute strokes across age groups and municipalities. These two distributions are then used to generate stroke incidents. Each generated stroke event consists of the patient's age group, municipality, day of the year, and time of the day. This dataset is then matched with the population dataset, to predetermine the stroke patients as well as the point in time when the stroke will occur.

When executing the model, the travel behavior, i.e., each trip of an individual, and the resulting locations of each individual of the population is simulated over time. The generated NHPP events define when the individual stroke incidents occur, and, at the generated time of each stroke incident, the individual's current location can be determined based on the simulated trips.

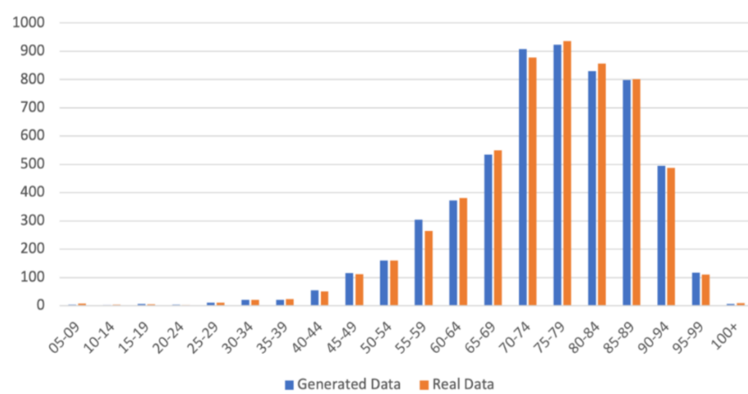
In recent years, ODD (Overview, Design concepts, and Details) protocols have been used to describe the structure and the dynamics of agent-based models in a standardized document [29]. They provide more detailed insights into the model and the underlying assumptions, which can be relevant for the interpretation of the results as well as for replicating experiments. The ODD of the model presented in this article can be found in [30].



(a) hour of the day (RSE: 0.026, RRSE: 0.160)



(b) municipalities in Skåne (RSE: 0.067, RRSE: 0.259)



(c) age group (RSE: 0.002, RRSE: 0.046)

Figure 2. Distribution of stroke incidents: (a) per hours of the day (b) per municipality in Skåne (c) per age group. For each distribution, the Relative Squared Error (RSE) and Root Relative Squared Error (RRSE) are given as measures of the quality of the generated data.

IV. Results of the Scenario Study in Skåne

We implemented the agent-based model of stroke patient travel behavior in the *Repast Simphony* simulation framework [31]. In the simulation, each time unit (tick) corresponds to 1 minute in reality. Hence, each day is simulated as 1440 ticks. For each tick, it is determined whether an individual will go on a trip and move to another location. When the predetermined stroke events occur, it is checked whether the individual is on a trip, to determine where the stroke occurred.

The probability distributions that we extracted from the dataset are shown in Figure 2. The charts show the real data (orange) in comparison to the NHPP events we calculated (blue). There are only minor deviations from the original data for the stroke incidents per hour, per municipality, and per age group. To quantify how well the artificial data replicates the original data, the Relative Squared Error (RSE) and Root Relative Squared Error (RRSE) are given as measures. No significant deviation of the generated data from the real data can be observed considering the hour of the day (RRSE: 0.160) and the age group (RSSE: 0.046). Only for the municipalities in Skåne, a difference can be observed for Malmö (RRSE: 0.259). This might be due to a bias, which results from Malmö's role as center of the region and as the city has notably more inhabitants compared to all other cities and municipalities in Skåne.,

Instead of simulating all inhabitants of Skåne, we only simulated the trip activities of those individuals that were predetermined to suffer from a stroke. This is to reduce the computational complexity of the simulation. To reduce the effect of stochastic variations in the results, we replicated the simulation five times and calculated the average values from these runs.

On average, 3 912 strokes occur in our simulation. The results indicate that 3 839 (98.1%) strokes occur at home whereas 73 (1.9%) strokes happen while the individual is on a trip and at another location. To check the plausibility of these results and to validate the study, we compare them to existing data. In the RVU travel data, only 15% of the recorded trips are performed by individuals that are 65 years of age or older, the main risk group for suffering from a stroke. Out of these trips, only 35% are taken in the afternoon, which is the time of the day where the occurrence of a stroke is most likely.

Moreover, we analyzed the dataset of stroke incidents from SHR. Out of 3 842 stroke incidents of patients that live in Skåne, which were recorded within SHR, 3 830 actually got their treatment in Skåne. 3 106 (80.84%) of the patients that got a treatment in Skåne also got it within their municipality or at the hospital that is responsible for their municipality. Out of the remaining 736 patients (19.16%) that did receive their treatment at another hospital, 497 patients live in municipalities where the responsible hospital does not provide emergency services around the clock. Of the remaining 239 patients, 80 were treated at Skåne University Hospital, which also provides highly specialized treatments for severe cases, 57 received treatment at private facilities, whose exact location is unknown, and 59 were treated at a hospital in a neighboring municipality, which might be due to the patients living closer to the hospital in the neighboring municipality. In total, only 46 patients (1.2%) receive their treatment obviously outside their home municipality, where it can be assumed that they were traveling. This corresponds to the results of our simulation.

V. Conclusions

In this article, we address the challenge of generating a realistic population of stroke patients, which takes travel behavior into account. Such an artificial population of stroke patients is required in agent-based simulations and allows for the assessment of different stroke logistics policies, such as the optimal placement of MSUs across a region. We used aggregated and individual-based data from different sources, from which we derived probability distributions that were then used to generate an artificial population of agents.

To demonstrate the feasibility of the presented approach, we used data from the region of Skåne in southern Sweden. In the presented study, we simulated the travel behavior of stroke patients to investigate where strokes occur. Through this, a better understanding of the spatial distribution of stroke occurrence is achieved. This is relevant, for instance, for the optimal distribution of MSUs, such that the time to treatment is reduced for stroke patients.

Our results show that the generated artificial population corresponds to the real data in terms of the time of the day at which strokes occur, the distribution of strokes across the municipalities, and the age group of the patients. In total, approximately 1.9% of the strokes occur while the individual is on a trip and not in their municipality of residence. This observation corresponds to data on strokes that was provided by the healthcare provider. Hereby, were able to show by means of simulation that traveling only has a minor impact on where strokes occur and, thus, for policy making in stroke logistics.

The generated artificial population of stroke patients is based on socio-demographic, healthcare, and travel data of the investigated region, to ensure the realistic representation of the real-world population. Yet, the presented model can also be applied to other regions, assuming that the required input data is accessible. This facilitates the conducting of agent-based simulation studies for investigating the effects different stroke logistics policies might have. It also increases the credibility of the simulation results such that conclusions can be drawn regarding the real world.

As part of future work, we plan to incorporate the results from the population generation into simulations for assessing and comparing different policies for stroke logistics. Moreover, we intend to investigate and include seasonality effects into the model, i.e., tourists that come to the region and changed travel behavior during weekends.

Acknowledgment

We would like to thank *Södra sjukvårdsregionen* for the provision of the anonymized data on the occurrence of strokes in Skåne.

References

[1] Y. Béjot, H. Bailly, J. Durier, and M. Giroud, “Epidemiology of stroke in Europe and trends for the 21st century,” La Presse Médicale, vol. 45, no. 12, pp. e391–e398, 2016.

[2] H. A. Wafa et al., “Burden of stroke in Europe: thirty-year projections of incidence, prevalence, deaths, and disability-adjusted life years,” Stroke, vol. 51, no. 8, pp. 2418–2427, 2020.

[3] E. Stevens, E. Emmett, Y. Wang, C. McKevitt, and C. Wolfe, “The burden of stroke in Europe: the challenge for policy makers,” 2017. Available: https://www.stroke.org.uk/sites/default/files/the_burden_of_stroke_in_europe_challenges_for_policy_makers.pdf [retrieved: Oct, 2021].

[4] R. A. Grysiewicz, K. Thomas, and D. K. Pandey, “Epidemiology of ischemic and hemorrhagic stroke: incidence, prevalence, mortality, and risk factors,” Neurologic clinics, vol. 26, no. 4, pp. 871–895, 2008.

[5] S. Walter et al., “Bringing the hospital to the patient: first treatment of stroke patients at the emergency site,” PloS one, vol. 5, no. 10, p. e13758, 2010.

[6] S. Barnes, B. Golden, and S. Price, “Applications of agent-based modeling and simulation to healthcare operations management,” in Handbook of healthcare operations management, Springer, 2013, pp. 45–74.

[7] S. Almagooshi, “Simulation modelling in healthcare: Challenges and trends,” Procedia Manufacturing, vol. 3, pp. 301–307, 2015.

[8] S. Amouzad Mahdiraji, O. Dahllöf, F. Hofwimmer, J. Holmgren, R.-C. Mihailescu, and J. Petersson, “Mobile stroke units for acute stroke care in the south of sweden,” Cogent Engineering, vol. 8, no. 1, p. 1874084, 2021.

[9] P.-O. Siebers, C. M. Macal, J. Garnett, D. Buxton, and M. Pidd, “Discrete-event simulation is dead, long live agent-based simulation!,” Journal of Simulation, vol. 4, no. 3, pp. 204–210, 2010.

[10] A. A. Tako and S. Robinson, “The application of discrete event simulation and system dynamics in the logistics and supply chain context,” Decision Support Systems, vol. 52, no. 4, pp. 802–815, Mar. 2012, doi: 10.1016/j.dss.2011.11.015.

[11] F. Lorig, E. Johansson, and P. Davidsson, “Agent-Based Social Simulation of the Covid-19 Pandemic: A Systematic Review,” JASSS, vol. 24, no. 3, p. 5, 2021.

[12] E. Cabrera, M. Taboada, M. L. Iglesias, F. Epelde, and E. Luque, “Optimization of Healthcare Emergency Departments by Agent-Based Simulation,” Procedia Computer Science, vol. 4, pp. 1880–1889, 2011.

[13] A. Djanatliev and R. German, “Prospective healthcare decision-making by combined system dynamics, discrete-event and agent-based simulation,” in 2013 Winter Simulations Conference (WSC), 2013, pp. 270–281.

[14] T. Monks, M. Pitt, K. Stein, and M. James, “Maximizing the population benefit from thrombolysis in acute ischemic stroke: a modeling study of in-hospital delays,” Stroke, vol. 43, no. 10, pp. 2706–2711, 2012.

[15] P. Chemweno, V. Thijs, L. Pintelon, and A. Van Horenbeek, “Discrete event simulation case study: Diagnostic path for stroke patients in a stroke unit,” Simulation Modelling Practice and Theory, vol. 48, pp. 45–57, 2014.

[16] E. Berge et al., “European Stroke Organisation (ESO) guidelines on intravenous thrombolysis for acute ischaemic stroke,” European stroke journal, vol. 6, no. 1, p. I–LXII, 2021.

[17] K. Fassbender et al., “‘Mobile stroke unit’ for hyperacute stroke treatment,” Stroke, vol. 34, no. 6, pp. e44–e44, 2003.

[18] V. J. Calderon, B. M. Kasturiarachi, E. Lin, V. Bansal, and O. O. Zaidat, “Review of the mobile stroke unit experience worldwide,” Interventional neurology, vol. 7, no. 6, pp. 347–358, 2018.

[19] J. Kim et al., “Economic evaluation of the Melbourne mobile stroke unit,” International Journal of Stroke, vol. 16, no. 4, pp. 466–475, 2021.

[20] J. P. Rhudy Jr et al., “Geospatial visualization of mobile stroke unit dispatches: a method to optimize service performance,” Interventional neurology, vol. 7, no. 6, pp. 464–470, 2018.

[21] T. G. Phan, R. Beare, V. Srikanth, and H. Ma, “Googling location for operating base of mobile stroke unit in metropolitan Sydney,” *Frontiers in neurology*, vol. 10, p. 810, 2019.

[22] J. Al Fatah, A. Alshaban, J. Holmgren, and J. Petersson, “An agent-based simulation model for assessment of prehospital triage policies concerning destination of stroke patients,” *Procedia Computer Science*, vol. 141, pp. 405–412, 2018.

[23] K. Chapuis and P. Taillandier, “A brief review of synthetic population generation practices in agent-based social simulation,” in *Proceedings of the Social Simulation Conference 2019 (SSC)*, Mainz, Germany, 2019.

[24] N. Fournier, E. Christofa, A. P. Akkinepally, and C. L. Azevedo, “An integration of population synthesis methods for agent-based microsimulation,” in *Proceedings of the Annual Meeting of the Transportation Research Board, Washington, DC, USA*, 2018, pp. 13–17.

[25] N. Huynh et al., “Generating a synthetic population in support of agent-based modeling of transportation in Sydney,” in *Adapting to change: the multiple roles of modelling, 20th International Congress on Modelling and Simulation (MODSIM2013)*, Adelaide, Australia 2013.

[26] S. Dytckov, F. Lorig, P. Davidsson, J. Holmgren, and J. A. Persson, “Modelling Commuting Activities for the Simulation of Demand Responsive Transport in Rural Areas.,” in *VEHITS*, 2020, pp. 89–97.

[27] Region Skåne, “Travel Survey in Skåne,” (*Resvaneundersökning i Skåne*). 2013. Available: https://utveckling.skane.se/publikationer/rapporter-analyser-och-prognoser/resvaneundersokning-i-skane [retrieved: Oct, 2021].

[28] P. W. Lewis and G. S. Shedler, “Simulation of nonhomogeneous Poisson processes by thinning,” *Naval research logistics quarterly*, vol. 26, no. 3, pp. 403–413, 1979.

[29] V. Grimm *et al.*, “The ODD protocol for describing agent-based and other simulation models: A second update to improve clarity, replication, and structural realism,” *Journal of Artificial Societies and Social Simulation*, vol. 23, no. 2, 2020.

[30] A. Alassadi, “An Individual-based Simulation Approach for Generating a Synthetic Stroke Population.” 2021. Available: http://urn.kb.se/resolve?urn=urn:nbn:se:mau:diva-41895 [retrieved: Oct, 2021].

[31] Repast Simphony, Available: https://repast.github.io/ [retrieved: Oct, 2021]

Exploring Adolescents' Experiences with Personalized Content on Social Media: A Qualitative Study

Ashley Rebecca Bell, Merete Kolberg Tennfjord, Miroslava Tokovska and Ragnhild Eg
School of Health Sciences
Kristiania University College
Oslo, Norway
E-mail: {Ashleyrebeccaholt.Bell, Meretekolberg.Tennfjord, Miroslava.Tokovska, Ragnhild.Eg}@kristiania.no

Abstract—**This work-in-progress paper examines adolescents' experiences with personalized content on social media and how it influences them. Through group interviews with Norwegian students aged 15 to 19 years, we investigated their awareness, comprehension, and emotions towards targeted and personalized content. The sample consisted of 48 participants (20 males and 28 females). The preliminary analysis uncovered three themes: 1) Encounters, awareness, and comprehension, 2) Emotions, and 3) Increasing use and appreciation.**

Keywords-social media; digital competence; influence; adolescent; personalized content.

I. Introduction

Young people spend a lot of time online. In Norway, the average exceeds five hours a day for adolescents and young adults [1]. This age group is also very active on social media [2], which implies that they are exposed to social influence both in their physical and digital lives. The continuing increase in so-called screen time has caused alarm, among researchers and government agencies alike [3][4]. Adolescents' use of social media has received particular focus, likely due to the time spent, but also because this age group might be less digitally competent than they believe themselves [5][6]. In fact, research has shown that adolescents are largely unaware of how personalization shapes their everyday life [7][8]. Moreover, social comparison and social influence is prominent in adolescents' [9], this may make this age group particularly vulnerable to targeted and personalized online content. On the other hand, some claim that moral panic has biased the research in a negative direction, thus there is a need for more nuanced studies on the impact of social media, including potential positive effects of exposure to social media content [10][11].

The body of research on adolescents' use of social media is substantial [12]. However, recent criticism stresses the methodological limitations of many of the quantitative studies, such as correlations between screen time and mental health measures [4]. A few recent studies have instead used qualitative methods to better understand how adolescents experience social media and their impact. Some look at targeted advertising [13][14], others look at curated news stories [7][15]. Others still attempt to uncover how people reason about the technology behind social media, particularly algorithms [8][16]-[19], but these do not focus on adolescents as a separate group.

Following the sound direction of recent research, this qualitative study examines adolescents' experiences with personalized content and how personalized content shape the digital world of youth, both positively and negatively. With this work, we wish to address the consequences of social media that remain unclear from the current body of research. This unclarity is partly due to methodological limitations [4], and partly due to contradictory research findings that point to small and large, positive and negative, and sometimes absent effects of screen time, on well-being [20].

Considering that media consumption is no longer a passive process, but a mutual and active exchange of information, we need more insight on this age group's digital competence related to social media technologies, we also need to understand how potentially vulnerable adolescents navigate their personalized internet realities and how they are affected. This need underlines the aim of this study to assess adolescents' experience with targeted and personalized content on social media.

The article is structured into five sections. Following Section I, the introduction, Section II describes the method, including information about the sample, ethical considerations, material, data collection and analysis. In Section III, the preliminary results are presented and discussed; it is divided into three sub-sections, one for each theme. Section IV addresses the study's strengths and limitations. Finally, Section V presents the conclusions.

II. Method

The study presented here is a work-in-progress built on a qualitative design with eight focus group interviews. These interviews represent participants' varied experiences, to map out associations, variations, and different aspects of experiences on a selected topic [21]. Thus, the study aims for insight on subjective experiences with personalized content.

A. Sample

Prior to recruitment, principals from two different schools in the same region were contacted through e-mail. Thereafter, an employee at each school was assigned with the responsibility of recruiting students willing to participate, following our inclusion criteria. The students were recruited from different classes and the respective teachers informed the students about the project. A random draw was done by the teacher in classes where more students than needed were willing to participate. A few participants were unable to attend the interview due to quarantine, in those situations we were able to recruit additional participants from a waiting list.

The inclusion criteria were that the participants had to be students in secondary school, aged between 15 and 19 years old, and willing to participate in the study. The final sample included 48 participants (20 male and 28 female students). The youngest participants (12 males, 12 females) were recruited from the last year of lower secondary school (aged 15-16). The remaining participants were recruited from three levels of upper secondary school, 12 (6 males, 6 females) from level one (aged 16-17), six (1 males, 5 females) from level two (aged 17-18) and six (1 male, 5 females) from level three (aged 18-19). Participants were interviewed with their peers in groups of six, making it a total of eight focus group interviews. One male participant was excluded in retrospect due to his considerably older age; he was judged to be unrepresentative of the sample's general level of digital competence. Thus, there are 19 males included in the analysis.

B. Ethics Statement

After volunteering for the study, participants received and signed an informed consent form, which they later brought to the interview. Students aged 15 years also provided a parent's consent. Each focus group interview started by introducing the purpose and content of the study, including information about their ethical and voluntary rights. The study protocol, data plan and related documents received approval by the Norwegian Centre for Research Data (reference 644850). Anonymization was ensured by transcribing the interviews and allocating fictitious aliases. All participants received a gift card for their time, valued equivalent to 35 USD / 30 EUR.

C. Material

The current study is part of a larger project with an overall aim to assess social media habits among adolescents. The larger project includes an ongoing longitudinal diary study where we aim to follow 24 adolescents through high school. For the purpose of this work-in-progress, only questions and findings on adolescents' experiences with targeted and personalized content on social media are analyzed and reported. For each focus group, a timing of 90 minutes was scheduled, including an introduction for the study's purpose. A semi-structured interview guide was prepared with open-ended questions to ensure a coherent narrative of experiences with targeted and personalized content on social media.

The interviews were recorded with a secure Dictaphone application running on three mobile devices simultaneously, each placed in a different location in the interview room.

D. Data Collection and Analysis

All interviews were conducted between April and June 2021, in suitable rooms at the respective schools. Each interview lasted between 42 to 91 minutes, excluding the introduction and de-brief, and was recorded and transcribed verbatim. Two researchers were present throughout the interviews, the researcher leading the interview was always the same. The researcher who did not lead the interview used a spreadsheet to note down the time and order of speakers.

The preliminary analysis is based on transcriptions of recorded interviews, aided by notes on speakers and times. Transcripts were reviewed to identify specific experiences, and the initial analysis of the transcripts resulted in temporary themes that originated from the interview guide and the study's intent [22]. Thereafter, a theoretical interpretation was performed, so that the transcripts could be systematized to cover the various themes and sub themes meaningfully.

The analysis was a joint effort that relied on Brinkmann and Kvale's steps [23] for interpretation and conveyance of understanding; participants' quotes represent understanding of self, interpretations of quotes correspond to critical understanding based on common sense, and implications are placed in a larger context of theoretical understanding.

The selection of included quotes is the result of the researchers' mutual agreement on how best to shed light on the relevant major themes that emerged through the data analysis. The quotations presented in this study have been translated from Norwegian to English, they have also been edited for better readability. Nonetheless, the quotations have been kept as close to the original statements as possible.

III. Preliminary Results and Discussion

All participants had one or more social media profile which they had used from the age of 10 to 12. The main reasons provided for joining social media were fear of missing out and keeping in touch with friends and family. The high availability of having a phone and having a large amount of screen time in general, was mentioned. These findings correspond to the results from a Norwegian national survey on adolescents, where 75 – 79% of females and males between the ages of 15 to 19 reported having minimum 3 hours of daily screen time. Furthermore, 36% of respondents between 13 and 19 years reported spending a minimum of 3 hours on social media [2]. In the current study, the reported average time spent on social media platforms was 3 to 4 hours on normal weekdays. The most popular and most used social media platforms mentioned by our participants were TikTok, Snapchat and Instagram, across all ages. Although the large majority of participants stated that they 'follow' people on social media, meaning that they have taken action to receive content from friends, family, influencers and other celebrities, some of them modified this response later and clarified that they mostly followed friends and only a few celebrities.

The pattern appears to be that most do not have a particular plan for what type of content they want to watch while on social media. Instead, they let the platform make the selection on their behalf, based on the accounts they follow and what they have liked before. As Rebecca (15-16) put it: "Like, I follow only what I find interesting and, um, my friends or people I know". Ethan (15-16) from a different interview added: "I think most people tend to be on 'For You'", referring to the page on TikTok where random videos

 ISBN: 978-1-61208-927-0

pop up based on their previous actions. The overall observation that adolescents do not deliberately seek out and select specific content may indicate that they freely allow social media to influence them, be it a conscious or an unconscious decision.

The reported experiences with targeted and personalized content on social media converged under three main themes: 1) Encounters, awareness, and comprehension, 2) Emotions, and 3) Increasing use and appreciation.

A. Encounters, Awareness and Comprension

Awareness and comprehension about targeted and personalized content differed to some extent across gender and age groups. Participants in the age of 17 to 19 expressed broader understanding and greater awareness of personalized and targeted content throughout the interviews, compared to the youngest age groups. The same pattern of broader understanding and greater awareness was seen for the females as compared to the males. There is little research addressing age and sex differences in social media usage among the young, thus it is premature to extend the interpretation of these differences. However, on the age matter, a qualitative study has shown that students in the age 19 to 22 did have an understanding of personalization [15].

Most of the groups mentioned indirectly that they encountered targeted and personalized content on their most popular social media platforms (Instagram, TikTok, Snapchat, YouTube), before we asked questions related to personalization. TikTok was predominant, and many participants said that they quickly observed that they were receiving personalized content while on TikTok. "But like, the thing about TikTok is that they notice what you like, so they come up with suggestions on videos for you. If, for example, you like a football video, then a lot more football videos may show up", explained Marcus (15-16). Meredith (17-18) also emphasized and showed a broad understanding of targeted and personalized content: «There are algorithms and such, aren't there? That somehow find out what you look at, what you like and what you sort of bump into, or what you search for and such. That's what kind of makes my TikTok full of food and humor, while um others are full of other things." As found by Swart [16], some of the algorithms that personalize content are easier to recognize than others. For instance, when labelled as 'suggestions for you' or 'for you', content can more easily be recognized as personalized compared to more subtle personalization [16]. This was also the case for the participants in our study. Several of the participants explicitly mentioned the 'For You' page on TikTok, revealing their reflections on the targeted and personalized content. They also pointed out that the content they encountered on their social media platforms was uniquely selected for them. For example, when we asked what they saw while on TikTok, Victoria (15-16) said: "It's of course very different the content we get, because it [TikTok] tries to like show you videos that it thinks you will like. So, it's kind of very different from person to person."

It emerged through the interviews that most participants had experiences where their engagement to specific content or items on social media and/or online browsing would lead to related advertisement. As Regina (18-19) put it: "Like, if I search for something on a regular website, it's often that I see advertisement for that thing I searched for, when I enter Facebook." Rebecca added: "They kind of want you to click on more things, because… Um, one time when I was on TikTok, it came up an advertising link for a product that I looked at. And then when I went on Instagram, the same thing showed up there too [as an advertisement]." Similar experiences with online actions resulting in targeted advertising across platforms, were reported in a qualitative study of Facebook's newsfeed. Combined, these findings point to a blending of commercial and regular content that may be difficult for social media users to discern. Hence, it might be difficult for adolescents to distinguish whether they are being influenced through social media.

B. Emotions

A majority of the participants explained that they enjoyed receiving personalized content because it brought them relevant and interesting content, rather than irrelevant and uninteresting. This was prominent both for regular content and for commercial content and advertising. For example, when we asked participants how they felt when they received targeted and personalized content, Joanna (16-17) replied: "It's nice, then only content you like to watch appears", with some fellow classmates agreeing with her. Even though Joanna did not use the word 'influence', she indirectly conveyed that personalized content had a positive influence on her daily life and well-being. Other participants shared similar appreciations of social media's positive influence. Enjoyment of targeted and personalized content has been reported earlier, for instance with young people emphasizing the benefits of recommended systems [16].

Conversely, several of the participants expressed that they felt unease towards targeted and personalized content. "It's like seeing my phone predict my next choice (…). Your phone or an app based on what you have pressed or which videos you have liked, somehow in a way can predict how you are as a person. It's a little, or it's not a little, it's very scary", said Mia (15-16). Even though many agreed with her and shared her fear, several of the participants disagreed and held on to the positive sides of personalized content on social media. Nevertheless, a couple did express some fear when it came to how much the applications knew about them. Lucas (16-17 years) explained one of the reasons for why he thought of personalization as 'scary': "If one is on a website, they know exactly how fast I move the mouse to when I press on that thing [I'm looking at]. And they can take that data to different advertisers." Not everyone felt unease, however, some simply felt annoyed. When Noah (16-17) shared his thoughts on targeted and personalized content, he said: "Well, it's good that they do it, but it can sometimes be a bit too much. For example, if I search for a hoodie I want, then advertisements come up all the time for it, for a few months on all my social media channels." His voice stressed the words 'all' and 'all the time'. A mixture of negative emotions towards receiving targeted content have also been found in previous studies; Youn & Kim [13] found that some of the young adult participants voiced their experiences with personalized advertisement as scary and creepy, whereas others found it annoying and irritating.

Receiving personalized advertisement without ever searching for the product was something many participants had experienced. Several expressed that they had a feeling that the phone could hear them, adding that this experience was the scariest when it came to personalization. Miranda (15-16) explained: "It has happened to me, that I have talked about one thing [verbally], and then a few days later a lot of advertisement has shown up for that thing [I talked about]. Then I'm like, was I kind of monitored now?" This feeling was shared by many participants across interviews. These experiences have also been shared by participants in other qualitative studies [17][19]. However, these statements represent personal theories, theories that have yet to be scientifically verified [25]. As Meredith added: 'It might just be a conspiracy theory."

No clear age difference was found for the themes relating to emotions of enjoyment and unease concerning personalized content, although the participants from upper secondary school came across as the most reflected age group. Furthermore, there were participants across all groups who said they did not care that they received personalized content. Although the younger participants expressed little reflection on the reason, the participants from the two highest levels of upper secondary school hypothesized that the lack of concern was due to them becoming accustomed or acceptive of personalized content. The age group differences stand in accordance with the oldest showing better general comprehension and expressing more advanced reflections on targeted and personalized content. For example, Richard (15-16) said: "I don't think as much about it [personalized content], because clearly I like it." On the other hand, the older Regina said: "Like, I know many people who thinks it's [personalized content] kind of uncomfortable. But I notice that I don't really care so much about it, because you do accept it." A fellow female classmate Ashley (18-19) added: "I think many of us have gotten used to it, being tracked online. You are aware of it, but everyone gets tracked online anyways, so you can't really do anything about it unless you just decide to not have social media anymore." Considering that adolescents have previously been found to be less digitally competent than they themselves believe [5], [6], it follows that the lack of concern may be more than habituation. The acceptance of algorithmic intervention may be partly driven by superficial comprehension of how the technology accomplishes personalization, as well as a lack of understanding of how it influences them. On the other hand, it may also be motivated by benefits that in certain contexts are deemed to outweigh the cost of giving up personal data [26].

C. Increasing Use and Appreciation

Where some participants were mostly uneasy, others were ambivalent on the topic of personalization, others again were positive. Across several interviews, participants expressed how the personalization improved their experiences with social media. These participants shared an appreciation towards the applications for making social media a nice and easy experience with their personalized strategy. For example, Maria (16-17) said: "I kind of think that if I only got content on my phone that wasn't interesting to me, I probably would have used social media much less. So that's probably the reason to why I use social media a lot, because I only receive content I find interesting", with many of her fellow classmates agreeing with her. Her comment sheds light on how personalized content not only influences, but also increases social media usage. Relatedly, algorithmic awareness has previously been found to increase social media usage; one proposed explanation is that an adolescent's knowledge of algorithmic selections leads to more control and acceptance [8].

Among the participants in this study, some of the youngest males were impressed with the social media applications. A few talked about how the algorithm works, and even though it scared them to a small extent, it did not bother them as much. "It's actually very impressive. They find out what I like very fast", said David (16-17). This echoes the ambivalence expressed by others, possibly indicating that not all situations are controllable and not all content is acceptable. A few participants explained that they were aware of the option to unselect content they are not interested in; for example, Rebecca explained that by doing this "they [social media platforms] make sure that the content [you are not interested in] gets taken away from your feed." At the same time, the participants who brought up this subject also had a tendency to add that they rarely made use of the option to unselect or block content; unless the content was especially disturbing, they would simply scroll on. The tendency to ignore rather than block content coincides with Swart's results [16], findings from both studies point to acceptance and appreciation of personalized content among adolescents. It remains unclear whether the tendency to not act, but rather ignore, unwanted content is only due appreciation, or whether it also reflects a lack of critical reflection and digital competence.

IV. Strengths and Limitations of the Study

Our study adds to a research field built mainly on a large body of quantitative studies, using focus group interviews that contribute insight based on a qualitative approach. This is a first strength of the study. Second, internal validity was prioritized by including a researcher with experience in qualitative research to supervise the data analysis. Third, both mixed and same-sex focus groups were used to enable a

 ISBN: 978-1-61208-927-0

variety of opinions and interactions during the discussions. Fourth, our sample size is large considering the qualitative design. Throughout the interviews most themes and topics were repeated, supporting the assumption that topics relevant to personalized content on social media was sufficiently described and discussed. Fifth, most of the participants were unaware of the monetary compensation prior to volunteering, hence financial motivation was likely not present.

There are some limitations to this study that are important to mention. First and foremost, although the study was designed to be explorative, we might have missed determinants due to selection bias. Moreover, a rather homogeneous sample was included, particularly in upper secondary school where female participants outnumbered the males. Additionally, this study is based on a cross section. Even though we did find differences across age and gender, we do have the grounds to predict individual development over time. Finally, it should be noted that the study was conducted in Norway where internet usage and social media are widely common [2]. This may cause a skew in our participants' experiences on social media and their understanding of personalization; although their digital competence may have shortcomings, it may still be more advanced than what can be observed among adolescents in other countries in- and outside Europe. Consequently, our results may not be generalizable to populations where social media are less common and digital competence is lower.

V. Conclusion

Social media were actively used by all participants, with TikTok, Snapchat and Instagram being used the most. The majority of the participants revealed that they did not have a plan when using social media, many tended towards using different systems for recommendations. Most had encountered targeted content, but only the older participants delivered reflections on how their previous actions could facilitate this personalization. Personalized content improved experiences with social media for several participants, which also led to increased social media usage. Regarding their emotions towards targeted content, the participants typically enjoyed and appreciated personalized content. Some, however, shared sentiments of unease, this was predominant for targeted advertisement. Moreover, some of the participants did not care whether they received targeted content, instead they stated that they had chosen to 'just accept it'. This may represent a lack of choice when it comes to receiving personalized content, particularly salient for adolescents who want to be on social media partly due to fear of missing out. Few participants used available options to block content, most would simply scroll on. Unexpectedly, several participants believed that their phone could hear them. Even though the participants themselves assumed that this was a conspiracy theory, it was a prominent finding and a sentiment shared by participants across interviews. This finding exemplifies that adolescents' understanding of social media personalization does not always reflect advanced digital competence. Future research should aim for longitudinal studies that follow individuals' development over time, to obtain more accurate predictions and a more comprehensive overview over adolescents' experience with targeted and personalized content on social media. This work is currently ongoing by this project group.

Acknowledgment

This study received funding from Kristiania University College. The authors thank Ringerike municipality for their cooperation and help with recruitment, and all the adolescents that volunteered as participants in the study.

References

[1] Statistisk sentralbyrå [Statistics Norway], "Bruk av ulike medier, etter kjønn og alder [Use of different media, by gender and age]," *SSB.no*, 2021. [Online]. Available from: https://www.ssb.no/statbank/table/12947/

[2] A. Bakken, "Ungdata 2021: Nasjonale resultater [Young data 2021: National results]," *NOVA*, 2021.

[3] Medietilsynet [The Norwegian Media Authority], "Barn og medier 2020: Om sosiale medier og skadelig innhold på nett [Children and media 2020: On social media and harmful content online]," *Medietilsynet*, 2020.

[4] A. Orben, "Teenagers, screens and social media: a narrative review of reviews and key studies," *Soc. Psychiatry Psychiatr. Epidemiol.*, vol. 55, no. 4, pp. 407–414, 2020.

[5] E. Porat, I. Blau, and A. Barak, "Measuring digital literacies: Junior high-school students' perceived competencies versus actual performance," *Comput. Educ.*, vol. 126, no. June, pp. 23–36, 2018.

[6] F. Khan and E. Vuopala, "Digital competence assessment across generations: A Finnish sample using the digcomp framework," *Int. J. Digit. Lit. Digit. Competence*, vol. 10, no. 2, pp. 15–28, 2019.

[7] E. Powers, "My News Feed is Filtered?: Awareness of news personalization among college students," *Digit. Journal.*, vol. 5, no. 10, pp. 1315–1335, 2017.

[8] M. Eslami *et al.*, "I always assumed that I wasn't really that close to [her]": Reasoning about invisible algorithms in news feeds," in *Proceedings of the Conference on Human Factors in Computing Systems (CHI)*, 2015, pp. 153–162.

[9] L. A. Shapiro and G. Margolin, "Growing up wired: Social networking sites and adolescent psychosocial development," *Clin. Child Fam. Psychol. Rev.*, vol. 17, no. 1, pp. 1–18, 2014.

[10] V. Schønning, G. J. Hjetland, L. E. Aarø, and J. C. Skogen, "Social media use and mental health and well-being among adolescents – a scoping review," *Front. Psychol.*, vol. 11, p. 1949, 2020.

[11] S. Livingstone, G. Mascheroni, and E. Staksrud, "European research on children's internet use: Assessing the past and anticipating the future," *New Media Soc.*, vol. 20, no. 3, pp. 1103–1122, 2018.

[12] P. M. Valkenburg, A. Meier, and I. Beyens, "Social media use and its impact on adolescent mental health: An umbrella review of the evidence," *Curr. Opin. Psychol.*, vol. 44, pp. 58–68, 2022.

[13] S. Youn and S. Kim, "Newsfeed native advertising on Facebook: young millennials' knowledge, pet peeves, reactance and ad avoidance," *Int. J. Advert.*, vol. 38, no. 5, pp. 651–683, 2019.

[14] E. Van den Broeck, K. Poels, and M. Walrave, "How do users evaluate personalized Facebook advertising? An analysis of consumer- and advertiser controlled factors," *Qual. Mark. Res.*,

vol. 23, no. 2, pp. 309–327, 2020.

[15] A. Oeldorf-Hirsch and P. Srinivasan, "An unavoidable convenience: How post-millennials engage with the news that finds them on social and mobile media," *Journalism*, 2021.

[16] J. Swart, "Experiencing algorithms: How young people understand, feel about, and engage with algorithmic news selection on social media," *Soc. Media Soc.*, vol. 7, no. 2, pp. 1–11, 2021.

[17] M. Eslami *et al.*, "First I 'like' it, then I hide it: Folk theories of social feeds," *Conf. Hum. Factors Comput. Syst. - Proc.*, pp. 2371–2382, 2016.

[18] O. Alvarado and A. Waern, "Towards algorithmic experience: Initial efforts for social media contexts," *Conf. Hum. Factors Comput. Syst. - Proc.*, vol. 2018-April, pp. 1–9, 2018.

[19] T. Bucher, "The algorithmic imaginary: exploring the ordinary affects of Facebook algorithms," *Inf. Commun. Soc.*, vol. 20, no. 1, pp. 30–44, 2017.

[20] A. Orben, T. Dienlin, and A. K. Przybylski, "Social media's enduring effect on adolescent life satisfaction," *Proc. Natl. Acad. Sci. U. S. A.*, vol. 116, no. 21, pp. 10226–10228, 2019.

[21] S. Wilkinson, "Analysing focus group data," in *Qualitative Research*, D. Silverman, Ed. Sage, 2011, pp. 83–100.

[22] R. A. Krueger and M. A. Casey, *Focus Groups. A Practical Guide for Applied Research*, 5th ed. Sage Publications, 2014.

[23] S. Brinkmann and S. Kvale, *Interviews: Learning the Craft of Qualitative Research Interviewing (vol. 3)*. Sage Publications, 2015.

[24] A. Dyrendal and D. Jolley, "Conspiracy theories in the classroom: Problems and potential solutions," *Religions*, vol. 11, no. 10, pp. 1–11, 2020.

[25] E. Pan, J. Ren, M. Lindorfer, C. Wilson, and D. Choffnes, "Panoptispy: Characterizing audio and video exfiltration from Android applications," *Proc. Priv. Enhancing Technol.*, vol. 2018, no. 4, pp. 33–50, 2018.

[26] N. Bol *et al.*, "Understanding the effects of personalization as a privacy calculus: Analyzing self-disclosure across health, news, and commerce contexts," *J. Comput. Commun.*, vol. 23, no. 6, pp. 370–388, 2018.

An Object-Based Refocusing Scheme for Light Field Video Content

Nusrat Mehajabin, Yixiao Wang, Hamid Reza Tohidypour, Panos Nasiopoulos, Mahsa Pourazad
Electrical and Computer Engineering
University of British Columbia
Vancouver, BC, Canada
e-mails:{nusratm, yixiaow, htohidyp, panosn, pourazad}@ece.ubc.ca

***Abstract*— Existing Light Field (LF) refocusing techniques refocus to all the pixels of a certain depth plane. However, in reality, the human eye focuses only on the object of interest while everything else is in depth-wise out of focus. In this paper, we propose a LF refocusing technique that is consistent with human visual perception. To this end, we perform instance segmentation on LF content and bring the whole object of interest in-focus rather than only the parts of the object that are in the same depth plane or all the objects that are on the same depth plane as the object of interest. Experimental results show that the proposed method is more consistent with the human visual perception than existing methods, yielding significantly improved visual quality results.**

Keywords-light field; refocusing; Human Visual System (HVS); instance segmentation.

I. INTRODUCTION

LF technology emerged as an "upgrade" to the way we capture and reproduce visual information [1][2]. It offers even more immersive and holistic imaging experience than 360 video and omnidirectional stereo videos [3]. It allows post-shoot refocusing, perspective shifts, depth of field change, and 3D-like content generation with great precision. In fact, refocusing is the most far-reaching potential application of LF technology and the foundation for more realistic mixed reality applications. As augmented reality (AR)/ virtual reality (VR)/ mixed reality (MR) technologies use position and eye tracking, the experience needs to adjust to user's head and eye movement making it more comfortable and immersive. However, with the current state of LF refocusing, we can only alter the focal plane of a captured LF and refocus on all the objects (pixels) belonging to that focal plane. In other words, we bring all the pixels pertaining to the desired depth in-focus and everything else is out of focus.

LFs are captured either by plenoptic cameras or camera arrays. Plenoptic cameras [1] place an array of microlenses in between primary lens and photosensor to capture angular information. Limited photosensor resolution forces us to choose between spatial or angular resolution. In contrast, camera arrays [2] arrange multiple cameras on a rig to capture a scene. The distances between the lenses of the cameras (centimeters) are far greater than they are in plenoptic cameras (nanometers). This means that the point of views are further apart in camera array than they are in plenoptic camera. For camera array setups, the number of cameras dictates the angular resolution/number of viewpoints. Each camera's photo-sensor captures a single image, resulting in higher spatial resolution LFs. Traditional camera array systems are bulky and require a lot of hardware [4] but through camera miniaturization [5] these problems are being rapidly solved. As camera array content has larger baseline, typical refocusing methods lead to aliasing problem in the out of focus region [6].

A stereo-image refocusing method was introduced by Busam et al. [7]. This method selectively blurs the image based on the estimated depth using the stereo image, to create a refocused effect. However, this method was not extended for more than two cameras. Similar problems were found in the works of Cossairt et al. [8] and Bando et al. [9]; the former creates a refocused image using three images, whereas the latter generates the entire LF from a single image. Recent method by Wang et al. [10] also proposes to generate the out of focus region using depth-based anisotropic filters and in-focus region is produced by reconstruction based super resolution. Up to this point, all LF refocusing research assumed the new focal plane for refocusing will be parallel to the camera. Another recent work by Alain et al. [11] considered the scenario where the viewer tilts their head and the desired refocus plane and viewpoint are no longer parallel to the camera. In summary, all the above-mentioned approaches are designed for refocusing to a new focus plane, thereby, bringing all the pixels that are a certain distance from the camera in-focus and rendering everything else as depth wise blur. However, when we observe a scene and focus on an object, every part of the scene having the same distance from our eyes does not come into focus for us. Instead, we see that object clearly and everything else is in depth wise blurred with respect to that object.

In this paper, we propose a realistic, more immersive, and more visually pleasing object-based LF refocusing technique, which uses a deep learning network to synthesize an appropriate number of new views and another deep learning network for object segmentation.

 ISBN: 978-1-61208-927-0

(a) (b) (c)

Figure. 1. (a) original view (90th frame), (b) COCO annotator segmented view (90th frame) (c) Deep learning network segmented view (91st frame)

The rest of this paper is organized as follows. In Section II, we present our object segmentation-based enhancement method. Experimental results are presented and discussed in Section III. We conclude our work in Section IV.

II. PROPOSED METHOD

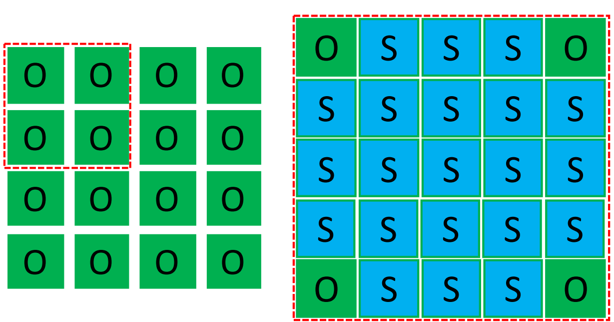
Our proposed refocusing scheme for LF camera array videos uses a deep learning-based view synthesis method and a shift and sum approach combined with a unique object segmentation-based enhancement technique for the in-focus object. Viewers select the object they wish to refocus on, and our method refocuses on that object while depth wise blurring the rest of the scene. The following subsections describe our approach in detail.

A. *Object Segmentation of LF videos*

At first, we segment individual objects in the video. We used an object segmentation deep learning network Detectron2 [12] on LF videos [13] and segmented the objects. We used COCO Annotator [14] to annotate 1 frame per second for the LF videos and trained Detectron2 using these frames. Then, we used the trained network to segment all the other frames of the video. Figure 1 (a)-(c) show the original frame, the COCO Annotator annotated frame and the Detectron2 segmented frame correspondingly.

B. *View Synthesis*

After object segmentation, to reduce the aliasing artifacts caused by the wide baseline of camera arrays, we synthesize novel views in between existing views using a factor of *n*. Here, *n=1* is equivalent to one novel view between two adjacent views and 1 view between each pair of horizontal/vertical synthesized views. Therefore, the total number of views is $(nN - n+N)^2$, where $N \times N$ is the arrangement and number of cameras on the camera array. We used a pre-trained fully-convolutional encoder-decoder deep learning network [15] architecture (modeled after the popular convolutional neural network VGG-19 [16] by the Visual Geometry Group) to synthesize the novel views. This network does not require any camera parameter information, and thus it can be generalized to any LF video dataset. Given two input views captured by two horizontally/vertically aligned cameras and the distance between those two cameras, the network can synthesize as many novel views between the input views as desired. Figure 2 shows view synthesis for *n=3*.



(a) (b)

Figure. 2. (a) Original Views, (b) After n=3 view synthesis for top left original 2×2 views

C. *LF Refocusing*

During the refocusing process, one camera will be picked as the reference camera. Then, the user selects any object on the reference view to refocus on. We estimate the depth of that object using Depth Estimation Reference Software (DERS) [17]. Next, we need the disparity shift of all the views from the reference view at the determined depth. The disparity shift for original views can be found in [13]. The synthesized views are calculated by linearly interpolating between the disparity shifts of the two adjacent original views. Finally, we apply the generalized shift and sum algorithm [11] using the interpolated and original disparities to produce the refocused video.

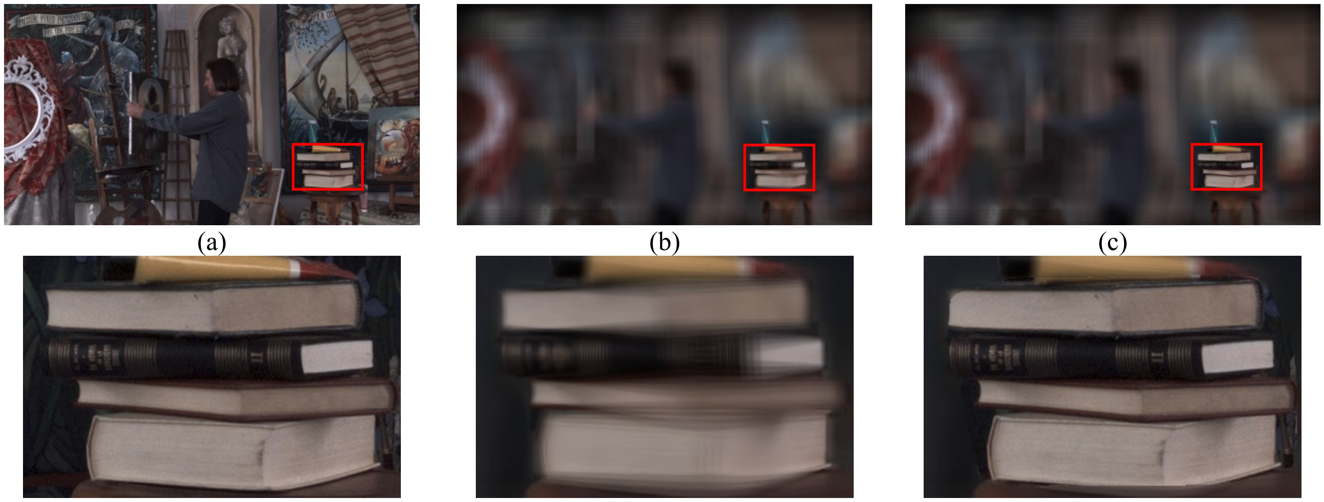
D. *Object Segmentation based Enhancement Method*

After refocusing, we see that all the objects/pixels of the refocused plane are in-focus rather than the object of interest. We also observe that the refocused plane appears to be a little blurry, especially when it is close to the camera. The reason for this is that the synthesized views are not as accurate as the original views and as a result the average values for the in-focus pixels are not accurate either. To address these problems, we introduce an object segmentation-based enhancement method. First, we segment the object of interest from the reference view using the trained deep learning network. Next, we replace the pixels values of the segmented object at the refocused view with those of the reference view.

III. EXPERIMENTAL RESULTS

We used the Interdigital LF video dataset [13] to evaluate the proposed approach. The LF videos were captured by a

 ISBN: 978-1-61208-927-0



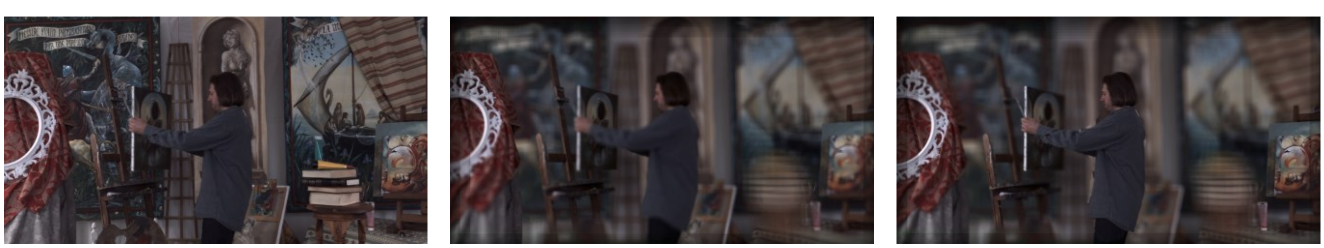
(a) (b) (c)

(d) (e) (f)

Figure. 3. (a) Original reference view, (b) Refocusing without enhancement, (c) Refocusing with object segmentation-based enhancement, (d), (e) and (f) are the enlargements of refocused objects of (a), (b) and (c), respectively

synchronized 4×4 camera array at 30fps. The cameras are 70*mm* apart with 50°×37° field of view. Each LF video has 2048×1088 spatial resolution in raw 4:2:0 8bit YUV format and is 12.3 seconds long (i.e., 372 frames). We demonstrate the original reference frame, refocused frames without and with our proposed object segmentation- based enhancement in Figure 3. We have experimented with different numbers of synthesized views $n = \{0, 1, 2, 3, 5, 10\}$, at various depths (in meters) from the camera: $z = \{1.9, 2.0, 3.0, 3.2, 4.0\}$.

For demonstration purposes, we show the 75th frame of the "Painter" LF video sequence in Figure 3. We observed that as we increase the value of n for view synthesis, the refocusing results improve, with acceptable results achieved by $n = 3$ (total 169 views with 16 original views). Based on the above observations and the increased computational complexity of generating more views, we decided to fix $n = 3$. Results of both without and with enhancement refocused at a 2m distance are shown in Figure 3 (b) and Figure 3(c), respectively. From Figure 3, it is obvious that object segmentation-based enhancement results are more consistent with human visual perception, more visually pleasing and natural compared to the results where object segmentation has not been used. The object of interest here are the books on the stool and they have been brought in sharp focus with object segmentation-based enhancement, whereas the background experiences depth wise blur. Please refer to the zoomed results in Figure 3(f). When refocused without object segmentation-based enhancement, as in Figure 3 (b), we observe the in-focus region/object is not at sharp focus, but rather looks a little blurry and suffers from some aliasing artifacts. This is more evident in the zoomed in version of Figure 3 (e). This is because we used original and synthesized views for refocusing and the synthesized views are not accurate and as a result the refocusing is not accurate either. Therefore, an enhancement technique is essential. For both with and without enhancement, the background still has some aliasing artifacts. This can be mitigated through more accurate view synthesis or by using blurring filters [10]. Comparing the backgrounds of the original all in-focus Figure 3 (d) and the proposed method in Figure 3 (f), we can notice that the background patterns (floral foliage from the painting behind) in Figure 3 (d) are clearly visible, whereas in Figure 3 (f) those patterns experience depth wise blur as they should in a human visual perception consistent refocused view. We also observe that the refocused region is blurrier if the object/region is closer to the camera. In Figure 4, we present the results of the same frame refocused on the painter at 3.2m distance from the camera. We notice the refocused region is blurry but free of any aliasing artifact. Even then, the object segmentation-based enhancement method brings the painter in sharp focus. The transition from in-focus to not in-focus region for Figure 4 (c) as well as for Figure 3 (f) looks slightly abrupt. For example, we do not see a smooth transition from the painter to background, while we



(a) (b) (c)

Figure. 4.(a) original reference view, (b) refocused on the painter at 3.2m distance and (c) refocused on the painter at 3.2m distance with enhancement would expect a smooth transition from the in-focus books on the table to the not in-focus region. This is a drawback of the proposed method. We leave this as future work, planning to explore the use of depth wise blending techniques for achieving better smoothing transition.

IV. Conclusion and Future Work

In this work, we presented an efficient and human-like visual perception refocusing scheme for LF camera array content. Our approach uses a deep learning network to synthesize an appropriate number of new views and an object segmentation-based enhancement technique to improve the overall visual quality of the refocused frame. We found that the quality enhancement approach improves the visual quality of the in-focus regions by replacing the blurry pixels of the object of interest with corresponding pixels from the reference view using object segmentation. As a result, our method achieves visually acceptable and natural-looking refocused LF videos. To the best of our knowledge, this is the first method designed to refocus camera array LF content, offering unprecedented immersiveness, consistency with human visual perception and an excellent infrastructure for producing high-quality mixed reality content. Along with this paper we publish the code and an easy-to-use UI application [18] which might be of special interest for the community. Our future work will focus on finetuning the object segmentation process and increasing the size of our training dataset to include as many unique objects as possible.

References

[1] R. Ng *et al.*, "Light Field Photography with a Hand-held Plenoptic Camera," Doctoral dissertation, Stanford University, 2005.

[2] B. Wilburn *et al.*, "High Performance Imaging Using Large Camera Arrays," ACM SIGGRAPH, pp. 765-776, 2005.

[3] R. S. Overbeck, D. Erickson, D. Evangelakos, M. Pharr, and P. Debevec, "A system for acquiring, processing, and rendering panoramic light field stills for virtual reality," *SIGGRAPH Asia 2018 Tech. Pap.*, vol. 37, no. 6, 2018, doi: 10.1145/3272127.3275031.

[4] G. Wu *et al.*, "Light Field Image Processing: An Overview," *IEEE J. Sel. Top. Signal Process.*, vol. 11, no. 7, pp. 926–954, 2017, doi: 10.1109/JSTSP.2017.2747126.

[5] H. M. Kim, M. S. Kim, G. J. Lee, H. J. Jang, and Y. M. Song, "Miniaturized 3D depth sensing-based smartphone light field camera," *Sensors (Switzerland)*, vol. 20, no. 7, pp. 2129, 2020, doi: 10.3390/s20072129.

[6] C. Huang, J. Chin, H. Chen, Y. Wang, and L. Chen, "Fast Realistic Refocusing for Sparse Light Fields," *IEEE Int. Conf. Acoust. Speech Signal Process.*, pp. 1176–1180, 2015.

[7] B. Busam, M. Hog, S. McDonagh, and G. Slabaugh, "SteReFo: Efficient image refocusing with stereo vision," *Proc. - 2019 Int. Conf. Comput. Vis. Work. ICCVW 2019*, pp. 3295–3304, 2019, doi: 10.1109/ICCVW.2019.00411.

[8] O. Cossairt, N. Matsuda, and M. Gupta, "Digital refocusing with incoherent holography," *2014 IEEE Int. Conf. Comput. Photogr. ICCP 2014*, pp. 1-9, 2014, doi: 10.1109/ICCPHOT.2014.6831819.

[9] Y. Bando and T. Nishita, "Towards Digital Refocusing from a Single Photograph," *15th Pacific Conference on Computer Graphics and Applications*, pp. 363-372, 2007

[10] Y. Wang, J. Yang, Y. Guo, C. Xiao, and W. An, "Selective Light Field Refocusing for Camera Arrays Using Bokeh Rendering and Superresolution," *IEEE Signal Process. Lett.*, vol. 26, no. 1, pp. 204–208, 2019, doi: 10.1109/LSP.2018.2885213.

[11] M. Alain, W. Aenchbacher, and A. Smolic, "Interactive Light Field Tilt-Shift Refocus with Generalized Shift-and-Sum," arXiv preprint arXiv:1910.04699 (2019).

[12] Y. Wu, A. Kirillov, F. Massa, W.-Y. Lo, and R. Girshick, "Detectron2," Available from: https://github.com/facebookresearch/detectron2, 2019.

[13] N. Sabater *et al.*, "Dataset and Pipeline for Multi-view Light-Field Video," *IEEE Comput. Soc. Conf. Comput. Vis. Pattern Recognit. Work.*, vol. 2017-July, pp. 1743–1753, 2017, doi: 10.1109/CVPRW.2017.221.

[14] J. Brooks, "COCO Annotator." Available from: https://github.com/jsbroks/coco-annotator/, 2019.

[15] T. Zhou, R. Tucker, J. Flynn, G. Fyffe, and N. Snavely, "Stereo magnification: Learning view synthesis using multiplane images," *ACM Trans. Graph.*, vol. 37, no. 4, 2018, doi: 10.1145/3197517.3201323.

[16] K. Simonyan and A. Zisserman, "Very deep convolutional networks for large-scale image recognition," *3rd Int. Conf. Learn. Represent. ICLR 2015 - Conf. Track Proc.*, pp. 1–14, 2015.

[17] S. Rogge *et al.*, "MPEG-I Depth Estimation Reference Software," in *2019 International Conference on 3D Immersion (IC3D)*, 2019, pp. 1–6, doi: 10.1109/IC3D48390.2019.8975995.

[18] N. Mehajabin, "Human Visual Perception Consistent Light Field Refocusing." Available from: https://github.com/Nusrat17/Light-Field-Refocusing, Vancouver, 2021.

Chaos-based Protection Data for Digital Communication

Belqassim Bouteghrine
Lcoms
Université de Lorraine
Metz, France
email:belqassim.bouteghrine@univ-lorraine.fr

Camel Tanougast
Lcoms
Université de Lorraine
Metz, France
email:camel.tanougast@univ-lorraine.fr

Said Sadoudi
Laboratoire Télécommunications
Ecole Militaire Polytechnique
Algiers, Algeria
email:sadoudi.said@gmail.com

Mohammed Rabiai
Laboratoire Télécommunications
Ecole Supérieure Ali Chabati
Reghaia, Algeria
email:mohammed.rabiai2013@gmail.com

***Abstract*—Due to advancements in digital technologies in recent years, the security of exchanged data has become the most attractive topic for many researchers. Consequently, several cryptography schemes have been introduced and proposed for securing the exchanged sensitive data in the network. In this paper, we propose new chaos-based protection in order to secure both the exchanged identity text and the image data. In addition, we applied the proposed encryption to secure the exchanged heterogeneous data inside a C# chat application. The analysis of the simulation results shows that the proposed scheme offers a better performance in terms of security and robustness than some similar schemes.**

***Keywords*—data security; cryptography; chaos; C# application.**

I. INTRODUCTION

With the advent in Internet and networking applications, security becomes a major concern in the current era of information technology. The security threats and attacks are increased due to the huge amount of exchanged data over the network. As a solution to these threats, information security is a well known proposal which provides protection to data availability, privacy, and integrity [1]. Moreover, data encryption is considered as the most traditional technique that secures highly confidential information by using some conventional algorithm, which already exists [2]. Looking for more flexibility and security, Saraf et al. [3] have proposed an AES(Advanced Encryption Standard)-based encryption and decryption for text and image data. For text encryption, 128-bit text inputs are synthesized and simulated using a code composer studio tool in C developing language code. For image encryption, a Java developing language code is synthesized and simulated by Java Application Platform. By combining the AES and the Elliptic Curve Cryptography (ECC), [4] proposes an extension of a public-key-based cryptosystem. To overcome the drawbacks shown in the traditional 128-AES, the introduced scheme proposes a hybrid encryption system including ECC and AES schemes. The optimized technique includes a trade-off between the key space (192 bit) and the number of iterations (12). For text encryption application, a new technique has been proposed in [5]. The proposed new technique addresses the leak of mapping the characters to refine points in the elliptic curve showed in classic techniques. The main idea of this solution is to pair values of plain text and corresponding ASCII to serve as input for the elliptic curve based encryption. The proposed algorithm is designed to be used for encryption and decryption of exchanged text data. In [6], Singh et al. presented a new encryption scheme based on symmetric key encryption. The proposed algorithm converts the plain text to get the corresponding ASCII values, which are considered as the input text of the cryptosystem. Similarly, the decryption process starts also by converting the cipher text to ASCII values which will be the input of this process. In [7], Chandra et al. proposed double encryption, which is a content-based algorithm that implements a folding method and a circular bit-wise operation. In this technique, encryption of plaintext occurs two times with a secret key, providing cipher text by using a circular bit-wise binary addition operation. Another concept based on double encryption is proposed in [8] to provide high level of security. In this technique, the plaintext is encrypted by an encryption technique using a secret key, which is also encrypted by another algorithm. Then, the plaintext is encrypted again using the encrypted secret key. However, all of these proposals suffer from key distribution and resources consumption, which make them less suitable for constrained devices and real time applications [9]. Moreover, more complex schemes have been highlighted by many studies proving their high computational cost, which affects mainly the resource-limited devices that are included in the new networks [10].

One of the advanced cryptography techniques is Attribute-Based Encryption (ABE), which was introduced to overcome the limited functionalities of the traditional public key cryptography schemes [11]. However, in multi-authority

 ISBN: 978-1-61208-927-0

systems, many complicated issues can be experienced when the ABE systems are built (revocation problem) [12]. For example, to tie the work of all authorities together, some existing systems use a central authority, which can cause a bottleneck problem and is contradictory to the distributed control principle [12].

Nowadays, chaotic encryption method seems to be much better than traditional encryption methods [13]. Chaos-based schemes have introduced the use of chaotic system properties such as sensitivity to initial condition and loss of information. Therefore, many chaos-based encryption methods have been presented and discussed in the last decades. Moreover, Babaei [14] included a logistic chaotic map as an input of a One-Time-Pad algorithm (OTP) for image encryption application. In addition, for text files encryption, authors have proposed a new algorithm based on a chaotic selection between original message strands and OTP DNA strands [14]. The obtained result of the proposed solution proved the efficiency of the proposed algorithm in both image and text encryption. However; all these schemes have shown some shortcomings regarding the key space offered by the chaotic system and the robustness of the used chaotic system. Hence, unlike all the previous proposals, we introduce through this paper a novel and dynamic chaos-based cryptosystem in order to secure both the exchanged identity text and the image data. In addition, we applied the proposed cryptosystem for secure exchanged heterogeneous data inside a C# application. Therefore, the main contributions of this paper are as follows: (i) A new four-dimensional (4-D) chaotic system that shows good chaotic properties; (ii) A new and a simplified algorithm based on a chaos system and a hash function for multimedia data encryption purpose.

The rest of this paper is organized as follows. Section 2 gives the proposed chaotic system. Section 3 includes the application of the configurable chaos-based cryptosystem. Conclusion and some perspectives are given in Section 4.

II. The Proposed Configurable Cryptosystem

The proposed configurable chaos system is multidimensional system including several systems (2-D, 3-D and 4-D systems) that are extracted from our proposal given in [17].

The first system is a 2-D dimension described as follows:

$$\begin{cases} X(n+1) = 1 - a * X(n)^2 + Y(n) \\ Y(n+1) = d * X(n) \end{cases} \tag{1}$$

The 3-D system defined by five (05) nonlinear terms and three (03) controllers is described as follows:

$$\begin{cases} X(n+1) = 1 - a * X(n)^2 + (Y(n) * Z(n)) \\ Y(n+1) = 1 - b * Y(n)^2 + (X(n) * Z(n)) \\ Z(n+1) = d * X(n) * Y(n) \end{cases} \tag{2}$$

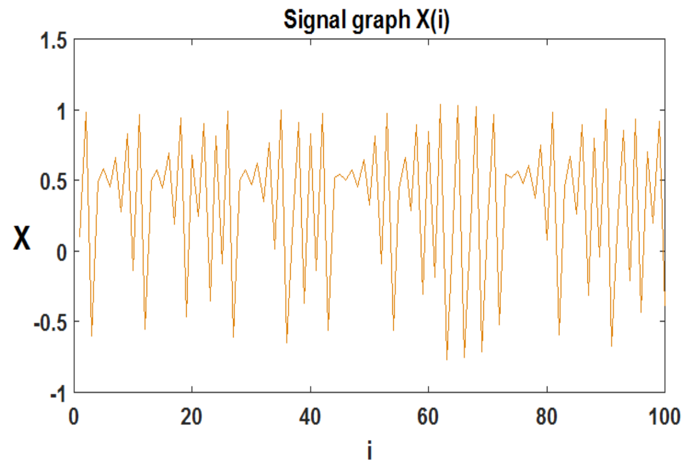


Fig. 1: Signal Graph X(i) of the Proposed Chaotic System.

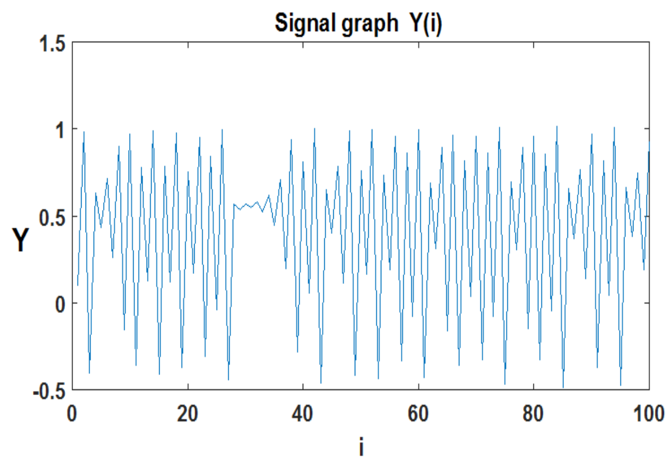


Fig. 2: Signal Graph Y(i) of the Proposed Chaotic System.

Finally, the proposed 4-D map with seven (07) nonlinear terms is given as follows:

$$\begin{cases} X(n+1) = 1 - a * X(n)^2 + (Y(n) * Z(n) * P(n)) \\ Y(n+1) = 1 - b * Y(n)^2 + (X(n) * Z(n) * P(n)) \\ Z(n+1) = 1 - c * Z(n)^2 + (X(n) * Y(n) * P(n)) \\ P(n+1) = d * X(n) * Y(n) * Z(n) \end{cases} \tag{3}$$

where X, Y, Z and P are the state variables and a, b, c and d are the control parameters or the controllers of the system.

To obtain the chaotic behavior of the proposed system (see Figures 1 to 10) , we define the values of the controllers as: a=1.65; b=1.45; c=1.7 and d=0.35; all with initial state of $X(0)$=$Y(0)$=$Z(0)$=$P(0)$ = 0.1. All these values are selected to ensure the chaotic behaviour of the proposed system, using the algorithm presented in [18].

Figures 1 to 4 show the signals of the variables X, Y, Z and P, which confirm the behaviour of the system. Moreover, we used the plan projection of the trajectories obtained through

 ISBN: 978-1-61208-927-0

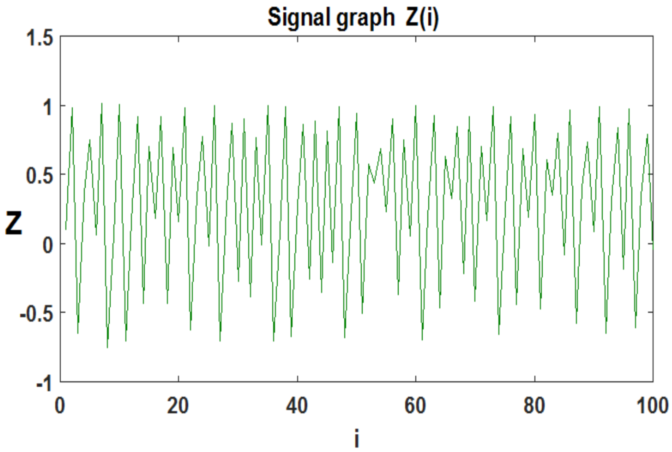


Fig. 3: Signal Graph Z(i) of the Proposed Chaotic System.

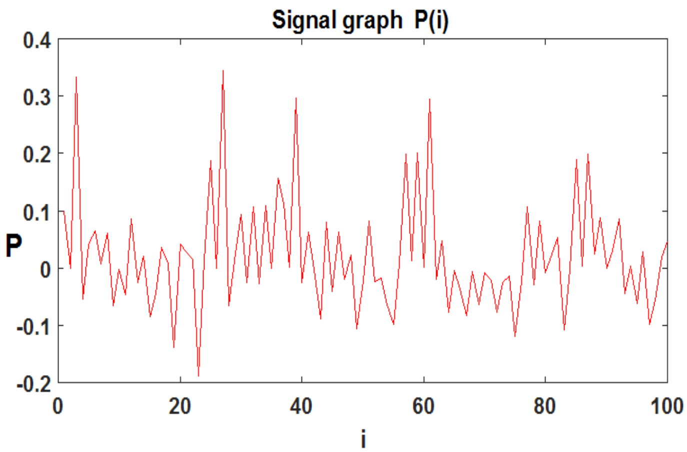


Fig. 4: Signal Graph P(i) of the Proposed Chaotic System.

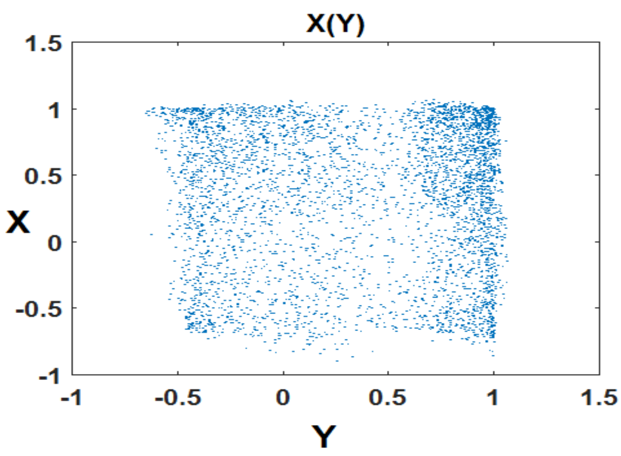


Fig. 5: Trajectory Graph X(Y) of the Proposed Chaotic System.

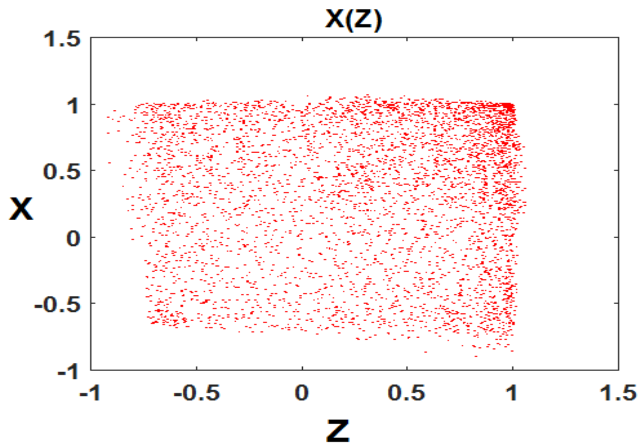


Fig. 6: Trajectory Graph X(Z) of the Proposed Chaotic System.

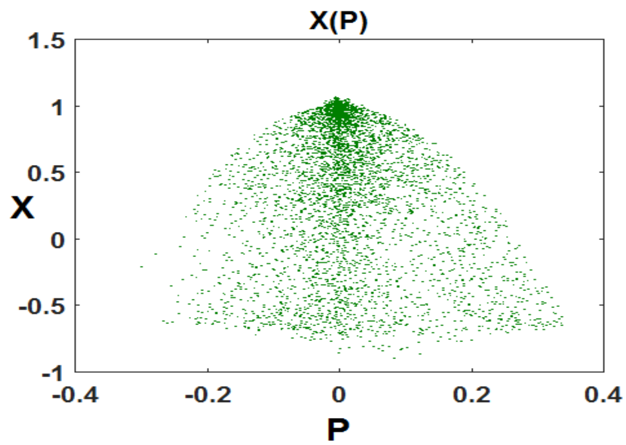


Fig. 7: Trajectory Graph X(P) of the Proposed Chaotic System.

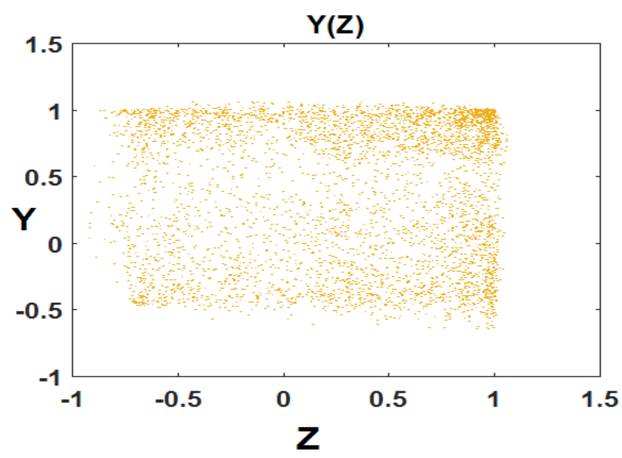


Fig. 8: Trajectory Graph Y(Z) of the Proposed Chaotic System.

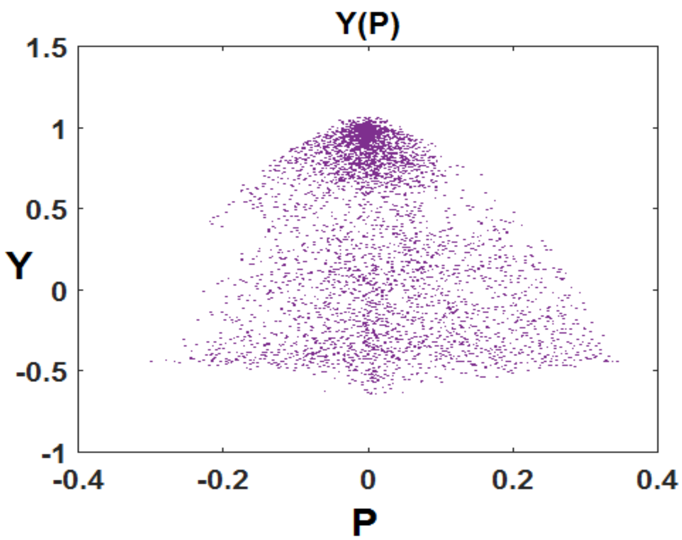


Fig. 9: Trajectory Graph Y(P) of the Proposed Chaotic System.

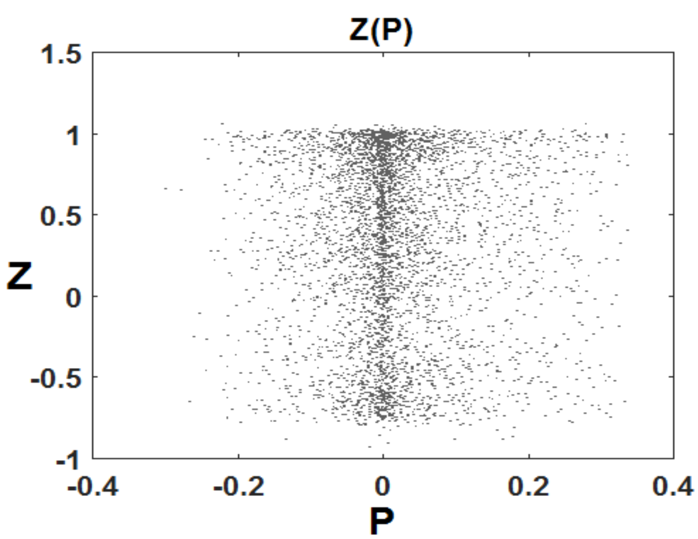


Fig. 10: Trajectory Graph Z(P) of the Proposed Chaotic System.

these variables to confirm the chaotic behaviour, as shown in Figures 5 to 10.

III. Application of the Proposed Cryptosystem

We present an application of the proposed configurable chaos system to secure the exchanged sensitive data in digital communications.

A. Algorithm Design and Implementation

A secure communication channel is a software application that includes user's interface and a cryptosystem to ensure data encryption. Due to the variety of the exchanged data and the high demand of lightweight cryptosystem, we introduce a configurable chaos-based cryptosystem using the chaotic maps defined by equations (1), (2) and (3). The proposed algorithm,

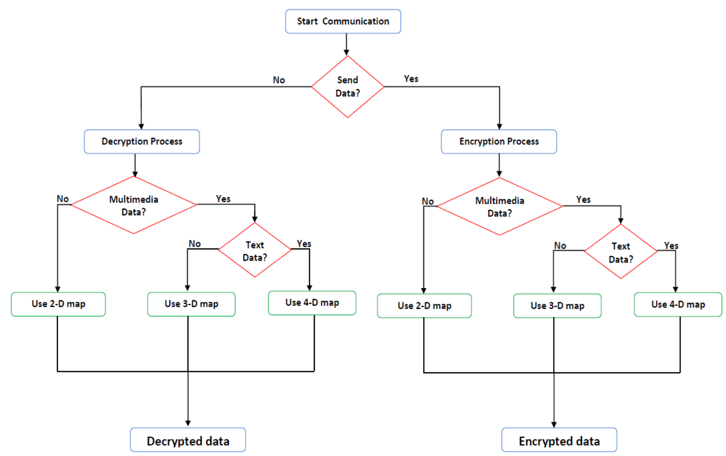


Fig. 11: The Proposed Algorithm Flow Chart.

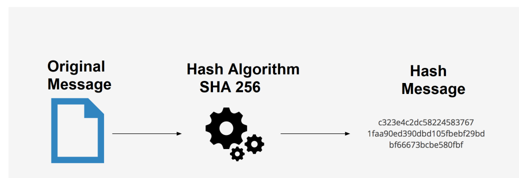


Fig. 12: Hash Function Design.

as shown in the flow chart in 11), runs as follows:
(i) Once the communication is established, we distinguish between two (2) main cases: sending data or receiving data;
(ii) In the case of sending data, we run the encryption process according to the data type. For only text data, we use the 2-D system for the encryption. Then, for only image data, we use the 3-D system. Finally, we use the 4-D system in the case of both image and text data;
(iii) In the case of receiving data, we run the same steps as in (ii) for the decryption process according to the received data type.

The reason of using the 2-D system for encrypting only text data is that the text data does not require a higher dimensional chaotic system. Moreover, we used the 3-D system only for image encryption in order to follow the approach based on the 3-D chaos system proposed in [18]. Finally, the 4-D system is used for encryption of heterogeneous data (text and image) by allowing three (3) components for the image and one (1) component for the text.

To enhance the security of encrypted text, we include the solution called SHA2 (Secure Hash Algorithm 2) or SHA256 (see Figure 12) as hash function which is considered better than MD5 (Message Digest 5) and SHA1 [15]. The proposed hash function is implemented using some widely used security applications and protocols, including Transport Layer Security (TLS), Secure Sockets Layer (SSL) and Internet Protocol Security (IPsec).

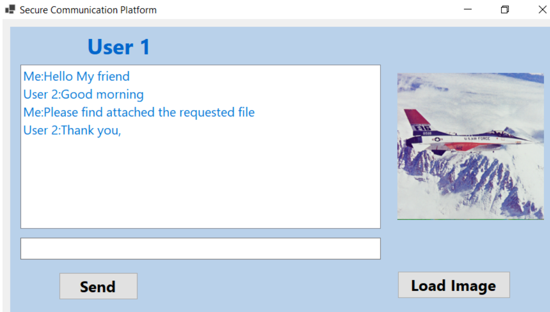


Fig. 13: First User's Interface.

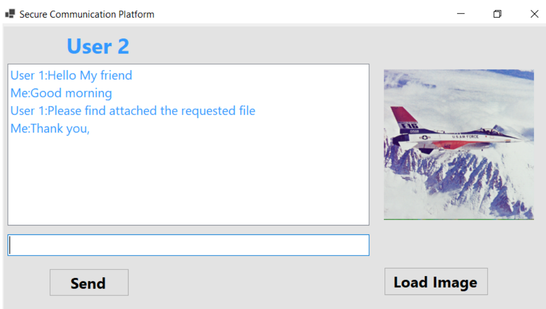


Fig. 14: Second User's Interface.

B. Performance Analysis

We use C# programming language to implement the proposed solution and application. The proposed application is composed of two (02) interfaces for exchanging messages (see Figure 13 and Figure 14), and a third separate interface to show the encryption process's results (see Figure 15).

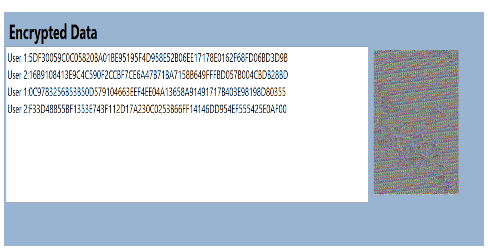


Fig. 15: Encrypted Exchanged Data Using the Proposed System.

1) Key Sensitivity: To evaluate the sensitivity to initial conditions of the proposed system, we consider a changing by 10^{-10} of the initial values related to the variables $X(0)$, $Y(0)$, $Z(0)$ and $P(0)$. The sensitivity to the slightest changes of the different variables is obtained by generating two trajectories L1($X(0)$,$Y(0)$,$Z(0)$,$P(0)$) and L2($X(0)$+10^{-10}, $Y(0)$+10^{-10}, $Z(0)$+10^{-10}, $P(0)$+10^{-10}) keeping the same control parameters. The results shown in the Figures 16 to 19 prove that, even with the weakest difference in initial values attributed to $X(0)$,$Y(0)$,$Z(0)$ and $P(0)$, we observe significant changes after only around 50 iterations, which confirms the sensitivity dependence on the initial conditions of the proposed maps.

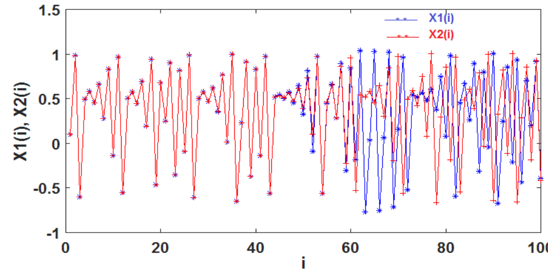


Fig. 16: Sensitivity of the Signal X(i).

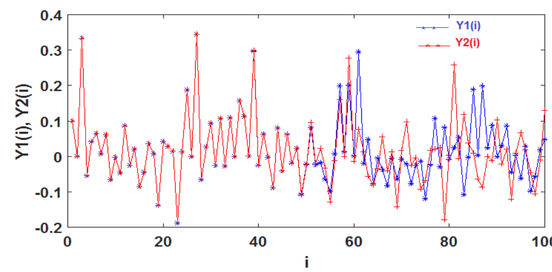


Fig. 17: Sensitivity of the Signal Y(i).

2) Key Space: Usually, chaos-based cryptosystems are made of Pseudo-Random Number Generators (PRNG) used as key streams for ciphering. Among the required conditions for an encryption scheme to be secure, we find the large key space condition to resist against brute-force attacks [16]. Thereby, the analysis of the key space parameter, which is defined by the number of the parameters and the size of the

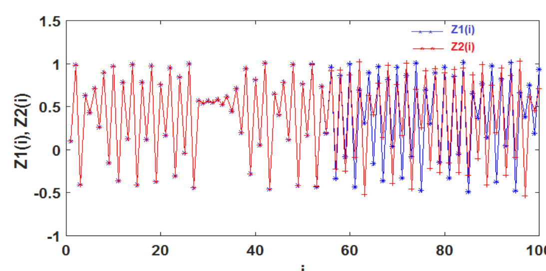


Fig. 18: Sensitivity of the Signal Z(i).

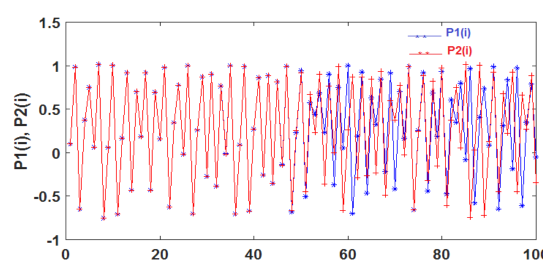


Fig. 19: Sensitivity of the Signal P(i).

 ISBN: 978-1-61208-927-0

desired key, is used as a basis of comparison between the proposed system and some existing systems. Therefore, by supposing the generation of cipher keys on 32 bits, the key space parameter is computed for each map and showed in Table I.

TABLE I. KEY SPACE COMPARISON.

Cryptosystems	Key space value
The proposed (2-D)	2^{128}
The proposed (3-D)	2^{192}
The proposed (4-D)	2^{256}
AES	2^{128}
DES (Data Encryption Standard)	2^{56}
3-DES	2^{168}

3) Security of Hash Encryption: In practice, there are two common methods used to attack the hash encryption algorithm.

The first method is based on finding the collision by introducing different characters, which would help to get the same hash values when the collision occurs. Therefore, the attacker could crack the SHA256 by obtaining the same hash value with the one used during the encryption process. However, in our case with 256 bits of SHA256 and 32 bits of the generated chaotic sequence, the task of cracking our algorithm becomes impossible.

The second method found in the literature for attacking the hash encryption algorithm is called exhaustive method. For some short and simple combination, this method is very efficient. Nevertheless, due to the adopted process of this method based on single character scan, and the combination of the words in the dictionary, the exhaustive method is difficult to work with the number of the characters included in the output of the SHA256 hash encryption algorithm.

IV. Conclusion and Future Work

With the development of Internet and digital networking applications, security has become a major concern in the current era of Information Technology.

Unlike all the previous related works, we presented in this paper a novel and dynamic chaos-based cryptosystem in order to secure both the exchanged identity text and the image data. First, we described and analyzed the different dimensional chaotic systems (2-D, 3-D and 4-D). Then, we applied the proposed chaotic systems inside a C# chat application to secure the exchanged data. The encryption/decryption processes are run using the 2-D system for exchanged text data, the 3-D system for only image data and the 4-D system for both text and image data. Results showed that the proposed chaotic maps are very sensitive to initial conditions and provide larger key space to perform secure communication.

As future work, the integration of digital FPGA (Field-Programmable Gate Array) technology for data encryption in an IP-communication with the proposed solution will be investigated. Moreover, the evaluation of the proposed scheme where several input data of different types and complexities will be performed and compared against the results obtained through existing schemes.

References

[1] S. Singh, P. K. Sharma, S. Y. Moon, and J. H. Park, ”Advanced lightweight encryption algorithms for IoT devices: survey, challenges and solutions,” Journal of Ambient Intelligence and Humanized Computing, pp. 1–18, 2017.

[2] R. R. Salavi, M. M. Math, and U. P. Kulkarni, ”A Survey of various cryptographic techniques: from traditional cryptography to fully homomorphic encryption,” Innovations in Computer Science and Engineering, pp. 295–305, 2019.

[3] K. R. Saraf, V. P. Jagtap, and A. K. Mishra, ”Text and image encryption decryption using advanced encryption standard,” International Journal of Emerging Trends and Technology in Computer Science (IJETTCS), vol. 3, pp. 118–126, 2014.

[4] N. Mathur and R. Bansode, ”AES based text encryption using 12 rounds with dynamic key selection,” Procedia Computer Science, vol. 79, pp. 1036–1043, 2016.

[5] L. D. Singh and K. M. Singh, ”Implementation of text encryption using elliptic curve cryptography,” Procedia Computer Science, vol. 54, pp. 73–82, 2015.

[6] U. Singh and U. Garg, ”An ASCII value based text data encryption system,” International Journal of Scientific and Research Publications, vol. 3, pp. 2250–3153, 2013.

[7] S. Chandra, B. Mandal, S. S. Alam, and S. Bhattacharyya, ”Content based double encryption algorithm using symmetric key cryptography,” Procedia Computer Science, vol. 57, pp. 1228–1234, 2015.

[8] S. C. Iyer, R. R. Sedamkar, and S. Gupta, ”A novel idea on multimedia encryption using hybrid crypto approach,” Procedia Computer Science, vol. 79, pp. 293–298, 2016.

[9] P. Dixit, A. K. Gupta, M. C. Trivedi, and V. K. Yadav, ”Traditional and hybrid encryption techniques: a survey,” Networking communication and data knowledge engineering, pp. 239–248, 2018.

[10] R. R. Al-Dahhan, Q. Shi, G. M. Lee, and K. Kifayat, ”Survey on revocation in ciphertext-policy attribute-based encryption,” Sensors, vol. 19, p. 1695, 2019.

[11] V. H. Kalmani, D. Goyal, and S. Singla, ”An efficient and secure solution for attribute revocation problem utilizing CP-ABE scheme in mobile cloud computing,” International Journal of Computer Applications, vol. 129, pp. 16–21, 2015.

[12] L. Pang, J. Yang, and Z. Jiang, ”A survey of research progress and development tendency of attribute-based encryption,” The Scientific World Journal, vol. 2014, 2014.

[13] M. Philip and A. Das, ”Survey: Image encryption using chaotic cryptography schemes,” IJCA Special Issue on “Computational Science-New Dimensions and Perspectives” NCCSE, pp. 1–4, 2011.

[14] M. Babaei, ”A novel text and image encryption method based on chaos theory and DNA computing,” Natural computing, vol. 12, pp .101–107, 2013.

[15] D. Rachmawati, J. T. Tarigan, and A. B. C. Ginting, ”A comparative study of message digest 5 (MD5) and SHA256 algorithm,” Journal of Physics: Conference Series, vol. 978, p. 012116, 2018.

[16] G. Alvarez and S. Li, ”Some basic cryptographic requirements for chaos-based cryptosystems,” International Journal of Bifurcation and Chaos, vol. 16, pp. 2129–2151, 2006.

[17] B. Bouteghrine, C. Tanougast, and S. Sadoudi, ”Design and FPGA implementation of new multidimensional chaotic map for secure communication,” Journal of Circuits, Systems and Computers, p. 2150280, 2021.

[18] B. Bouteghrine, C. Tanougast, and S. Sadoudi, ”Novel image encryption algorithm based on new 3-d chaos map”, Multimedia Tools and Applications, vol. 80, pp. 25583-–25605, 2021.

IslandPaint: Digital Painting Floating Island Design

Wanwan Li
Department of Computer Science
George Mason University
Fairfax, Virginia, US
wli17@gmu.edu

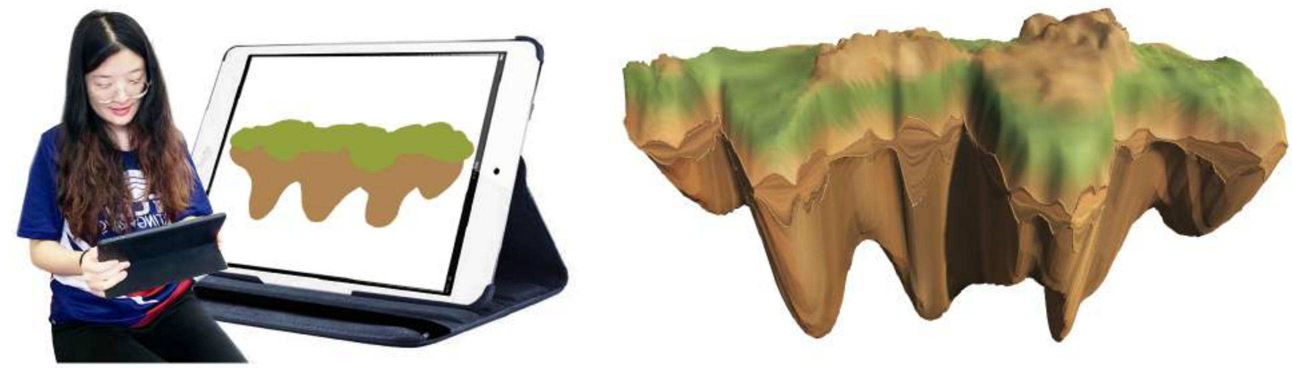


Fig. 1. Demo of IslandPaint: a smart digital painting interface for floating island design. Given the user's arbitrary digital painting of floating island (left), the 3D model of the floating island is automatically generated with our approach (right).

***Abstract*—In this paper, we present a smart digital design interface, IslandPaint: digital painting floating island design. Through IslandPaint, users can design 3D floating islands with simple 2D single-view conceptual digital paintings. As shown in our numerical experiments, after the procedural modeling process proposed by us, 3D floating islands that look like the original 2D paintings can be generated automatically. Given our interface, floating islands design becomes easier for digital art designers, digital multimedia producers, digital movie makers, and digital game authors.**

Keywords*—*digital culture; digital art design; digital painting; interactive interface; procedural modeling.

I. Introduction

With the rapid development of digital multimedia technologies, digital culture becomes a critical part of people's lives. As important ingredients of digital culture, digital arts, digital movies, and digital games are gaining more and more popularity among young people. Computer graphics technology plays an important role in digital art design. With a realistic graphics rendering engine, various types of amazing effects can be visualized realistically on screens, or even on immersive devices. Given these inevitable trends of digital culture's progressing and propagating, computer graphics modeling technologies open people's field of view. The virtual world is beyond the imagination and not beneath the facts. Physics laws in the limited real-world will no longer exist in the entire virtual digital world. The floating island is definitely solid proof of this point of view.

As a direct derivation of the digital culture, floating islands are those islands floating in the sky or space that can never be seen in the natural world. Due to the attractive visual effects and their special existence, floating islands are becoming more and more widely welcomed by digital art designers, digital movie conductors, digital game authors, players, and audiences. Typically, floating islands are the terrain blocks that look like those mountains which are pulled out from the soils and they mostly look like a small part of a terrain that is cut out from a larger part of the terrain.

However, traditional terrain procedural modeling methods are not easily applied for procedural floating island generation. Even though there are some existing works that are aiming at generating floating islands automatically, most of their approaches are based on complex logic flow and have not considered the well-studied terrain features. Also, none of the existing works have considered the interactive user interface for procedural floating island modeling. Therefore, it is challenging to devise an efficient procedural modeling approach to automatically synthesize the floating island from users' conceptual design. In this paper, we present a digital painting-based interface, IslandPaint, to help users design their floating island with conceptual digital paintings. As shown in Figure 1, a demo of our proposed interface is presented: The left subfigure shows a user's original digital painting of a floating island; the right subfigure is the 3D model generated with our approach. Demo video of this example can be accessed at [1]. Contributions of our work include:

- Devising a novel digital painting-based interface for floating island procedural modeling.
- Conducting experiments to demonstrate the results of digital painting-based floating island procedural modeling.
- Discussing the limitation of our approach and proposing future works to extend our interface, to inspire the follow-up works on this research direction.

 ISBN: 978-1-61208-927-0

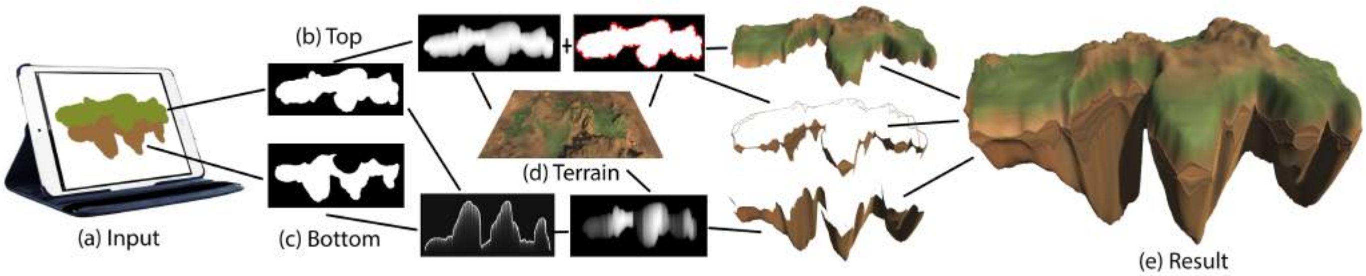


Fig. 2. Overview of our technical approach.

II. Related Works

Terrain Procedural Modeling. Lots of terrain procedural modeling technologies have been widely studied in computer graphics research communities. The history of research works on terrain procedural modeling can be dated back to the late 20th centuries. Since 1982, when Fournier et al. [2] propose stochastic models to add fractal details on curves and surfaces, the idea of procedural terrain modeling has born. However, the first work on terrain procedural modeling might have been started even earlier. In 1985, the idea of image texture synthesizer for terrain modeling has been proposed by Perlin et al. [3]. In 1989, the first eroded fractal terrain has been generated by Musgrave et al. [4]. After that, procedural terrain texturing modeling approaches have been widely studied by Ebert et al. [5] in 2003. Since 2007, digital elevation models have been applied to terrain synthesis [6]. Due to advanced technologies in parallel computing, the tasks for generating complex procedural terrain were moved from the CPU to the GPU in 2007 [7]. At the same time, special terrain features, such as spheroidal weathering have been modeled by Beardall et al. [8]. In 2009, with the notion of human-centered computation, interactive user interfaces have been applied onto terrain procedural modeling [9]. At the same time, other complex terrains, such as arches have been successfully modeled by Peytavie et al. [10]. Later, in 2014, procedural generation of 3D canyons has been studied by De et al. [11]. In 2015, parallelity, realism, and controllability have been systematically incorporated in the terrain procedural modeling process. In 2017, volumetric terrain features have been considered in the procedural generation process [12]. Recently, a desertscape terrain generation approach has been proposed by Paris et al. [13] in 2019. At the same time, procedural modeling techniques in riverscapes synthesis have been studied by Peytavie et al. [14]. Most recently, Argudo et al. [15] have systematically simulated the growth of glaciers terrains. Obviously, there is a trend in the research communities that two factors are very important considerations for terrain procedural modeling: one being considering the scientific aspect of the terrain features while another being the interaction and controllability from the users. Therefore, comparing with other existing work on floating island synthesis, our work focuses on these two factors for interactive procedural floating island generation.

Procedural Floating Islands. Designing and generating floating islands or floating continents is an interesting topic for digital movies and games designs. There are lots of works, especially within the digital multimedia design industry, that are focusing on how to generate floating islands smartly. For example, Houdini procedural modeling tutorials [16] have been posed to teach users how to generate floating islands using Houdini [17], a 3D animation software application developed by Toronto-based SideFX. Houdini has been widely adopted as the PRISMS suite of procedural generation software tools. Similarly, 3D Blender [18] tutorials share similar methods [19], [20] and a voxel plugin [21] shows a procedural method to generate voxel-based floating islands. However, all methods are very hard for the users to parameterize an arbitrary floating island from their own will, and the learning curves to master these interfaces are very high for beginners. Therefore, those approaches to generate floating islands lack users' control. On other hand, Houdini or Blender-based procedural modeling approaches have not considered professional procedural modeling approaches [5], [22], [23] studied by researchers. Rather, they all are trying to deform a given manifold surface, such as a sphere, through different sorts of noises, to generate different types of floating terrains. Another related work is proposed by Sandberg et al. [24], but unfortunately, their work is directly deleting the triangles outside the terrain shape and directly copying the bottom mesh from the top mesh, therefore, it results in very poor modeling quality. Although these works can be applied to digital arts or games, the limited control from the users will result in the degradation of the originality and the value of their artworks designs. Different from these existing works, our work focuses more on the user's control over their floating island designs. Also, we model the floating island based on professional terrain procedural modeling approaches.

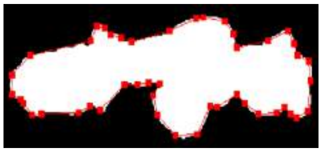
III. Overview

Figure 2 shows the overview of our approach. Given an image of 2D conceptual digital painting floating island design as input (a), we segment the top image (b) and bottom image (c) according to the color palette, which in this case is grass blue as the top and dark brown as the bottom. Then, we perform separate tasks for the top and bottom images differently. For the top image, we do an image shape distribution analysis

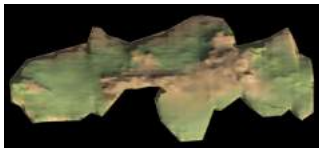
 ISBN: 978-1-61208-927-0

(a) Input of the top shape image.

(b) Silhouette extraction.



(c) Polygonization of silhouette.



(d) Polygonized terrain mesh.

Fig. 3. Illustration of the terrain shape extraction process.

along the y-axis (the blurred image on top) to get the basemap for the floating island's top heightmap. Simultaneously, we to a contour polygonization as the border shape of the floating island. For the bottom image, we apply a half-distribution analysis of the image shape and then we get a silhouette of the bottom part of the floating island (the white curve on the bottom). Then, we multiply the half-distribution onto the top image so that we get a basemap for the floating island's bottom heightmap (the blurred image on the bottom). Detailed term concepts and mathematical definitions will be expanded and explained in the following section.

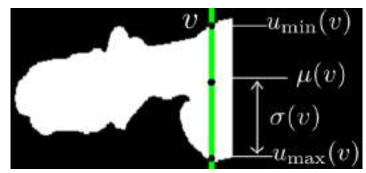
Then, according to the feature map of the generated terrain (d), we synthesize the top mesh of the floating island through the top image, top basemap, and contour polygon (terrain shape). Similarly, we synthesize the bottom mesh of the floating island through the top image, bottom basemap, and contour polygon. In order to avoid any intervals between the top mesh and the bottom mesh, we introduce the middle mesh as a strip that connects the silhouette of the top mesh and the silhouette of the bottom mesh. After the last step of combining these three terrain meshes seamlessly, we get the synthesized floating terrain as the output of our approach (e).

IV. Technical Approach

In this section, we will present the detailed concepts and mathematical definitions for those terms mentioned in the previous section. Note that our approach is proposed based on an important hypothesis that the user's original digital painting design is the abstract conceptual design and there is a loss of depth and texture details. For simplification of the digital image understanding process, we assume the top shape of the original floating island conceptual design is flat.

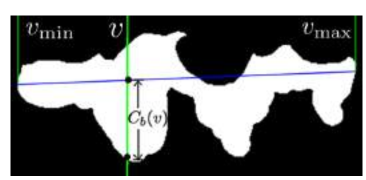
Terrain Shape Extraction. Given the above assumption, we can extract the terrain shape from the top image in three steps shown in Figure 3. First, as shown in (b), we need to track the silhouette of the white area of the top image using a directional table-based binary image silhouette extraction algorithm [25]. Next, as shown in (c), given these pixels in the extracted silhouette from the top image, we do a line fitting algorithm to approximate the shape of the silhouette as a polygon; We also call this a polygonization process of the top shape. Polygonization is important for reducing the noises on the edge of the synthesized floating island terrain. Then, the last step is to trim the 2D square terrain mesh into polygonized terrain mesh. As shown in (d), we take advantage of the Active Edge Table (AET) polygon filling algorithm [26] and modify it to generate the trimmed terrain mesh with polygon edges [27]. This terrain shape extraction process can be both applied on the top mesh and the bottom mesh synthesis for the procedural floating islands generation.

Terrain Basemap Synthesis. The basemap of the terrain is an important concept for the elevation-based terrain procedural modeling techniques. Basemap is typically used for mixing the elevation map of terrain through two different elevation maps, one is the basemap $B(u, v)$ while the other one is the featured heightmap $H_0(u, v)$. Then, the elevation map of the resulting terrain is the $H(u, v) = \alpha(\beta B(u, v) + (1 - \beta)H_0(u, v))$ where $\alpha \in \mathbb{R}$ is the heightmap scale factor and $\beta \in [0, 1]$ is the basemap scale factor. Through this calculation, featured heightmap $H_0(u, v)$ is used for adding features on top of the terrain, while basemap $B(u, v)$ plays an important role in setting the foundation of the terrain. In our work, we consider the basemap to synthesize the terrain heightmap from a given featured heightmap $H_0(u, v)$.

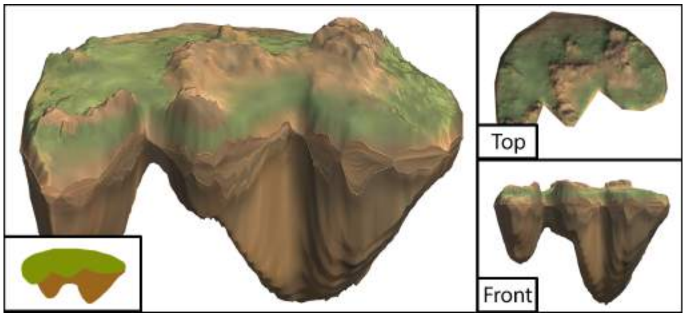


From the observations that floating islands have lower elevations near the edge while higher elevations far away from the edge, therefore, we consider a statistical method to evaluate the basemap B(u, v); We call it image shape distribution analysis. The idea is, given a texture coordinate (texcoord) on a binary image and given a direction, say, v-axis, then the image shape distribution analysis along v-axis will return two functions: shape mean $\mu(v)$ and shape deviation $\sigma(v)$. Let binary image $I(u, v)$ return 1 where texcoord (u, v) is inside the shape; Otherwise, $I(u, v)$ return 0. Then, as shown in the above figure, shape mean $\mu(v)$ is lying on the central curve of the image shape. Mathematically, $\mu(v) = (u_{\min}(v) + u_{\max}(v))/2$ where $u_{\min / \max}(v) = \min / \max\{u | I(u, v) = 1\}$. Similarly, $\sigma(v) = (u_{\max}(v) - u_{\min}(v))/2$. Then, we calculate the basemap of terrain $B(u, v)$ as:

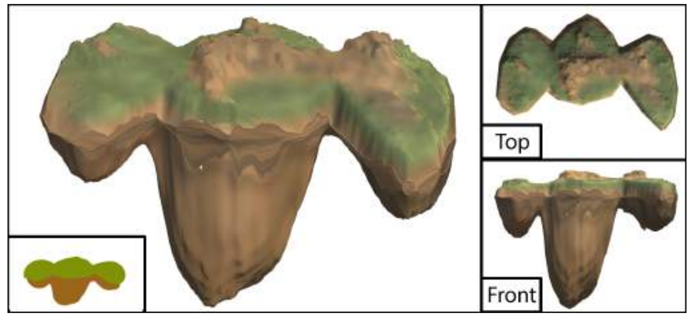
$$B(u, v) = \begin{cases} \sin(\cos^{-1}\left(\frac{|u-\mu(v)|}{\sigma(v)}\right)) & \sigma(v) \neq 0 \\ 0 & \sigma(v) = 0 \end{cases} \tag{1}$$



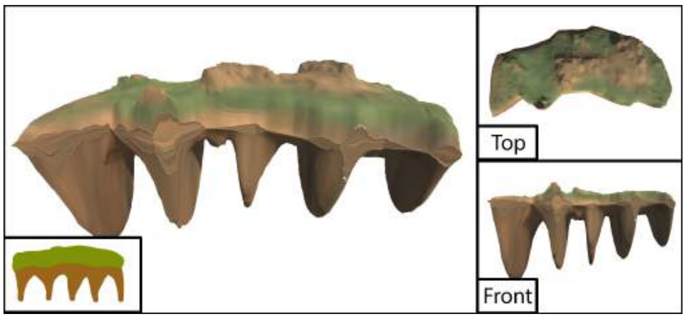
Bottom Shape Analysis. In order to analyze the shape of the bottom part of the floating island, we define another calculation: half-distribution analysis of the image shape. This calculation is similar to the previous distribution analysis process. But, this time, we introduce two texcoords $v_{\min}$ and $v_{\max}$., which is the left most point and right most point on the image shape. Mathematically,



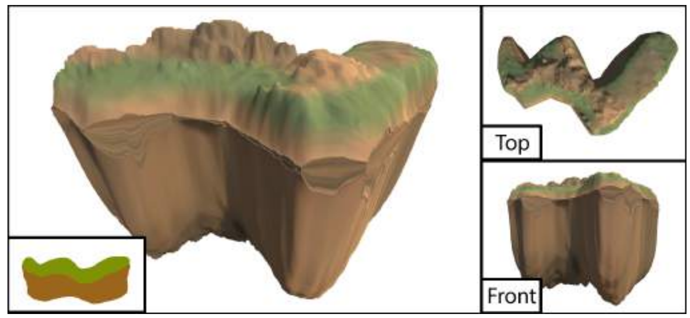
(a) Floating island design 1.



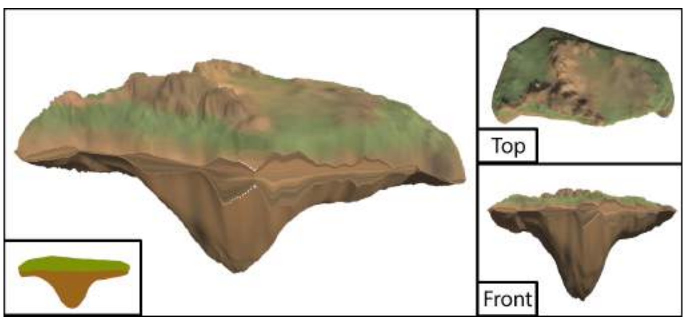
(b) Floating island design 2.



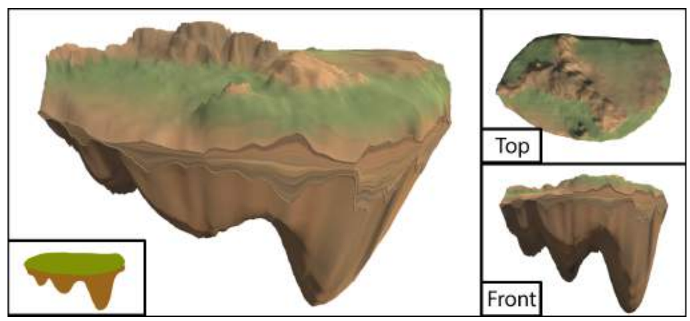
(c) Floating island design 3.



(d) Floating island design 4.



(e) Floating island design 5.



(f) Floating island design 6.

Fig. 4. Experimental results of procedural floating island generations given different user inputs.

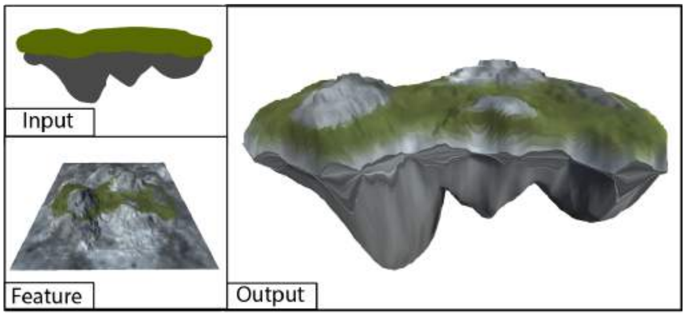
$v_{\min / \max} = \min / \max\{v | \exists u \in [0,1] \Rightarrow I(u,v) = 1\}$. Then, as shown in the above figure, the bottom shape curve $c_b(v)$ can be calculated through this formula: $c_b(v) = \mu(v) + \sigma(v) - [(1-t)\mu(v_{\min}) + t\mu(v_{\max})]$, where $t = (v - v_{\min})/(v_{\max} - v_{\min})$. Then, the bottom basemap $B'(u,v) = c_b(v)B(u,v)$, where $B(u,v)$ is the basemap function defined in Equation 1.

Floating Island Generation. After the top basemap and bottom basemap are calculated, the floating island is ready to be assembled from those elevation maps. The top heightmap of the floating island is $H_{\text{top}}(u,v) = \alpha_{\text{top}}(\beta_{\text{top}}B(u,v) + (1 - \beta_{\text{top}})H_0(u,v))$. As the bottom heightmap of the floating island is beneath the sea level, therefore $\alpha_{\text{bottom}} < 0$. Then, we have the bottom heightmap of the floating island as: $H_{\text{bottom}}(u,v) = \alpha_{\text{bottom}}(\beta_{\text{bottom}}B'(u,v) + (1 - \beta_{\text{bottom}})H_0(u,v))$. After the final generation of the top mesh and buttom mesh using these heightmap equations, we add another mesh called middle mesh to make up the intervals between these two meshes. Then, the final floating island is generated with our approach.

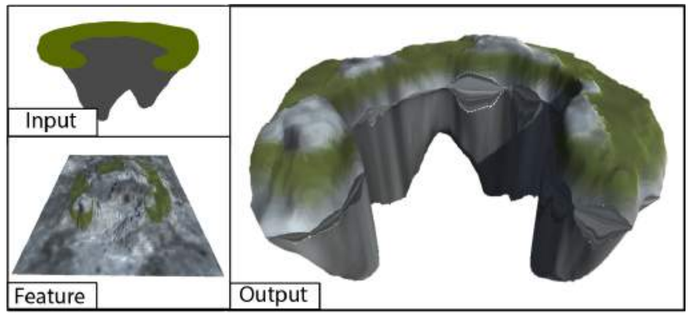
V. Experimental Results

In order to validate the effectiveness of our approach, we have conducted a series of computational experiments. As shown in Figure 4, we have collected six different digital paintings of floating island design. Given these designs, we run our algorithms to automatically generate the floating islands that are resembling the original input designs. We have implemented our algorithms on Unity 3D with the 2019 version. The hardware configurations contain Intel Core i5 CPU, 32GB DDR4 RAM, and NVIDIA GeForce GTX 1650 4GB GDDR6 Graphics Card. Figure 4 shows the results of the procedural floating island generations with the following settings. For the top terrain mesh, the settings are: heightmap scale $\alpha_{\text{top}} = 0.2$; basemap scale $\beta_{\text{top}} = 0.2$. For the bottom terrain mesh, the settings are: heightmap scale $\alpha_{\text{bottom}} = 0.8$; basemap scale $\beta_{\text{bottom}} = -2.5$. The terrain feature heightmap $H_0(u,v)$ is generated with the standard canyon filters. Subfigures are showing the top view and front view, respectively, for each synthesized 3D floating island terrain.

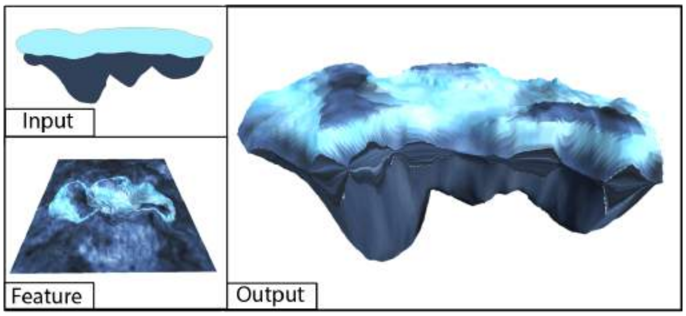
 ISBN: 978-1-61208-927-0



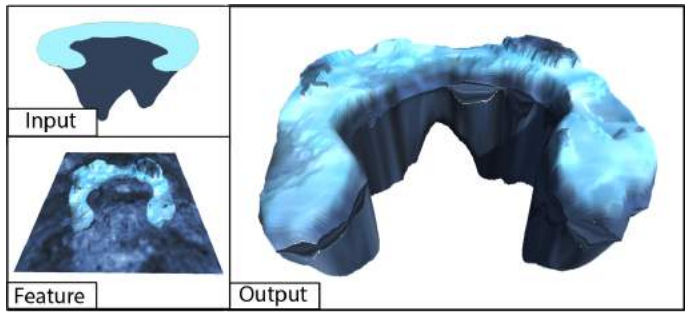
(a) Stony mountain style for design 1.



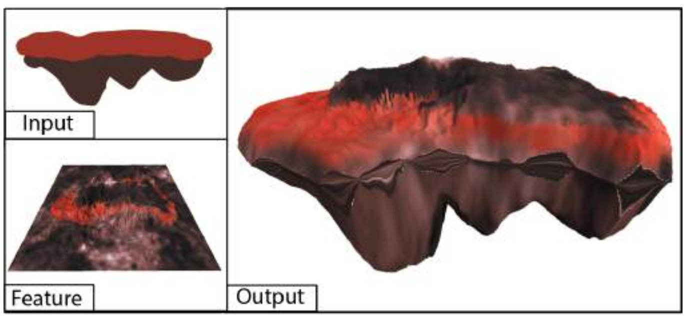
(b) Stony mountain style for design 2.



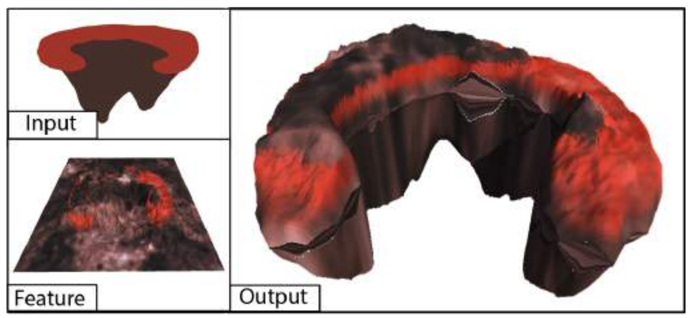
(c) Glaciers landscape style for design 1.



(d) Glaciers landscape style for design 2.



(e) Volcanic landscape style for design 1.



(f) Volcanic landscape style for design 2.

Fig. 5. Experimental results of changing terrain features and textures. In this figure, we present the visual effects when applying different types of terrain features on the same digital painting input. The first column shows the synthesized floating islands on the first digital painting input with different terrain features. The second column shows the synthesized floating islands on the second digital painting input with different terrain features. The first row shows the synthesized floating islands with stony mountain-style features for the first design and the second design, respectively. The second row and the third row show the synthesized floating islands with the glaciers landscape style and the volcanic landscape style, respectively.

As we can see from Figure 4, the generated floating islands are matching well with the user's conceptual digital painting designs. For example, in subfigure (b), we can see three spherical blocks specified in the user's original digital painting design as plotted in the left-bottom corner where the blocks on two sides are smaller than the center block. The same effects appear in the result. Also, in order to consider the foreshortening effects on the digital painting concept design from an orthogonal view, we provide an automatic scaling step to stretch the top image (green part) so that the 3D results are zoomed-in along the z-axis of depth direction. By default, the scaling factor is set to 1.5 and this effect is obvious in subfigure (d). Users can also manually set up this scaling factor to adjust the synthesized 3D outputs to satisfy their expectations.

Changing Terrain Features and Textures. Besides testing our proposed interface with different user inputs, we have tested the robustness of our approach on different types of terrain features and terrain textures. As shown in Figure 5, with the same terrain settings as claimed before, different terrain features are added onto the generated floating islands. In this experiment, we take two different digital paintings from users as inputs. For each input, we applied three different types of terrain features and textures. These are: stony mountain style textures, glaciers landscape style textures, and volcanic landscape style textures, respectively. As shown in the results, our approach can not only generate realistic floating islands according to users' different digital paint designs, but also can be able to add different types of terrain features.

VI. Conclusions

In this paper, we present IslandPaint, a smart user interface for digital painting-driven floating island design. In order to let users efficiently design the 3D floating islands with simple 2D single-view conceptual digital paintings, we proposed a novel approach to automatically extract the 3D information hidden in the conceptual designs. We first propose a hypothesis that the users' paintings are focused on flat floating islands. Then, we segmented the top shape and bottom shape using an image segmentation algorithm. In the next steps, we extract the polygon geometry from the top image and extract the height information from the bottom image. Therefore, we can reconstruct the floating islands whose top views are matching with the top image correctly while the front views are matching with the bottom image correctly. Then, after the procedural modeling process proposed by us, 3D floating islands that look like the original 2D paintings will be automatically generated. As shown in the experimental results, we validated our approach through different user's digital painting designs and the results look promising. At the same time, we tested our interface on different types of terrain features. Both results show that our approach can be compatible and extended with existing terrain procedural modeling technologies very well.

However, there still are some limitations in our work. First, our approach is based on the hypothesis that the user's digital paintings are merely referred to as those floating islands that have flat top surfaces. As a matter of fact, there are lots of floating island design works that are referring to the bumping terrains. Therefore, our approach will not be able to work correctly on these scenarios. In order to solve this, it will rely on proposing an optimization framework to extract the 3D information from the 2D paintings by minimizing the costs functions that are evaluating how well the reconstructed 3D information matches with the perceived 2D information. This is a challenging topic and is worthy to explore as future work. On the other hand, our interface does not allow users to add too many details on the terrain surface. This limited the freedom of degree on user's artistic creations. However, by adding more details of the design, such as wrinkles, the degree of the user's control over the floating island design process will improve significantly. This is another challenging topic to try as the follow-up of this research work.

According to the experimental demonstration of our proposed interface presented in this paper, we believe that, using the interface of IslandPaint proposed by us, floating islands design will become easier for digital art designers, digital multimedia producers, digital movie makers, and digital game authors in the near future. Also, we believe that our work opens an interesting research topic on interactive procedural floating island design and will attract more researchers to further explore academic studies along this direction and follow up with the technical approaches presented in this paper.

References

[1] W. Li, "Islandpaint: Digital painting floating island design," https://youtu.be/YXgmF89UIvY, Nov 2021.

[2] A. Fournier, D. Fussell, and L. Carpenter, "Computer rendering of stochastic models," *Communications of the ACM*, vol. 25, no. 6, pp. 371–384, 1982.

[3] K. Perlin, "An image synthesizer," *ACM Siggraph Computer Graphics*, vol. 19, no. 3, pp. 287–296, 1985.

[4] F. K. Musgrave, C. E. Kolb, and R. S. Mace, "The synthesis and rendering of eroded fractal terrains," *ACM Siggraph Computer Graphics*, vol. 23, no. 3, pp. 41–50, 1989.

[5] D. S. Ebert, F. K. Musgrave, D. Peachey, K. Perlin, and S. Worley, *Texturing & modeling: a procedural approach*. Morgan Kaufmann, 2003.

[6] H. Zhou, J. Sun, G. Turk, and J. M. Rehg, "Terrain synthesis from digital elevation models," *IEEE transactions on visualization and computer graphics*, vol. 13, no. 4, pp. 834–848, 2007.

[7] R. Geiss, "Generating complex procedural terrains using the gpu," *GPU gems*, vol. 3, pp. 7–37, 2007.

[8] M. Beardall, M. Farley, D. Ouderkirk, J. Smith, M. Jones, and P. K. Egbert, "Goblins by spheroidalweathering." in *NPH*, 2007, pp. 7–14.

[9] G. J. De Carpentier and R. Bidarra, "Interactive gpu-based procedural heightfield brushes," in *Proceedings of the 4th International Conference on Foundations of Digital Games*, 2009, pp. 55–62.

[10] A. Peytavie, E. Galin, J. Grosjean, and S. Mérillou, "Arches: a framework for modeling complex terrains," in *Computer Graphics Forum*, vol. 28, no. 2. Wiley Online Library, 2009, pp. 457–467.

[11] D. M. De Carli, C. T. Pozzer, F. Bevilacqua, and V. Schetinger, "Procedural generation of 3d canyons," in *2014 27th SIBGRAPI Conference on Graphics, Patterns and Images*. IEEE, 2014, pp. 103–110.

[12] M. Becher, M. Krone, G. Reina, and T. Ertl, "Feature-based volumetric terrain generation," in *Proceedings of the 21st ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games*, 2017, pp. 1–9.

[13] A. Paris, A. Peytavie, E. Guérin, O. Argudo, and E. Galin, "Desertscape simulation," in *Computer Graphics Forum*, vol. 38, no. 7. Wiley Online Library, 2019, pp. 47–55.

[14] A. Peytavie, T. Dupont, E. Guérin, Y. Cortial, B. Benes, J. Gain, and E. Galin, "Procedural riverscapes," in *Computer Graphics Forum*, vol. 38, no. 7. Wiley Online Library, 2019, pp. 35–46.

[15] O. Argudo, E. Galin, A. Peytavie, A. Paris, and E. Guérin, "Simulation, modeling and authoring of glaciers," *ACM Transactions on Graphics (TOG)*, vol. 39, no. 6, pp. 1–14, 2020.

[16] H. Beyer, "Procedural floating islands - houdini," https://www.youtube.com/watch?v=jzdACcJSl9c, Aug 2019.

[17] E. Goffredo, "A tool for procedural destruction in houdini shattering+ dynamics," *Masters. Bournemouth University*, 2010.

[18] L. Flavell, *Beginning blender: open source 3d modeling, animation, and game design*. Apress, 2011.

[19] Imphenzia, "Let's make a floating island in 10 minutes in blender," https://www.youtube.com/watch?v=Wh7QD-3ZgLw, Jan 2020.

[20] S. F. Humanity, "Blender 2.9 - procedural floating islands with sorcar addon (sfh5 wip)," https://www.youtube.com/watch?v=EeOt_Ubt6E4, Jul 2020.

[21] J. Kelly, "Floating islands," https://wiki.voxelplugin.com/Floating_Islands, October 2020.

[22] R. M. Smelik, K. J. De Kraker, T. Tutenel, R. Bidarra, and S. A. Groenewegen, "A survey of procedural methods for terrain modelling," in *Proceedings of the CASA Workshop on 3D Advanced Media In Gaming And Simulation (3AMIGAS)*, vol. 2009, 2009, pp. 25–34.

[23] E. Galin, E. Guérin, A. Peytavie, G. Cordonnier, M.-P. Cani, B. Benes, and J. Gain, "A review of digital terrain modeling," in *Computer Graphics Forum*, vol. 38, no. 2. Wiley-Blackwell Publishing Ltd., 2019, pp. 553–577.

[24] R. Sandberg, "Generation of floating islands using height maps," 2013.

[25] Y.-L. Lin and M.-J. J. Wang, "Automated body feature extraction from 2d images," *Expert Systems with Applications*, vol. 38, no. 3, pp. 2585–2591, 2011.

[26] M. R. Dunlavey, "Efficient polygon-filling algorithms for raster displays," *ACM Transactions on Graphics (Tog)*, vol. 2, no. 4, pp. 264–273, 1983.

[27] L. A. Piegl and A. M. Richard, "Tessellating trimmed nurbs surfaces," *Computer-Aided Design*, vol. 27, no. 1, pp. 16–26, 1995.

Digital Transformation from Traditional Education Towards VR Education : Case Study Plans

Luxia Dong
Curriculum and Teaching Methodology
Beijing Language and Culture University
Beijing, China
dongluxia1992@163.com

***Abstract*—As Virtual Reality (VR) technologies have become popular and democratic in recent years, academic researchers have been exploring ways to employ advanced VR technologies in traditional education and edutainment. In this paper, we present comprehensive digital transformation case study plans about how to apply VR technologies to modern educations. In our proposal, the teacher standing in front of a blackboard is teaching in a classroom in a traditional way, while, after the digital transformation through our case study plan, the teacher will teach in virtual reality and students will present in a virtual classroom. In this paper, we will explore and prospect important considerations for achieving such a goal through our case study plans.**

Keywords—digital transformation; e-education; e-learning; edutainment; virtual reality.

I. INTRODUCTION

With the rapid development of electronic multimedia technologies, education has become an interesting area for fast digital transformation. Such evolution in digital transformation from traditional education towards electronic education is inevitable due to the upgrade of modern computer technologies. In particular, Computer Graphics Animations (CGA) and Virtual Reality (VR) are two powerful areas that can affect the education industry in a tremendous way. With a realistic graphics rendering engine, various types of amazing effects can be visualized realistically on screens, or even on immersive devices such as virtual reality display headsets. This opens a novel vision of how education can affect students' lives.

Many recent research works have focused on VR education and VR training. Some examples include: children education proposed by Roussou et al. [1], immersive virtual reality museum educational tool proposed by Huang et al. [2], and virtual reality-based rehabilitation training applications for people with intellectual disabilities developed by Standen et al. [3]. In addition, Matsentidou et al. [4] developed a VR application for training and enhancing the social skills of children with autism through immersive visualizations in a VR cave environment, Webster et al. [5] proposed an immersive virtual learning environment for corrosion prevention and control training, Chang et al. [6] proposed an immersive virtual environment for foreign language teaching, Bastiaens et al. [7] studied the role of virtual world design for supply chain education, Rahimian et al. [8] developed an immersive game-like virtual reality interface for Architecture-Engineering-Construction (AEC) professionals education, Ali et al. [9] devised an interactive virtual chemistry laboratory for simulation of high school experiments, Griol et al. [10] proposed an approach to develop intelligent learning environments by means of immersive virtual worlds, Braun et al. [11] populated a virtual learning environment for interpreting students with bilingual dialogues to support situated learning in an institutional context, Kleven [12] proposed an approach for medical training and health education through a virtual university hospital, De Ribaupierre et al. [13] developed virtual reality serious games for healthcare training enhancement, Roussou [14] studied young learn-ers' activity within interactive virtual environments, Detlefsen [15] proposed a method to teach middle-school children astronomy using ego-centric virtual reality, and Izatt et al. [16] proposed an immersive visualization and fitting tool for neutrino physics education.

However, no research works have proposed a comprehensive case study plan on how to apply a thorough digital transformation from traditional education towards VR education. In this paper, we discuss the important facts about the teaching strategies in VR. Next, we propose three detailed case study plans for elementary school classes for teaching Chinese as a second language in virtual reality. These case study plans include (1) VR classroom activities, (2) a full VR lesson design, and (3) a multi-cultural project. In the end, we illustrate the diagnostic assessments for differentiation of students in a VR class.

II. TEACHING STRATEGIES IN VR

An important question is: through VR technologies, what are the teaching strategies and activities that the teachers should plan to use to help students meet the lesson's objectives? In addition, what are the steps that the teacher will take to deliver this lesson (e.g., introduce the author, read the poem, etc.)? In this section, we list what we expect the teacher and students to do as part of this activity through VR teachings.

Critical Thinking. Critical thinking is very important for education. For example, in order to let the students think, students can be asked to write down the advantages and disadvantages of their choice of careers. Also, students can be asked to evaluate themselves and their peers, come up with a self-reflection, and revise the project at the end. In the end, such activity can be simulated in a virtual classroom that gives students rewards through virtual things such as VR flowers and

VR toys, etc. to increase the students' interest in answering questions.

Group Work. In a VR classroom, students can be asked to evaluate their classmates and peers. Also, students can be asked to finish a task in their group by collaborating in VR.

Literacy skills. Finally, students can present their final work in writing and deliver it through electronic documents. This part can be done in VR living writing boards.

III. Case Study Plan I: VR Classroom Activities

In this section, we give some example of classroom activities planned for VR.

A. Activity1: Present Topic "Me and My Family" in VR.

We design a class activity in VR that allows students to present the topic "Me and My Family" in the a virtual classroom. In this class, the teacher will send the learning material to the students in advance, and they will present what they learn in the virtual class. The purpose of this activity is to stimulate the students' learning motivation, make connections with the language skills and real-world, as well as prompt the students' critical thinking and group work skills.

Before the VR Class. The teacher will send the instructions' video and the Quizlet link to the teams 3 days in advance. The students will learn the new words by themselves using Quizlet. The students will make a presentation about the topic before the lesson and present it in the virtual class. After the students finish their presentation, they will hand it in, and the teacher will let them know if they need to add something to reach the presentation standards.

During the VR Class. The students will present the topic in the VR classroom, including basic information about family members, their jobs and their own dream school, dream job, what are the advantages and disadvantages of choosing their dream school, why they choose a particular career, and so on. The students can choose VR video or VR slides, or VR 3D animation for this presentation. After that, the students will be asked to review their own presentation and their peers' presentation, writing feedback on the presentation through VR interactions.

After the VR Class. The students will be asked to revise their presentation and write down their self-reflection on what they learned from the presentation and how they can make it better next time. After that, they will hand in the final work for evaluation by the teacher. Also, the students will be asked to evaluate their experience in the VR classroom. This is important for improving the VR classroom application.

B. Activity2: Learning new Vocabulary and Sentences in VR.

Through help with VR applications, teachers may give the students more supportive and specific comments on their work through VR interactions. Teachers can comment on the students work and give them positive feedback, but that may not be specific enough in traditional classroom. Rather, in a VR classroom, teachers can give more specific feedback to the students and make the students feel they really did a great job on the presentation through VR gifts. Secondly, VR apps can remind teachers to ask students' opinions regarding previous presenters. In addition, VR apps can make the students interact more with each other, not only present by themselves. They can also discuss some points with their classmates through VR chat boards. Below is the detailed plan.

Before the VR Class. The students will be given the vocabulary Quizlet link in advance. They will study by themselves at home through the VR headset and will have a competition that will include the entire VR class.

During the VR Class. The students will be evaluated by the teacher if they already understand the pronunciation of the new vocabulary during the VR class. Besides, there will be a quiz competition to see if the students understand the meaning of the new vocabulary. The teacher will observe and take notes in the process of evaluating and make reteach plans as necessary through VR animations.

After the VR Class. The students will be asked to draw a picture or write a sentence using VR controllers, or explain in a different language the words they found hard to understand in VR.

IV. Case Study Plan II: A Full VR Lesson Design

Here, an example of a full VR lesson design is presented. The target amount of time for the full lesson is 40 minutes. During the VR class, first, let the students use Pin Yin to read simple texts independently. Then, let the students write in VR by dictating the Chinese characters to be learned under the Four Skills Requirement (listening, speaking, reading, and writing). After that, let the students understand basic, simple language materials closely related to their personal lives and everyday situations. In the end, let students continue to develop good habits in listening and speaking. Students will be able to present the topic "Me and My family" in Chinese. Students will be able to connect the prior knowledge (such as my family, hobbies, etc.) to the new knowledge (such as career, occupations, etc.). Students will be able to talk about their dream school and dream job in a critical way.

Evaluations of VR Class. The evaluation of the VR class can be done through three criteria: (1) Whether the students can use Chinese to do presentations; (2) Whether the students can pronounce different job names in Chinese correctly; (3) Whether the students can work in a team or individually to finish the Quizlet task on understanding the meaning of new words.

Student Diversity and Differentiation. Different students develop different skills according to their own personal weak points. For listening, teachers can give the same instructions to the whole class, but check with everyone if they understand the instructions or if they need extra support. For example, teachers can use some English to explain complicated instructions. Teachers can use Chinese to talk to advanced students to meet their needs. For reading comprehension, students can be asked to read most of the content. Teachers can ask students' opinions to see if they need help through VR hints. Students can use simple words and sentences in their presentation, but VR gizmos can help students improve the vocabulary when they need it. For speaking, when students are doing presentations, since they prepare in advance, there might not a big problem with it. However, when it comes to answering questions, teachers can give them a chance to choose the question they feel comfortable answering by doing VR quests. This way, the students with lower speaking ability will not feel nervous in the class. For writing, there can be writing homework after the VR class.

Formative and Summative Assessments. As shown in the described in-class activity of the presentation on the topic ”Me and My Family”, students will present the topic in the VR classroom, including basic information about family members, their jobs and their own dream school, their dream job, what are the advantages and disadvantages to choosing their dream school, why they choose their career, and so on. They can choose VR video or VR PPT for this presentation. As for dictation, there can be a dictation in VR or by VR robot for this unit about the words learned that day. There can also be a Quizlet competition on vocabulary-related jobs. After the unit, at the end of the week, there will be a summative assessment on the topic of career, including speaking, reading comprehension, writing, listening, and other VR class activities.

V. Case Study Plan III: A Multi-Cultural Project

Project Overview. Here, we give an example of a VR class project proposal called Minorities in China. The China Studies program includes multi-cultural projects about the ancient town of Lijiang and Naxi culture in China, in which students will learn about China's ethnic cultures and special cultural practices. The Social Studies course includes ”Passport to the World”, which will lead students to understand the cultures and cultural differences around the world. Therefore, the idea of this project was born with the idea of leading students to understand the culture and cultural differences of China and other parts of the world through the Google Earth VR app, and by consulting materials and personal experience and making a culture introduction VR PPT about a certain place on Google Earth through virtual tours.

Project Objective. Students can learn to use VR technology tools (such as Google Earth App) to search information and sort out the information in a logical sequence. The community can understand more about the minorities in China after listening to the students' presentations. The whole school community would be more respectful of different cultures and have a better understanding of the school mission.

Project Description. All the students are divided into four groups. In the VR class of Chinese studies, they will learn about the minority cultures of Naxi and the ancient town of Lijiang under the guidance of the teacher and they will experience the secrets of minority cultures in the process of learning Dongba pictographs through VR applications. Then, the teacher will introduce the cultural characteristics of different countries in theme classes. Later, the teacher will introduce several minority cultures other than Dongba culture, such as African minority culture, American Indian culture, etc. on VR Google Earth. The students will be allowed to choose or search the minority culture they are interested in. Later, the information will be collected in groups in order for the students to learn about the cultural characteristics of ethnic minorities they are interested in, to introduce them to their parents at home, and make a VR PPT. In the end, the students will collect information and write interview questions. They will interview teachers or adults at school about their understanding of the minority culture and their first impression of it. The students will make VR posters to briefly introduce this special culture and put them on the doors and windows in the virtual classroom. These proposed VR class projects align with the missions in art, technology, and culture. This project aligns with culture. In the implementation of this VR project, teachers will link it to the art class and students will create VR posters to demonstrate different minorities. All students will use VR technology tools to search for information and show the presentation, so this project aligns with technology and art as well.

Project Syllabus. In weeks 1-2, the teachers will introduce the minority groups to the whole class through the VR classroom. Then, the students will discuss what impressed them and what are the minority groups they are interested in. Then, the students will choose a minority group in China to explore in the Google Earth VR app. Between weeks 3-6, the students will work in a group to search information such as facts, traditions, taboos, dress, etc. In week 7, the students will present and make the survey in the VR classroom. They will also be giving presentations to the community members in the school to introduce different minorities and interview the community's opinions regarding different minorities. In week 8, the students will have an evaluation. They will make posters and post them in different places in the VR classrooms. Teachers will use this rubric to evaluate the students work and their projects.

VI. Diagnostic Assessments for Differentiation

Importance. The data collected from the pre-assessments in VR education can help the teacher easily have a general idea about the students' learning stages. It is important to know the students in-depth as well. It can also guide the formative assessment or the summative assessment later in the learning process. Teachers can target the students' weaknesses to give instructions and assessments for the students through personalized VR classes. It is important for grouping as well. Either for homogeneous or heterogeneous grouping methods, the teachers need to know the differences between the students in advance. Teachers can give specific support with the data collected from the students. This is similar to a doctor helping the patient according to the diagnostic results. For teachers themselves, it can also be helpful. Teachers can use the data to make teaching plans and learning objectives instead of wasting time teaching subjects all the students already learned or understand. For example, when the teachers get the data from the pre-assessment, they can delete the object that may appear on the standard guidelines, but actually, for these students, they all get a good understanding of it. In this way, time can be saved for both teachers and students. Meanwhile, the learning proficiency and effectiveness are improved. This practice can also help with school-wide learning. By getting the data on the students, teachers from the whole school can find out the weaknesses of the students and can also cooperate with each other to help the students according to the pre-assessment data. This is also useful for parents' communication. With the data of the pre-assessment, teachers can easily have the evidence to show the parents how much their kids improved and in what areas the progress was made.

Impact on Students. In a VR classroom, the students can be both interested and challenged. They will listen more carefully and pay more attention to what they are doing because the teaching content can be both interesting and challenging for most of the students due to the powerful algorithms employed in VR applications. They will get a chance to improve themselves by focusing on whatever they need according to the pre-assessment. The students will enjoy group work more because teachers can form the groups according to the pre-assessment results and the VR is user-friendly for easy interactions. The grouping method will make all of the students feel comfortable and safe, which can improve the working efficiency at the same time. The students will get an idea on what the teachers' expectation is and will have a clear aim about what they need to do at the next stage. Students will be less stressed when they face summative assessments at the middle or the end of the semester because they know that, although there will not be the exact same questions, the learning objective will be the same, and if they work hard during the learning process, they will make progress for sure. Students will be more motivated in the VR classroom. Students will participate more in the different VR activities because they know that all of the assessments are related to each other; if they work hard, they can get a good result at the summative assessment. Meanwhile, they will enjoy the VR interface of the virtual school.

Pre-Assessment vs. Summative Assessment. How can teachers align the pre-assessment and the summative assessment for Chinese education in VR? After having the pre-assessment (dictation for each unit) in VR, teachers will understand what they should focus on at the next teaching stage. Then, teachers will finalize the learning goal for the whole semester and arrange different goals into different learning periods, such as monthly goals, weekly goals, even daily goals. Then, when teachers prepare the summative assessment, they can make sure all the content that appears in the assessment had been taught already. Teachers can separate the small goals into different learning units. They can give students pre-assessment in VR (Quizlet and Kahoot, because for the CAL students, most of the content are words and sentences.) on every unit to find out the difficulties. After the pre-assessment, the teachers can use the RTI method to separate students into different groups. The teachers can give differentiated instructions according to the pre-assessment results. They can set up different goals for students in different tiers, give different instructions, and design appropriate VR activities for different students. They can summarize and review the semester goal at the end of the semester. They can finalize the summative assessment according to the students' academic performance in different tires and the pre-assessment results. In addition, they can give students the summative assessment containing the whole semester goal which aligns with the pre-assessment as well.

Information from the Pre-assessment Data. Here, we address the question on how can the data that teachers gather from pre-assessment inform instruction and grouping practices in the VR classroom as well as how to use this data to make the teaching plan. Teachers will delete the objectives students already learned based on the pre-assessment data. Teachers will focus more on the objectives students have common difficulties with during the VR class activities. For the students who have their own strengths, but show some difficulties, teachers will differentiate when implementing activities. Teachers will use the pre-assessment data to group the students according to the different learning activities through the VR technologies. Teachers will mix students with different levels when teachers want them to help each other through VR communications. Besides, when the teachers want to make the activity meet each level of students' needs, they will use a homogeneous group of students. Collecting the pre-assessment data lets teachers know exactly where each student stands compared to their classmates and peers nationwide. So, teachers can make different groups of students and give them differentiated instructions. For example, if they have similar interests, they will be grouped into one group when teachers have different topics in the class, but towards the same teaching objectives. When teachers want the students from different groups to help each other, they will group students in a heterogeneous way to mix students belonging to different levels into one group. With the data of the pre-assessments, teachers can use the it to develop individual academic learning goals with students. Going beyond the individual student level, teachers will collaborate with other teachers in the school and adjust the school-wide goal. For example, the pre-assessment data can be used when developing Chinese teaching VR apps. Teachers will delete the learning objectives of the words and skills all students already have based on the pre-assessment. The teachers will make a record about the pre-assessment for other teachers' reference. If teachers feel a learning goal should be moved from the VR classes, they will suggest making some changes to the VR teaching package.

VII. Conclusion

In this paper, we present several thorough case study plans for welcoming the digital transformation from traditional education towards VR education. We first discuss the important facts about the teaching strategies in VR by addressing four factors in VR language education: (1) Critical Thinking, (2) Group Work, and (3) Literacy skills. Then, we propose three detailed case study plans for elementary school classes teaching Chinese as a second language in virtual reality. These case study plans include (1) VR Classroom Activities, (2) A Full VR Lesson Design, and (3) A Multi-Cultural Project. In the end, we illustrate the diagnostic assessments for differentiation of students in VR class. As for the VR classroom activities plans, we propose two different in-class activities: (1) student presentations in VR and (2) learning new vocabulary and sentences in VR. In the full VR lesson design, teachers will emphasize students' skills in reading using Pin Yin, students' skills in writing with VR by dictating the Chinese characters and students' understanding of basic, simple language materials closely related to their personal lives and everyday situations. In the multicultural project, students will learn about China's ethnic cultures and special cultural practices through VR Google Earth App and learn to speak Chinese as a second language at the same time. In future work, we will extend our proposal into a real VR teaching application package and conduct a large-scale user study to apply such teaching plans to elementary schools' digital education. We believe our proposal and follow-up works will become stepping stones to open a new age of digital education through virtual reality.

References

[1] M. Roussou, "Learning by doing and learning through play: an exploration of interactivity in virtual environments for children," *Computers in Entertainment (CIE)*, vol. 2, no. 1, pp. 10–10, 2004.

[2] Y.-C. Huang and S. R. Han, "An immersive virtual reality museum via second life," in *International Conference on Human-Computer Interaction*. Springer, 2014, pp. 579–584.

[3] P. J. Standen and D. J. Brown, "Virtual reality in the rehabilitation of people with intellectual disabilities," Cyberpsychology & behavior, vol. 8, no. 3, pp. 272–282, 2005.

[3]

[4] S. Matsentidou and C. Poullis, "Immersive visualizations in a vr cave environment for the training and enhancement of social skills for children with autism," in *2014 International Conference on Computer Vision Theory and Applications (VISAPP)*, vol. 3. IEEE, 2014, pp. 230–236.

[5] R. D. Webster, "Corrosion prevention and control training in an immersive virtual learning environment," in *CORROSION 2014*. OnePetro, 2014.

[6] B. Chang, L. Sheldon, M. Si, and A. Hand, "Foreign language learning in immersive virtual environments," in *The Engineering Reality of Virtual Reality 2012*, vol. 8289. International Society for Optics and Photonics, 2012, p. 828902.

[7] T. Bastiaens, L. Wood, and T. Reiners, "New landscapes and new eyes: The role of virtual world design for supply chain education," *Ubiquitous Learning*, vol. 6, no. 1, pp. 37–49, 2014.

[8] F. P. Rahimian, T. Arciszewski, and J. S. Goulding, "Successful education for aec professionals: case study of applying immersive game-like virtual reality interfaces," *Visualization in Engineering*, vol. 2, no. 1, pp. 1–12, 2014.

[9] N. Ali, S. Ullah, A. Alam, and J. Rafique, "3d interactive virtual chemistry laboratory for simulation of high school experiments," *Proceedings of EURASIA GRAPHICS*, pp. 1–6, 2014.

[10] D. Griol, J. M. Molina, and Z. Callejas, "An approach to develop intelligent learning environments by means of immersive virtual worlds," *Journal of Ambient Intelligence and Smart Environments*, vol. 6, no. 2, pp. 237–255, 2014.

[11] S. Braun and C. Slater, "Populating a 3d virtual learning environment for interpreting students with bilingual dialogues to support situated learning in an institutional context," *The Interpreter and Translator Trainer*, vol. 8, no. 3, pp. 469–485, 2014.

[12] N. F. Kleven, "Virtual university hospital as an arena for medical training and health education," Master's thesis, Institutt for datateknikk og informasjonsvitenskap, 2014.

[13] S. De Ribaupierre, B. Kapralos, F. Haji, E. Stroulia, A. Dubrowski, and R. Eagleson, "Healthcare training enhancement through virtual reality and serious games," in *Virtual, augmented reality and serious games for healthcare 1*. Springer, 2014, pp. 9–27.

[14] M. Roussou, "Examining young learners' activity within interactive virtual environments," in *Proceedings of the 2004 conference on Interaction design and children: building a community*, 2004, pp. 167–168.

[15] J. Detlefsen, "The cosmic perspective: Teaching middle-school children astronomy using ego-centric virtual reality," *Unpublished master's thesis). Aalborg University, Medialogy, Aalborg*, 2014.

[16] E. Izatt, K. Scholberg, and R. Kopper, "Neutrino-kave: An immersive visualization and fitting tool for neutrino physics education," in *2014 IEEE virtual reality (VR)*. IEEE, 2014, pp. 83–84.

Make OS Home: Home-Like Operating System in Virtual Reality

Wanwan Li
Department of Computer Science
George Mason University
Fairfax, Virginia, US
wli17@gmu.edu

Fig. 1. Demo of Make OS Home: an example to show a digital transformation from a traditional desktop in Windows 10 operating system (a) towards a desktop in a home-like operating system via virtual reality (b) where the desktop on a 2D screen is transferred into a 3D desk model in VR.

***Abstract*—With the rapid development of Virtual Reality (VR) technologies in recent years, VR displays have become more popular, democratic, and attractive for users. Therefore, academic researchers are exploring the way to employ advanced VR technologies to achieve a smooth digital transfer from traditional user interfaces towards VR interfaces. In this paper, we present Make OS Home: a digital transformation implementation prototype from a traditional 2D-screen-based operating system towards a home-like immersive 3D operating system in virtual reality. We will present implementation details about the interactions between users, VR controllers, and the operating system to achieve such digital transformation on operating systems.**

Keywords*—*digital transformation; operating system; virtual reality; virtual desktop.

I. Introduction

With the rapid development of Virtual Reality (VR) technologies, there are more and more chances to transform the traditional user interfaces into immersive user interfaces in VR. Such evolution in digital transformation provides researchers with lots of opportunities to explore how different user interactions between 2D screens-based platforms and 3D immersive VR platforms affect user experiences. Therefore, many research works on user VR experiences have been proposed in diverse aspects of life such as VR aided shape modelings [1], VR education and training [2], VR entertainments [3], VR sports [4], VR performance arts [5], VR music [6], VR agriculture [7], VR business management [8], etc. As one of the most fundamental studies of computer science, operating system design is a very important topic that can affect people's daily work and life. VR technologies provide infinite chances to change people's feelings about the operating system and computer-related working experiences. Therefore, it is a promising topic to show how the evolution of the operating systems can affect users' experiences and how to further extend such evolution through VR technologies.

During the 1980s, early ages of operating systems had no Graphical User Interfaces (GUI), such as Microsoft's MS-DOS [9]. Since 1985, Windows 1.0 first introduced GUI. Through various generations of the graphical Microsoft Windows operating systems [10]. We have Windows 10 as the most popular operating system today. As shown in Figure 2, the earliest GUIs of Windows operating systems mainly consisted of simple shapes, such as rectangles, rough vector icons, and monotonic colors themes, such as green and grays. Until Windows XP (2001), pictures were introduced into the main theme of OS. At the same time, icons were more photo-realistic than before which were drawn with simple vector graphics. Since Windows VISTA (2006), 3D effects were introduced when switching between windows using win+tab keys. This was a great evolution in Windows OS and gave users great visual effects. Later in Windows 7 (2009), while the 3D components were being kept, transparent icons were introduced. This was the peak masterpiece of work for windows with great visual effects and impressive user experiences. But unfortunately, due to the large amount of computation efforts that were put on graphical computing, the system was tending to be slow and wasting more electricity. Therefore, in Windows

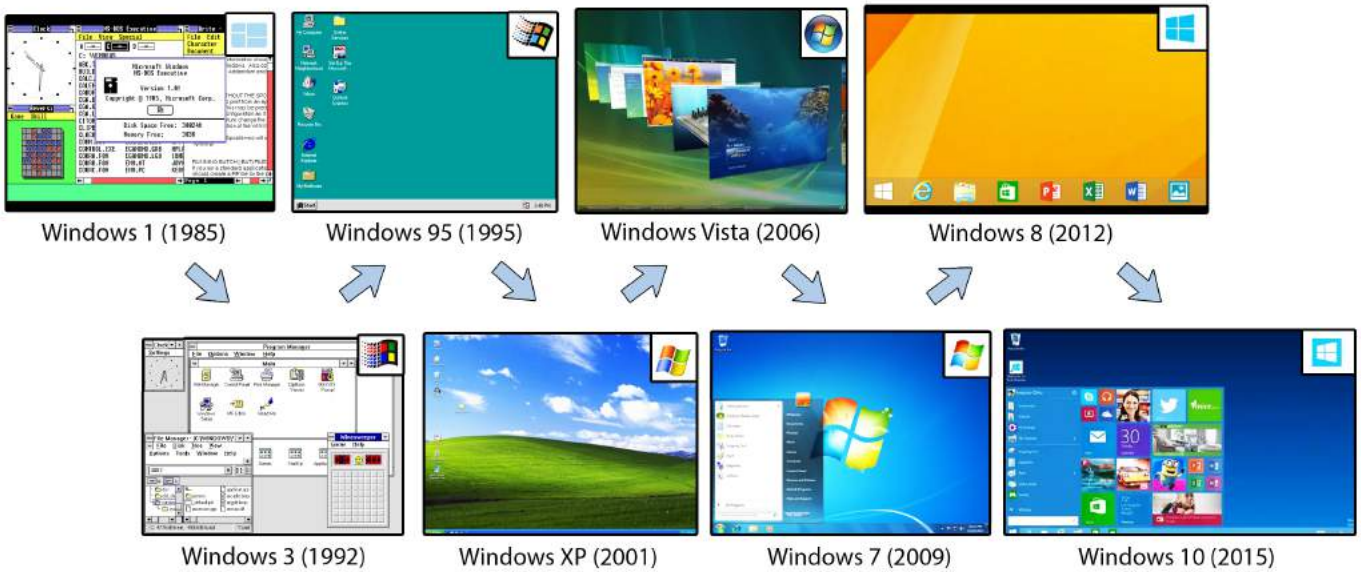


Fig. 2. History of windows operating systems from Windows 1 (1985) to WIndows 10 (2015).

8.1 (2012) and Windows 10 (2015), the 3D and transparent effects were removed. Then, system became faster and less power-demanding. The advantage of Windows 10 was the introduction of photo icons in the start menu. As we can see, within these 30 years, there were more than 10 different versions of Microsoft Windows operating systems. An obvious trend can be seen that Windows operating systems are becoming more and more user-friendly and environmental-friendly while achieving stronger visual performance and optimizing the system's efficiency.

As advanced technologies in virtual reality are emerging, a notion of "working in VR" is appearing as well. Lots of recent works are focused on moving workspace from the real world to virtual space in VR. For example, as shown in Figure 3 (a), *immersed* [11] presents a novel VR interface for creating private working space, supporting multiple virtual monitors without adding additional hardware. Also, *immersed* is portable as it supports mobile and wireless headsets so that it can be taken anywhere. As shown in Figure 3 (b), Virtual Desktop [12] is an application developed for the Oculus Rift / Rift S, HTC Vive, Valve Index, and WMR (Windows Mixed Reality) headsets that can visualize the screen of a computer as a virtual screen in VR. As shown in Figure 3 (c), VR-OS [13] is an operating system that replaces the monitor with a head-mounted display in an immersive virtual environment. It provides the virtual mouse and virtual keyboard that can match with the real ones on the desk. VR-OS allows powerful workflows in virtual reality platforms. As shown in Figure 3 (d), Falkengren et al. [14] presented a concept VR OS User Interface (UI) that was developed with basic OS features, such as viewing files and opening programs. As the closest work to ours, Falkengren et al. [14] developed a prototype virtual operating system that considers 3D icons and file browsers through VR operations, such as fragging and dropping. But unfortunately, all of those proposed works are actually pseudo-3D visualizations where all displays, icons and browsers are visualized through flat or curved virtual 3D surfaces which look like 2D plat or curved screens hanging in the 3D virtual environment. This visual effect lacks immersiveness.

Therefore, given these observations, we propose Make OS Home: a home-like operating system in virtual reality. In Make OS Home, all 3D icons can be created, dragged, and clicked in full 3D space that is not restricted to a flat surface of the pseudo-3D space. In this interface, users are able to manipulate 3D icons as if manipulating 3D things at home. During each operation on 3D icons in the virtual environment, operating system APIs will be invoked simultaneously to modify the file system within the operating system. At the same time, we provide a screen of the operating system through a virtual monitor, so that users can identify the operations that happened in the operating system while they are manipulating the 3D icons using VR controllers. Our work reveals a novel aspect and a new level of control degree for operating system user interactions and GUI, which opens a new dimension of how to interact with the operating system in an entirely immersive way. In the future, by regarding our interactive interface of Make OS Home as a prototype, extending our interfaces with other types of operating system operations, such as hardware settings, network settings, visualizing image and video within 3D volumes, and so forth, the GUI of the future operating system will be entirely transferred in virtual reality. As shown in Figure 1, a desktop of standard Windows 10 operating system is shown in (a); Through the implementation presented in this paper, the desktop will be transformed into a virtual desktop in home-like environment through virtual reality as shown in (b). The full demo of the video can be accessed at [15] which shows manipulating folders and documents with our devised VR interface.

(a) *immersed* [11].

(b) Virtual Desktop [12].

(c) VR-OS [13].

(d) Conceptual VR OS [14].

Fig. 3. Examples of related works on virtual desktops or conceptual virtual reality operating systems.

II. IMPLEMENTATION DETAILS

In this section, we present the implementation details of Make OS Home. In our implementation, we are mainly focusing on how to connect the file systems in an operating system with 3D virtual objects as manipulable icons in virtual reality and how to display such files system through to two views (1) a virtual monitor that records the screen of the operating system and (2) the user's 3D view in a virtual environment. Our work extends an operating system with VR operations through the proposed two views. We have implemented the Make OS Home system using Unity 3D with the 2019 version. We have implemented the VR interactive interface using the Steam VR 2.0 plugin. The hardware configurations include Intel Core i5 CPU, 32GB DDR4 RAM, and NVIDIA GeForce GTX 1650 4GB GDDR6 Graphics Card. The VR program is configured on Oculus Quest 2.0.

File System. Given our purpose to connect the file system with VR objects of 3D icons, we propose an extended version of the data structure to represent the file system. In our implementation, we mainly consider two types of files (1) a folder and (2) a document. A folder can have an arbitrary number of subfolders, a document has no subdocument. Therefore, a file system is typically a tree data structure. Let us call a node representing a folder or a document a file node, then, the file system is the tree consisting of a root node and its descendants. In our case, the root node is the desktop folder, and other subfolders on the desktop are its children. As shown in Figure 4, a detailed representation of the file node is presented. We store the file information, such as file name and file type (folder or document) within a class called FileValue. FileValue also contains the icon object which is a game object in Unity and the icon behaviour which is a C# class defining the interactions between icon and VR controllers. FileValue is always paired with a string called FileKey. The reason is we have maintained all file nodes not only in a file tree, but also in a Hash table for easy access.

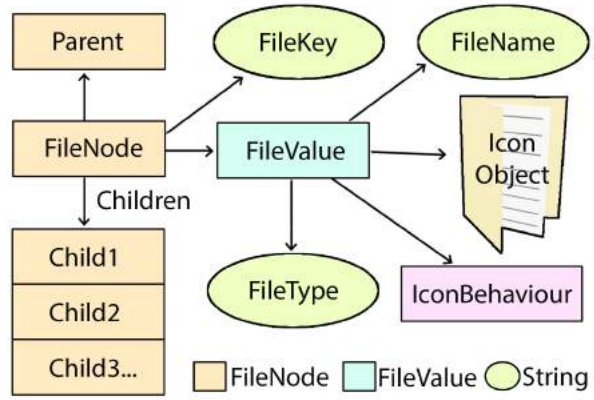
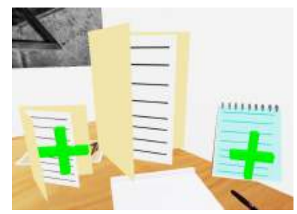


Fig. 4. Data structure of a file node which is the basic component of a file system in our Make OS Home interface. Different colors represents different C# classes in Unity.

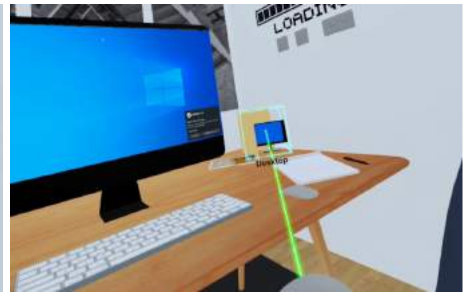
User Interactions. We have implemented several different file operations, such as creating file icons, dragging file icons, scaling file icons, and delete file icons. Each operation is followed by a selection detection, which is achieved by calculating a line intersection between the lightsaber shooting out from the controller and the selected object. After the selected object is determined, we will check whether there is a click on the right controller. If so, we will react according to which icon is selected: if the selected icon is the create folder or create document icon as shown in the figure above where there are green plus signs attached, then, we will call the system API to create that file at the current path. Otherwise, if the selected icon is a subfolder of the current folder, we will switch to that subfolder where all of the children files or documents in that subfolder will appear.



Perhaps, the selected icon is a document in the current folder. In this case, we will call a system API to run a notepad app to open such text file. Or, if the selected file icon is the current folder itself, then, we will hide all of the children subfolders and switch to its parent folder. If there are no clicks from the grab button on the right controller, then, we will detect whether the pinch button is pressed. If so, a dragging operation is applied on that file icon. If that file icon is dragged into a recycle bin icon as shown in the figure above, then, we will call a system API to remove that folder or file recursively. This operation can be achieved by adding a specially tagged collider onto the recycle bin so that every game object that hit the recycle bin will disappear. During the dragging operation, the user can also push the joystick up with the thumb to zoom in the 3D icon or push the thumb down to zoom out the 3D icon in the virtual environment.

(1) Pointing at a desktop icon in VR.

(2) Zooming in a desktop icon in VR.



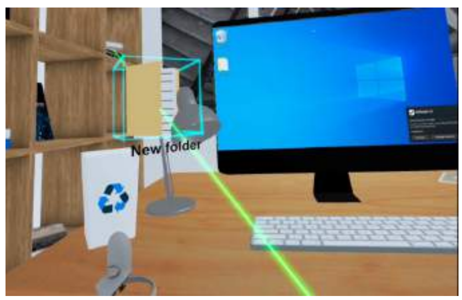
(3) Zooming out a desktop icon in VR.

(4) Clicking at a desktop icon in VR.

(5) Clicking at a create folder icon in VR.

(6) A folder and its icon in VR are created.

(7) Dragging a folder icon in VR.



(8) Deleting a folder icon in VR.

(9) A folder and its icon in VR are deleted.

Fig. 5. A running example of using the Make OS Home system (Part I).

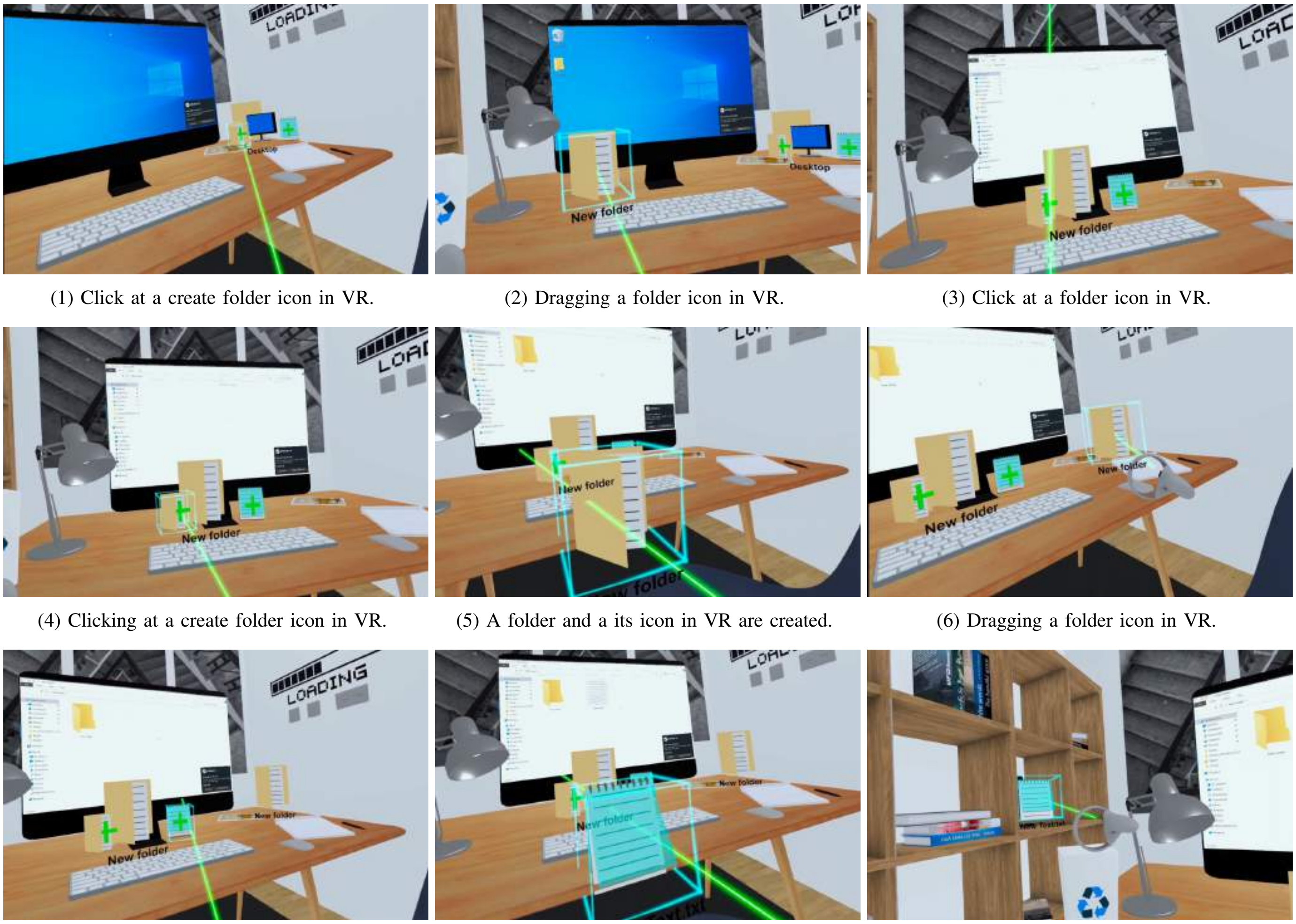
III. Experimental Results

In this section, we give a frame-by-frame demo of a running example to illustrate our proposed system. As shown in Figure 5, subfigures (1)-(3) demonstrate a process to zoom in and zoom out the desktop icon in VR. Users first point their controllers towards the desktop icon in VR. Then, the shining bounding box will pop up (1). When holding the pinch button down, users can push the joystick on the controller up and down to zoom in the desktop icon (2) and zoom out the desktop icon (3). Subfigures (4)-(9) demonstrate a process to create a folder and delete a folder. After a click at the desktop icon with the grab button on the controller, the create folder/document icon will pop up (4). After another click at the create folder icon (5), a new folder icon will be created randomly between the controller's position and the desktop icon position using a randomized linear interpolation (6). Then, users can drag the folder icon in mid-air (7) until it hits the recycle bin icon (8), the folder icon disappears (9). Note that the 2D folder icon on the desktop in the virtual screen appears and disappears together with the 3D folder icon simultaneously, as the system API is called to create and delete the file along with the user's VR operation automatically. Also, the screen recorder API will update the VR monitor screen's texture to reflect the changes made in the operating system.

There is another testing case in this experiment as shown in Figure 6. This time, the user creates a folder (1) but does not drag the folder to the recycle bin, instead, somewhere else nearby (2). When the user clicks on the folder icon, the user will navigate into that folder (3). If users click the create icon again, the files will be created under that folder. (4)-(6) show the process to create and drag a folder while (7)-(9) are creating and dragging a text document.

IV. Conclusion and Future Work

In this paper, we present Make OS Home: a digital transformation implementation prototype from a traditional 2D-screen-based operating system towards a home-like immersive 3D operating system in virtual reality. We demonstrate the functionalities of our proposed interface in the experiments. Through Make OS Home, users can successfully create, navigate, and delete the files when operating 3D icons in VR.



(1) Click at a create folder icon in VR. (2) Dragging a folder icon in VR. (3) Click at a folder icon in VR.

(4) Clicking at a create folder icon in VR. (5) A folder and a its icon in VR are created. (6) Dragging a folder icon in VR.

(7) Clicking at a create document icon in VR. (8) A document and a its icon in VR are created. (9) A document icon is put on a shelf in VR.

Fig. 6. A running example of using the Make OS Home system (Part II).

In future work, we will extend our proposed system by adding new features, such as moving folders into another through dragging the icons similar to the delete operation, adding a start menu in VR to trigger more apps other than the notepad app, adding hardware configuration settings in VR, adding network connections in VR, and rendering 3D images in VR, etc. In the end, we intend to build an entirely new VR OS without relying on another existing OS, such as Windows. We believe our work can open the new dimension to think about how the future operating systems will look like on a VR platform.

REFERENCES

[1] T. H. Dani and R. Gadh, "Creation of concept shape designs via a virtual reality interface," *Computer-Aided Design*, vol. 29, no. 8, pp. 555–563, 1997.

[2] J. Psotka, "Immersive training systems: Virtual reality and education and training," *Instructional science*, vol. 23, no. 5-6, pp. 405–431, 1995.

[3] K. Lancaster, *Warlocks and warpdrive: Contemporary fantasy entertainments with interactive and virtual environments*. McFarland, 1999.

[4] K. Ahir, K. Govani, R. Gajera, and M. Shah, "Application on virtual reality for enhanced education learning, military training and sports," *Augmented Human Research*, vol. 5, no. 1, pp. 1–9, 2020.

[5] S. Smith, "Dance performance and virtual reality: an investigation of current practice and a suggested tool for analysis," *International Journal of Performance Arts and Digital Media*, vol. 14, no. 2, pp. 199–214, 2018.

[6] S. Serafin, C. Erkut, J. Kojs, N. C. Nilsson, and R. Nordahl, "Virtual reality musical instruments: State of the art, design principles, and future directions," *Computer Music Journal*, vol. 40, no. 3, pp. 22–40, 2016.

[7] F. Yu, J.-F. Zhang, Y. Zhao, J.-C. Zhao, C. Tan, and R.-P. Luan, "The research and application of virtual reality (vr) technology in agriculture science," in *International Conference on Computer and Computing Technologies in Agriculture*. Springer, 2009, pp. 546–550.

[8] H. Patel and R. Cardinali, "Virtual reality technology in business," *Management Decision*, 1994.

[9] T. Paterson, "An inside look at ms-dos." *Byte*, vol. 8, no. 6, p. 230, 1983.

[10] T. Carpenter, *Microsoft Windows Operating System Essentials*. John Wiley & Sons, 2011.

[11] "immersed : Work faster in vr than in real life, Immersed Inc. All rights reserved," https://immersed.com/, 2021.

[12] "Virtual desktop, Valve Corporation. All rights reserved." https://store.steampowered.com/app/382110/Virtual_Desktop/, 2021.

[13] M. Krenn, "Vr-os," https://matthaeuskrenn.com/vr-os/, 2019.

[14] W. Falkengren, M. Lilja, A. Solback, A. Strandman, J. Swanberg, and A. Höglund, "Virtual reality operating system user interface," B.S. thesis, 2017.

[15] W. Li, "Make os home: Home-like operating system in virtual reality," https://youtu.be/0yyF0zItUZ0, Nov 2021.