Body Aura — A New Approach Towards Ambient Intelligence

Vision Paper

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***Abstract*—The 21st century will be characterized by a number of technical revolutions, which will not leave the ways in which humans interact unchanged. New forms of interactions will change our society in unforeseeable ways. On the other hand, pressing problems such as environmental protection, energy shortages, the spread of pandemic diseases, global crises, etc., demand novel approaches to collect and to correlate more precisely demographic data. To analyze this challenge and to investigate possible technological scenarios, this paper introduces the concept of a *Body Aura*, a digital extension of the body functions of a person or a group of persons to the environment.**

***Keywords*-Body Aura, ubiquitous systems, autonomic systems, self-representation, emergence**

I. Introduction

The 21st century will be characterized by a number of technical revolutions, which will not leave the ways in which humans interact unchanged. Current scenarios on pervasive devices and smart rooms, augmented reality, and even the (already outdated) idea of the "cyberspace" as a new type of human/computer interface barely scratch the surface. New forms of interactions will change our society in unforeseeable ways. On the other hand, pressing problems such as environmental protection, energy shortages, spreading pandemic diseases, global crises, etc., demand novel approaches to collect and to correlate more precisely demographic data; and this has to be done in a secure, reliable way, which respects issues such as privacy and trust.

Considering multiple achievements in areas such as sensor networks, augmented reality, distributed computing, and autonomic systems, the major question is not how to interact technologically with the digital computing, data, and communication resources, but to embed, to maintain, and, to relocate sufficient intelligence and functionality into pervasive devices and networks to perceive them as a useful and trusted extension of personal, professional, and societal spheres. Human activities do hardly occur in isolation but in almost all cases in relation to activities of other humans, organized by ad-hoc communications on various layers, work-flows, and with common as well as conflicting interests. The capability of pervasive and ubiquitous systems to perceive and to support not only individuals but also relations, objectives, interests, and patterns for (probably large) groups of humans becomes crucial for their practical applicability.

To analyze this challenge and to investigate possible technological scenarios, this paper introduces the concept of a *Body Aura*, which can be defined as a *digital extension of the body functions of a person or a group of persons to the environment, both to monitor, correlate and to effectively understand them in relation to the physical parameters, and to actually control those parameters, producing notifications, performance data, and alarms if necessary*.

The paper is organized as follows: Section II discusses the general concept of a Body Aura. This notion will be elaborated in more detail in Section III by means of a number of examples, which are used to identify challenges concerning the development of a Body Aura. Some technical aspects are discussed in Section IV. Section VI draws conclusions and gives an outlook on further work.

II. Concepts

The Body Aura vision assumes that in the near future a pervasive digitalization of the human environment (and bodies) will take place, which involves not only various sensors, control devices, communication facilities (wireless technologies of various kinds), data sources (such as RFID tags), but also storage capacities and processing power (a trend which is already visible today by the omnipresence of mobile devices). The notion of "processors per cubic meter" will become a meaningful unit. The deployment of pervasive applications and systems will become feasible, which today cannot even imagined, going beyond visions of augmented reality, pervasive and ubiquitous communication services. It will be the age of intelligent matter supporting the seamless extension of human bodies, minds, and interactions by information and communication technologies.

A Body Aura forms a vital personal field for both individuals and groups of people to provide various direct interactions between users and their environments, to support human activities both on a conscious and a sub-conscious level. A Body Aura establishes itself as a radically distributed system using resources (sensors, actuators, computing, storage, and communication) found in the proximity of its users without centralized elements. There is no "Body

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Aura gadget" to be carried around all the time, a Body Aura results from the ongoing interaction of those resources. User movement results in a re-location of parts of the Aura while maintaining both function and integrity.

Human interactions result in activities which are meaningful only in the context of a group, hence the person-centric conception of a Body Aura needs to be extended to an activity-centric conception: Instead of monitoring (and predicting) the current "state" of a solitary user, common activities of a set of users need to be recognized and represented. We refer to this transformational process to as the *emergence* of new Auras. Emergent Auras will not replace personal ones, but complement and extend them.

Body Auras can be considered as exemplificative instances of systems which strongly depend on the internal quality of self-awareness. A Body Aura needs, at any instance in time, be aware of its own configuration and internal operation as well as its relationship to its users and their environment. Autonomic features such as self-configuration, self-optimization, self-healing, and self-protection, but also self-organization capabilities, are vital for the functionality and survivability of Body Auras [1], [2].

III. Examples and Challenges

To explain the idea of a Body Aura in more detail and to identify the accompanying challenges, let us analyze a number of scenarios from various application areas:

A. Sports Health Monitoring

As a first basic example, consider a cyclist in training (Fig. 1). To obtain optimal training results, his Body Aura takes measurements of his body functions such as heartbeat, body temperature, breathing frequency, blood pressure, etc. To obtain a better estimate of the cyclist's performance, it takes also environment data such as temperature, air moisture, etc., into account. The current position of the cyclist is determined using GPS. A (hypothetical) actuator controlling the resistance of the bottom bracket is used to emulate accelerations, road conditions, etc.; data to emulate a real racetrack are downloaded and continuously updated via WLAN. The necessary computations are performed on various computing nodes in the current proximity of the cyclists. The Body Aura resides only to a certain part at the devices carried by the cyclists or mounted on his bike; other functions are performed by devices in this proximity.

This example illustrates the first main challenge that has to be addressed in the Body Aura approach, namely:

Homeostasis [3] (also called *meta-stability*) refers to the capability of a system to maintain its identity, function, and structure in the presence of continuously changing conditions. For instance, the cyclist's Body Aura has to continuously re-locate parts of it when its user leaves the range of fixed devices (computing nodes, WLAN access points) and enters the range of others. It has in particular the

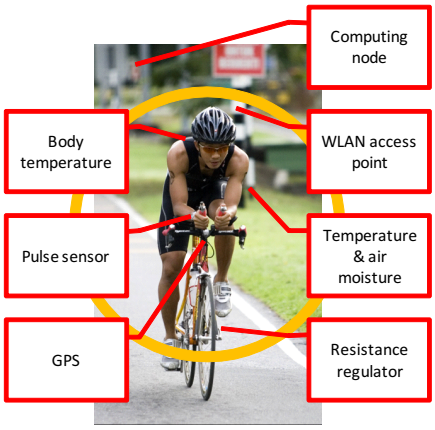

Figure 1. Health monitoring example

ability to predict the availability of resources for a certain time frame, and to degrade its functions in a graceful way if required resources are temporarily unavailable.

A Body Aura of a solitary person may comprise of only a handful of devices. Scalability becomes an issue if an Aura relates to more than one person. For instance, each member of a diving team needs to be aware of the body conditions of her partners, as well as of environmental conditions such as currencies, water temperature, etc. The selection of gas mixes and gas pressure, deceleration and acceleration speed, diving formation, and so on, are critical parameters for a successful and safe dive.

Context and situational perception. The above example illustrate that a precise detection of the current situation and context of a person in relation to other persons is another crucial capabilities of Body Auras. It also makes clear that contextual information can be obtained not only from environmental sensors but also from the interaction of several Body Auras.

B. Recreation, Entertainment, and Travel

Everybody who used to travel a lot immediately understands that localized information is of high importance, e.g., on public transportation, locations of recreational facilities and restaurants, current traffic conditions, and so on. Of course, the idea of localized information has been presented before. We use this example to identify another challenge:

Identification. How does a Body Aura identify the person it relates to? As already pointed out, there is no Body Aura device which allows for an authentication. If a Body Aura is not strongly tied to the body function of a specific person (where the actual configuration of worn sensors can be used as authentication criterion), the maintenance of the relation between Aura and user becomes a considerable challenge.

Consider a new class of role gaming applications where players assume roles in real life situations, based for instance on "spook" scenarios: Players try to investigate the pretended

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activities of other players (e.g., spy out the delivery of—in the game—crucial information to another player). Body Auras can be used to mediate between players, to pass information related to the game situation. Moreover, game opportunities and limitations depend on the particular role a player assumes. Not all players are willing or capable to show James Bond like mannerisms, but prefer a more realistic style. A Body Aura hence needs not only be capable to distinguish between game and "first life" situations, but also needs to be able to adapt to the specifics of the role a player tries to assume.

Adaptability and Learning. Games can be scripted, but the specific reactions of a player to a certain game are not predictable by the game provider, and will change gradually over time when the player becomes more experienced. Therefore, Body Auras need to be capable to learn about the specifics of the person it relates to, and adapt itself accordingly with respect to its assessment of the user's state, and its reactions to it, as well as its internal structure (prioritizing of data and processes for prediction and reaction establishment).

C. Catastrophe and Emergency Management

Consider a major emergency (a large fire, an earth-quake). The communication infrastructure might be impaired or not available at all, making it hard for rescue teams to locate injured persons, coordinate and prioritize their activities. Devices powered by batteries or local energy sources (sun-light collectors), etc. might be still working, capable to establish an ad-hoc communication network. Body Auras of the rescue team, members and people to be rescued will not only interact, collecting, and delivering crucial information, but in effect "merge" and perform collective activities in an expanded context.

Another example of Body Aura emergence is the detection of the propagation of epidemic diseases. Body Auras can provide a city- or even country-wide instrument to monitor people's body functions by the responsible authorities.

Emergence. We refer to the shift from the focus of a singular person to a group of persons, together with a reinterpretation and reassignment of Body Aura functions (that is, data are still related to body functions, but interpreted in the context of different tasks) to as Body Aura "emergence". The emergency scenario used to introduce this capability is of course an extreme example, in fact every group related activity supported by the interaction of Body Auras to provide services which make sense only in a group context relates to Body Aura emergence.

Self-assessment. Some applications of the Body Aura concept just require "best effort". For instance, for the cyclist in the first example it is not of importance if his Body Aura stops working for a couple of seconds because the momentarily available resources are insufficient. The emergency scenario however illustrates that in some contexts best effort is not desirable. In such situation, a Body Aura has been able to assess their own ability to work on an appropriate level given the current restrictions and limitations. If necessary it has to indicate problems to a human operator.

Two additional problems are immanent:

Security. How can it be ensured that personal information is not distributed to parties not allowed to have this information? How can Body Auras be secured against misuse?

Scalability. Progressing from the example of a cyclist trying to optimize his training efforts to the emergence of a population-wide Body Aura is a considerable step which can only be achieved if the envisioned highly distributed architecture of Body Auras is utilized to avoid single points of processing (and failure) and to keep state information as local as possible.

D. Work Convenience

Consider a group of workers. Their Body Auras do not only monitor their body functions, but also feedback information to the workers. For instance, a worker in a dangerous environment may get a notification about the level of her exhaustion. But also, the work flow itself can be assisted by providing sub-conscious interfacing functions to "smart" environments: The room temperature and illumination may be automatically adjusted by the Body Auras of office workers, equipment may adjust to the worker's preferences and physical state, etc.

User/Environment Interaction. Body Auras are envisioned to be more than complex measurement instruments; they actually will perform interactions with the environment on behalf of their users without an explicit user action. In this way, Body Auras may be viewed not so much as tools, but as extensions of the sensoric and haptic body functions of their users to a computerized environment.

IV. Technical Concepts

To describe the main concepts of the Body Aura idea, consider the "high level architecture" displayed in Fig. 2. The general idea departs from the assumption that a Body Aura can be suitable defined by a "Representation of its Self", which describes all aspects, which need to be considered to perform its tasks.

Sensors both related to the Body Aura users and their physical environment acquire raw data which are interpreted using the self-representation as a contextual frame. User augmentation and environment related actuators are used to feed back information to the users, and to interact with their environment. Additional resources for computing, communication, and storage, are integrated as additional supportive elements.

Representation of the Self. Self-awareness of Body Auras is a basic precondition for the establishment of functions such as autonomic distribution, homeostasis, prediction, etc. For that, an internal self-representation of Body Auras is

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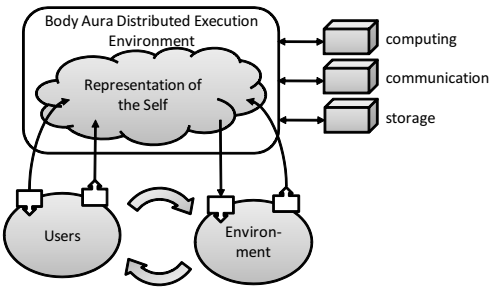

Figure 2. General Body Aura architecture

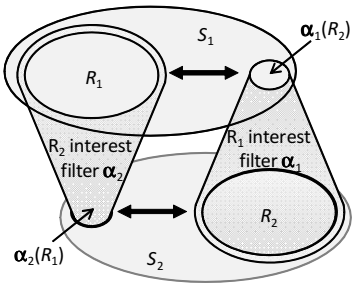

Figure 4. Abstracted composition of self-representations

required which has—with regard to the challenges identified in the previous Section III—to fulfil a number of properties (Fig. 3): It has to "store" data about the state of the users, their environment, and its own actual configuration (sensors, actuators, resources). We call this the representation of *situational knowledge*. Moreover, to provide for planning and prediction, it has to comprise a causal representation of the relevant (virtual and real-world) processes, accompanied by known facts about users, resources, etc. We refer to this type of information as *background knowledge*. Finally, a Body Aura performs a number of tasks to support or serve its users. These activities—defining the *purpose* of a Body Aura—need to be represented within the self-representation too (one might view them as "application layer" of a Body Aura).

Distribution and Scalability. Due to the distributed character of Body Aura there cannot be a centralized self-representation. Therefore, mechanisms are needed to manage a distributed version of the Body Aura model. We propose to use a holistic approach to represent the whole structure of the Body Aura on each contributing entity, but on different level of abstractions. An entity maintains model structures concerning its own functions and capabilities to a higher

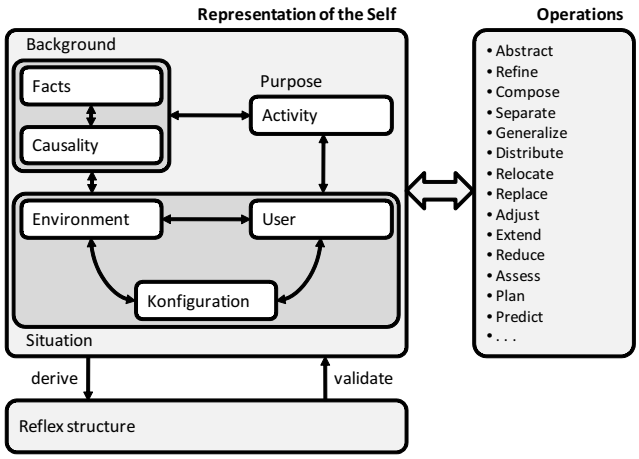

Figure 3. Self-representation, reflexes, and operations

degree of detail then the model structures describing adjacent entities. Body Auras are thus composed of various "knowledge fragments" and pre-defined or learned abstraction operations. The construction of composed representation and the determination of an appropriate level of abstraction with regard to a certain entity becomes an automatic process.

A comprehensive discussion of this idea of abstracted composition of self-representation is far beyond the scope of this vision paper; Fig. 4 provides an intuition by considering two sub-systems (devices, sensors, etc.) with self-representations R_1 and R_2, respectively, which are contributing to a Body Aura. Regarding of what is important for each of these systems to know from each other, a "filter" α_i is constructed which is used to scale down the self-representation of the other system. Thus the composite view of S_1 to the system comprising both system consists of R_1 composed with the abstracted view to R_2 according to α_1 (and similarly for S_2). A formal consideration of these mechanisms can be found in [4], [5].

Emergence of Auras is—on the level of the self-representation—performed by the application of composition/abstraction operations to the involved Auras. Mappings between group related activities and personal ones have to be understood as a reinterpretations of representation structures. This process has to be iterative: Joining of Body Auras will result in the emergence of another Body Aura, which can be merged with other Body Auras in a seamless process.

Reflex Establishment. Some activities of a Body Aura occur frequently and thus may be understood as general behaviour patterns which are applicable is several contexts. Thus instead of computing those patterns over and over again (including the validation of their effectiveness), "short cuts" can be established which apply those pattern without any further planning or analysis activities—they become "reflexes". We assume that the establishment of reflex patterns is likely to increase the efficiency of a Body Aura, and thus increase also the range of tasks which can be performed.

Context-awareness. The creation of self-representation requires adaptive, efficient and scalable methods for the exploitation and utilization of the information available about the user and the actual contextual conditions. An open system must be ready to detect relationships in a lightweight

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manner, often from raw data, about trends, frequent episodes, timely relationships and anomalies or abnormal situations. Another important aspect is the active extraction of predictive relationships, which enables the proactive handling of predicted near-term situations or presumptive future actions.

Learning and Adaptation. A new-born Body Aura with its limited, default knowledge is of much less use than an evolved, optimized one that is highly adapted to its environment and its user. Hence, mechanisms are needed to adjust the Body Aura's self-representation: New self-representation fragments get "learnt", existing ones get refined, replaced or removed. The progress of self-representations is envisioned as an automatic process, without human interaction or intervention—based on the trends, situations, or predictive relationships detected in the local Aura. There are several ways to facilitate this kind of evidence based refinement the models, for example techniques may be borrowed from reinforcement learning [6], data mining [7] or immunology [8]. However, the sole detection of these relationships within the data is not enough to create self-representation fragments. Cognitive aspects, higher-level decisions and goals are also vital for a Body Aura in the process of transforming a detected relationship into an actively utilized, executable self-representational model. High-level aspects may simply seek optimality (I already know a better strategy than what this relationship suggests) or may include meta-reasons (I don't want to what the observations suggest because it would hurt my environment and that's not in line with my meta-goals). In other words, a Body Aura needs to be able to learn from its experience, but is not forced to use the knowledge blindly, without control. Knowledge both emerges on the lower level from the observations, and on the higher level, including cognitive aspects.

Networking. Due to the non-centralized, and self-organized character of the Body Aura system, where the amount of conscious control is reduced radically, the classical telecommunication approaches cannot be used. The lack of centralized entities means that the Body Aura system is similar to an opportunistic or a delay-tolerant network in terms of communication. However the well-known ad hoc networking solutions cannot be adapted to the Body Aura system, as it is not taking into account the emergence of Body Auras, together with the regrouping process.

This means that the Body Auras (which could be represented as mobile nodes in the communication perspective) form mobility groups, and the structure of these groupings could heavily effect the propagation and relaying of the information in the system. The information propagation and the dissemination process is not only significantly influenced by the group mobility patterns of the Body Auras but also by the common decisions of the groups, for example which information are important for the given group, or which information should be disseminated to the neighbouring groups, namely merged Auras.

Security. The Body Aura dia removes static architectural features and in favour of heterogeneous structures, and moreover increases the independence from the "physical layer". Thus, its architecture and as a consequence its security architecture is completely detached from single hardware instances. Due to this feature, Body Aura also allows its distribution on multiple devices, representing a distributed client application which acts on behalf of the body the Aura is associated with.

In Body Aura, complete sets of devices, and several services which are spread among potentially numerous devices will act on behalf of a "body". Thus, the question arise: Who will be the principal, i.e., who authenticates what and what does this imply for the system? Novel mechanisms (e. g., based on biometric pattern recognition) need to be developed to establish a trust relation between Body Auras, users, and other involved parties.

Augmenting the Person. A Body Aura follows the activities of the person (the atomic level) or a group of persons through passive observation. If some tasks are recognized the Body Aura pursues all activities of the person and compares them to corresponding activity patterns. If more than one activity representation applies, these are treated as competing. Some of the tasks may reduce the amount of activity models which correspond to the current actions of the person. In some cases the Body Aura is not able to recognize what the user is doing and what his intention is. In this case the Body Aura tries to interact with the user. Hence, models for the interaction of persons with their own Body Auras are needed. But interaction between the person and the Body Aura is an additional load for the person and should happen as rarely as possible. A model is required, which describes several levels of interaction complexity (yes/no, item selection, commands) and its form (gestures, voice, mouse, keyboard).

V. Related Work

Over the last two decades, a new understanding of the relationship between human users and computer systems has emerged, grounded in visions developed in the early 90's, of ubiquitous computing [9] (i.e. computation moving out of the box to be pervasive in the user's ambient), augmentation of the real world [10] (i.e. enhancing physical reality with digital interaction), and wearable computing [11] (i.e. augmentation of humans with always-there computational services). These original visions have largely converged in today's digital world, with personal mobile devices that continually support their users, pervasive devices and services available in the ambient, and widespread technologies for linking digital interaction to the entities and activity in the real world (passive and active tagging [12], location systems [13], mobile augmented reality [14]). However, in spite of the paradigm shift that has taken place, there is a total lack of concepts for how the intelligence that is deeply and densely

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embedded in people's environments (in the form of sensors, actuators, digital media, smart objects, smart materials, etc.) can be harnessed to effectively support user activities and needs. Key barriers are the very limited representation of user context to the environment, and the centralized approach to interface complex computerized environments.

The distinct approach, in departure from the state of the art, is to develop the interface between people and complex computerized environments as a self-aware autonomic system conceived as a Body Aura around the user. In terms of high-level vision there have been precedents of conceptual work on auras or spheres around the user, e.g. Ferscha et al.'s Digital Aura as a thought model for interactions in a pervasive computing world [15] and Mynatt et al.'s Audio Aura providing serendipitous information via background auditory cues [16], but in practically all work on human-environment interaction, the sphere of interaction is implicitly defined by the nature of the infrastructure (network topology, communication range of user devices, sensor coverage).

VI. Conclusion and Further Work

In this paper, we have introduced the vision of a Body Aura, which acts as an information technological extension of the user's body functions to his or her physical environment, and is capable to provide a functions for (probably large) groups of persons as well, hence is applicable in a large variety of scenarios.

The Body Aura vision involves a number of research areas which cannot be addressed simultaneously. In our future research, we will concentrate of the following key issues:

1) One of the main concepts of the Body Aura approach is the definition and maintenance of a distributed "representation of the self" describing all operational aspects of a Body Aura at a "suitable degree of abstraction", defined by the knowledge requirements of devices contributing to the Aura. Although some work has been already conducted into this direction [4], [5], further research is needed.
2) Investigations on the interpretation of behavioral representations (UML Statecharts) of functions implemented on resource limited devices [17] indicate that it is possible to maintain computational models even on very small devices with suitable efficiency. Future research will address different modelling formalisms.
3) An open learning an adaptation model to systematically detect, refine and utilize relationships within the environment, with help of data mining techniques.

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