SIGNAL 2021

The Sixth International Conference on Advances in Signal, Image and Video Processing

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SIGNAL 2021 Editors

Pavel Loskot, ZJU-UIUC Institute, China

SIGNAL 2021

Foreword

The Sixth International Conference on Advances in Signal, Image and Video Processing (SIGNAL 2021), held between May 30 – June 3rd, 2021, continued the inaugural event considering the challenges mentioned above. Having these motivations in mind, the goal of this conference was to bring together researchers and industry and form a forum for fruitful discussions, networking, and ideas.

Signal, video and image processing constitutes the basis of communications systems. With the proliferation of portable/implantable devices, embedded signal processing became widely used, despite that most of the common users are not aware of this issue. New signal, image and video processing algorithms and methods, in the context of a growing-wide range of domains (communications, medicine, finance, education, etc.) have been proposed, developed and deployed. Moreover, since the implementation platforms experience an exponential growth in terms of their performance, many signal processing techniques are reconsidered and adapted in the framework of new applications. Having these motivations in mind, the goal of this conference was to bring together researchers and industry and form a forum for fruitful discussions, networking, and ideas.

We take here the opportunity to warmly thank all the members of the SIGNAL 2021 Technical Program Committee, as well as the numerous 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 efforts to contribute to SIGNAL 2021. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

Also, this event could not have been a reality without the support of many individuals, organizations, and sponsors. We are grateful to the members of the SIGNAL 2021 organizing committee for their help in handling the logistics and for their work to make this professional meeting a success.

We hope that SIGNAL 2021 was a successful international forum for the exchange of ideas and results between academia and industry and for the promotion of progress in the field of signal processing.

We are convinced that the participants found the event useful and communications very open.

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Classifying Vessels in Inland Waters Using Live Video Streams

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***Abstract*— Video surveillance systems used in vessels' traffic monitoring are being improved to eliminate the need for operator supervision. One desirable feature of such systems is the ability to count the number of passing vessels and determine their types. The paper presents straightforward algorithms that can determine the category of a vessel based on partial results of classification. The algorithms take as an input a series of vessel images acquired directly from the video stream by the detection module. Some of the images contain an inaccurately cropped ship or a part of it, and there are also occasions when ships or other objects in the background are erroneously cropped. The algorithms were implemented and experimental results from 100 video samples in four different qualities are presented. The results show that the method is suitable for a practical application.**

Keywords-vessel; classification; video surveillance; traffic monitoring; inland waters.

I. INTRODUCTION

Vessels' traffic is monitored on inland waters using video surveillance systems. These systems are being improved to eliminate the need for operator supervision. One desirable feature of such systems is the ability to count the number of passing vessels and determine their types. With the ability to assess the type of incoming vessel it is also possible to implement additional actions that can be undertaken depending on the detected type of a unit. For example, the movement of barges can be monitored to better plan the opening of bridges and locks, and recreational boats can be sent proper notifications.

This work is a part of the Ship Recognition (SHREC) project [1]. Its objective is to develop a system for vessel detection, identification, and tracking. Additionally, classifiers based on deep learning techniques have been developed that allow the vessels to be categorized into a series of types. These classifiers learned from images of vessels that were clipped out from previously recorded video streams. As the detection system returns a series of images of a ship with the same ID [2], the following question arises: what would be the quality of the classification if one tried to select a single class for the series of images? Additionally, the detection method sometimes inaccurately cuts the ship from the video frame and various artifacts appear in the background. There were no such images in the learning sets. Figure 1 shows how a picture with a vessel can be cut out of a video frame in such cases.

Together with the latest advances in computer vision for object detection and recognition, based closely on the development of deep learning techniques, massive progress was done in the field of ships identification and tracking in recent years. Traditional methods of classification focused on choosing key vessel's features, e.g., as in [3] or [4]. They obtained good results, however with small hull differences between vessels types and complex background of the environment, the practical use of these methods was limited. Then, with the development of Convolutional Neural Networks, such as Visual Geometry Group (VGG) [5], GoogLeNet [6], ResNet [7] and their wider accessibility, new methods were developed. The research works presented in [8] and [9] emphasize the latest focus on detection and classification methods using Convolutional Neural Networks (CNNs) for the purpose of ship recognition. One of the major problems in this field is building a large training sample set, because obtaining enough different images of different units is problematic. There is also no publicly available test dataset containing a wide variety of vessels, especially inland and recreational. This issue was raised in [10]-[12]. The latest research works use mainly end-to-end solution based on regression deep convolution networks, such as You Only Look Once (YOLO) [13][14].

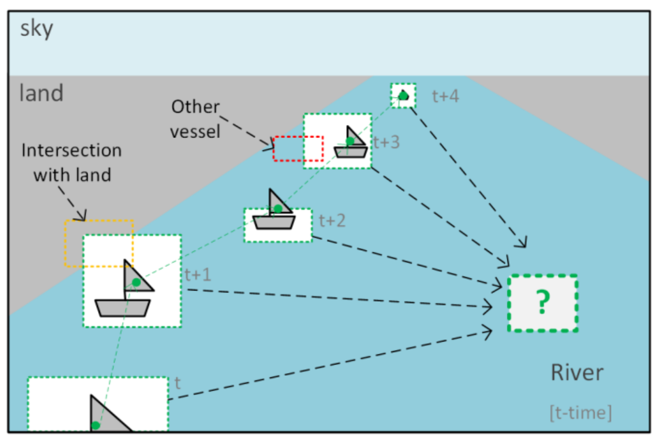

Figure 1. The problem of determining the class of a vessel on the basis of a series of images.

This paper presents straightforward algorithms that can determine the category of a vessel based on partial results. The algorithms take as an input a series of images of the vessel acquired directly by the detection module from the video stream. The category of a vessel for each image is determined by the classification module and, based on these results, the final category is computed. Some of the images contain an inaccurately cropped ship or part of it, and there are also occasions when ships or other objects in the background are erroneously cropped. We present experimental results from 100 video samples in four different qualities, which show that the method is suitable for practical use.

The rest of this paper is organized as follows. In Section 2, the algorithms for determining vessel category are described. Section 3 describes the experiments and their results. Section 4 concludes by presenting the results in the context of their practical application.

II. METHOD

The SHREC system contains a detection and tracking method that returns a series of images for each vessel passing in front of the camera. To classify a vessel into one of the categories, we have used a pretrained, 22-layer convolutional neural network GoogLeNet that can classify images into 1000 object categories (with none related to vessel classification). During two years of video registration, we obtained thousands of images of different vessels (both conventional and recreational) and initially divided the set into 21 categories of ships. As much as possible, attempts were made to collect photos representing each vessel category from different angles. However, it appeared that the agreed categories were too detailed, as we could not cover each category with enough image representation and some categories were almost impossible to distinguish from each other. Finally, the categories were reduced first to 11 and then to 7 (inland barge, port services ship, kayak, motor yacht, passenger ship, sail yacht, other). The reduction was made in consultation with monitoring centers operators. The transfer training was used to retrain the GoogLeNet CNN for chosen set of the images. The full research on this matter was presented in [15]. The quality of the obtained classification varied between 67% and 99%, depending on the similarities between classes. Nevertheless, in practice we do not need a correct classification for each image of a unit, but an accurate recognition from a series of images representing the detected vessel while it passes in from of camera. Two straightforward algorithms to determine one category for a series of images were designed:

1. Algorithm v1: compute the category for each image, then return the one that occurs most often. If two categories occur the same number of times, return the one that was computed first.
2. Algorithm v2: as above, but rejects small images, i.e., with width or height below 224 pixels. If all images are reject, proceed as in algorithm v1.

Such algorithms should allow to reject erroneous classifications based on vessel images that have a lot of objects in their background or contain incorrectly clipped vessels from a frame. A simple metric was defined: correct vessel classification ratio that is the ratio of the number of vessels correctly categorized over the sum of all vessels categorized. The metric is used to determine the quality of the proposed algorithms.

III. EXPERIMENTAL RESULTS

The classification based on a series of vessel images was tested using the prototype version of the SHREC system. The classification module was implemented using C# and OpenCvSharp3-AnyCPU (OpenCV wrapper for C#). In our experiments, the following computers were used:

1. Detection service and system core module: Intel Core i7-8750H, 16 GB RAM, SSD 256 GB, NVIDIA GeForce GTX 1050Ti, Windows 10 Pro (laptop).
2. Classification service: Intel Core i7-8700K, 32 GB RAM, SSD 1 TB, NVIDIA Quadro P4000, Windows 10 Pro (workstation).

We have used batch processing to play in real time all video files in each data set. Each data set contains 100 video samples. Each video sample shows one passing vessel in front of the camera. Figure 2 shows a series of images of the vessel that were captured from one of the video samples and the partial classification results. The data sets do not include video samples used to train the CNN classification network. The video samples were recorded in high 4K quality and then transcoded to lower quality and full high definition resolution, which resulted in four data sets:

1. Set A: 4K 3840 × 2160, 30 frames/s, bitrate 66 Mb/s, H.264 Advanced Video Coding (AVC) High@L5.1
2. Set B: 4K 3840 × 2160, 30 frames/s, bitrate 10 Mb/s, H.264 AVC High@L5.1
3. Set C: Full High Definition (FHD) 1920x1080, 30 frames/s, bitrate 8 Mb/s, H.264 AVC High@L4.2
4. Set D: FHD 1920x1080, 30 frames/s, bitrate 3 Mb/s, H.264 AVC High@L4.2

TABLE I. TEST RESULTS

Algorithm	Set A	Set B	Set C	Set D
Version 1	81%	80%	85%	81%
Version 2	80%	75%	81%	80%

Table 1 contains classification results for algorithm v1 and algorithm v2 for each data set. Algorithm v1 provided slightly better results. The correct vessel classification ratio for algorithm v1 and set C was 85% and it was the best result. Algorithm v2 for set B returned the worst result of 75%. The correct classification ratio for other tests was 80% or 81%. On average, a series of images for one vessel contains 20 elements.

IV. CONCLUSION

The classification quality depends on the detection quality. The detection method returns a series of images containing vessel's images that are clipped from a video frame based on motion detection. The background of the images is not cleared from other objects. It would be best to use camera views with scenes, where the ships background is only water. However, the system is intended for inland waters where cameras are located mainly on bridges and in narrow passages. Therefore, it is practically impossible to provide a homogeneous background. Additionally, some of the images in the series are clipped (when a vessel enters or leaves a camera view).

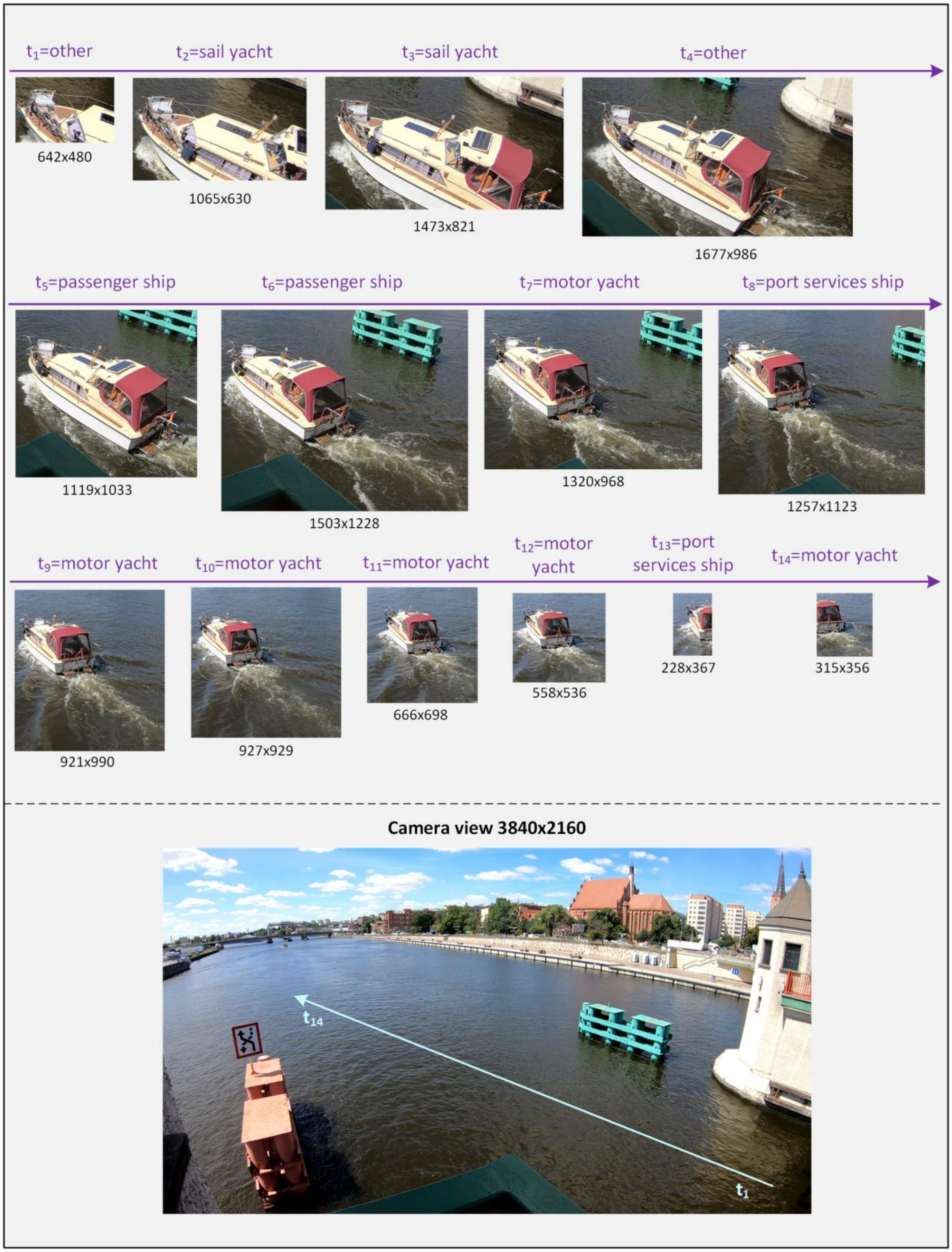

Figure 2. Example series of images with partial classification results.

In the case of heavy vessel traffic, there may be a situation where an additional vessel or vessels appear in the image. However, there will be one or several such images in a series, and in most cases the algorithms will reject the faulty classification results caused by them, as there will be more correct results remaining. In addition, the system requires that the cameras are located in narrow passages or on bridges, which limits the cases of passing ships.

During the preliminary works, three pre-trained neural networks were tested: AlexNet, SqueezNet, and GoogLeNet. Those networks are available in Matlab 2020b with Deep Learning Toolbox. The networks were trained with the same data sets and the best results were returned by GoogLeNet. In the future, our image database (the training dataset) will be periodically updated. The available pre-trained networks will be tested again. Replacing the classification module in our system is straightforward. If some new network returns better results, it can be used instead of the current one.

Discarding small images did not improve the quality of the classification and worsened it by a few percentage points. That was a result different from what was expected. On the other hand, as expected, increasing the compression ratio within a given resolution has caused a loss of qualification quality as compressed images have less details. However, the difference is not significant, therefore more compressed video streams can be used.

One of the most surprising results is the better performance for test set C (FHD resolution) than for set A (4K resolution). This is probably influenced by the detection method. The detection algorithm internally compresses frames to 1280x720 resolution. However, the result for both sets will not be exactly the same, as the compression for FHD is done differently (4k->FHD->720p instead of 4K->720p). We will investigate the exact cause of this in further works. Additionally, we are planning to test algorithms for background removal to increase the classification accuracy.

ACKNOWLEDGEMENT

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Technology for Overcoming the Global Tetralemma

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***Abstract*—We humans are now facing the four global issues (Global Tetralemma) related to Population, Food, Energy and Environment. The key issue is how to find out the cause of these problems and what are the possible solutions. Simply put, most of the problems are caused by human activities prioritizing economic promotion. It can be, however, noted that agriculture has a higher potentiality to play an important role in solving most of the problems in question. In this paper, the technologies being applied or to be applied to agriculture and its related sector are introduced focusing on the sustainable development of future society building, which means establishing and maintaining a harmonic balance between ecology and economy.**

Keywords - global tetralemma; space era high-tech agriculture; agricultural mechanization; policy and technology.

I. INTRODUCTION

Earth is the only planet on which humans can live a normal life. The global tetralemma refers to the four global issues consisting of population, food, energy and environment. Figure 1 shows this ecological concept. When the population increases, the food production must be increased. To increase the food production, more energy is needed. Energy consumption increases CO_2 production, which jeopardizes the environment. This creates a situation in which we, humans are facing three problems related to food, energy and the environment.

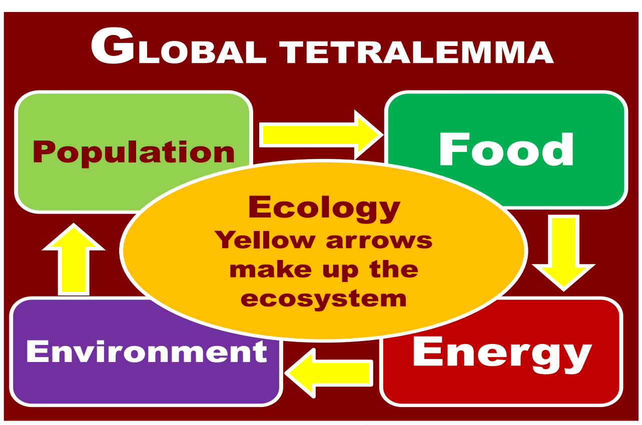

Figure 1. Schematic concept of global tetralemma

Figure 2 shows how economy breaks ecology and produces all the other problems. How to tackle and find the solutions for those problems is one of the main objectives of this paper.

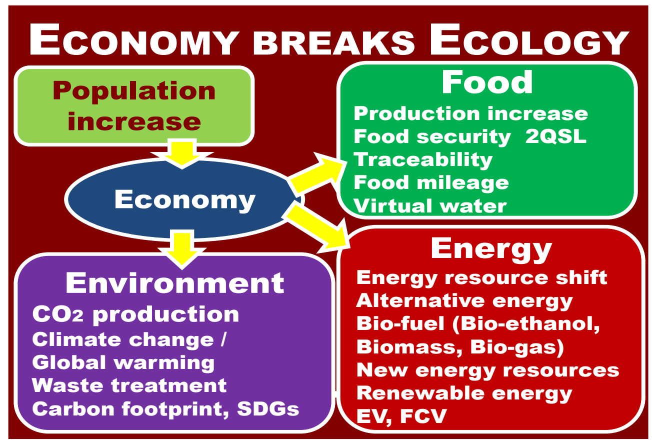

Figure 2. Economy breaks ecology and contributes to other problems

Currently, the world population is 7.8 billion and increasing by 80 million per year. Considering this figure carefully, about 140 million people are born and 60 million are dying each year. The difference of 80 million is the population increase. As the population grows, more food production is needed. It is said that the population engaged with food production is around 20% of the world population. This simply means that one farmer produces food for 5 persons, including himself.

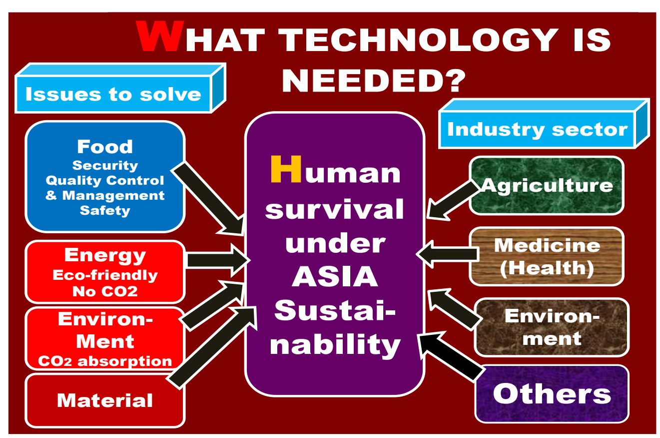

Figure 3. What technology is needed for.

Figure 3 shows the relationship between the issues we are facing and the industry sector. We are already facing two emerging global issues related to energy and the environment

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that we need to solve immediately, however, the final and optimum solution has not been found yet, in spite of many efforts being done by various scientists, researchers and engineers. This is really a competition of the production cost and price of petroleum with the other energy resources in which most of them are eco-friendly or environment friendly ones. Recently, petroleum price has been drastically coming down almost 1/3 compared to ten years ago, due to the new energy resource discovery of shale gas, in which the production cost is very much lower and more competitive. Methane hydrate is another possibility. Japan successfully developed the technology to take it out of the seabed in 2014, however, it is still not cost competitive. It will take a little bit more time to make it for the commercial base production. It may be guessed that the decrease in price of the petroleum may slow down the speed of technology development due to enough production to supply the market. On the other hand, the mitigation control of CO_2 gas may be delayed, and the global warming issue cannot be improved if this situation is continued. Which one should be chosen, energy or the environment, is one of the good examples to think about the real meaning of sustainable development or low carbon society building from the viewpoint of how the harmonic balance can be well maintained under this condition in promoting economy without jeopardizing the environment. The economy always makes us hesitate easily in making a choice. We, humans, already know that the fossil energy should not be chosen due to the cause of the global warming, however, the lower prices of oil entice us.

The author delivered a lecture entitled "Asian Agriculture Growth Strategy" in Prime Minister ABE's doctrine "ABEnomics" as one of the invited keynote speakers at the Agricultural Mechanization Session, JSAMFE (Japanese Society of Agricultural Machinery & Food Engineers) annual meeting held at Ryukyu University, Okinawa, Japan, May 17, 2014 [1][2]. Figure 4 is a schematic diagram showing ASEAN Economic Community should pick up the industrial sector for promoting the economy and how it should be done. It is already known that the ASEAN Economic Community was officially established in December 2015, however, it looks a little bit difficult to know what sector should be set as the main framework of the body to meet and achieve the final goal of the community. In the author's understanding, the goals should be 1) To make ASIA the world food pantry, enough to supply safe food on demand and 2) To stabilize the economy and maintain peace based on agriculture. The following shows the concept outline of ASEAN Economic Community proposed by the author and how it should be promoted step by step towards the final goal achievement.

Most Asian countries are more or less still relying on the economy of the agricultural production. ASEAN member countries are also in similar situation, except some of them. It is already well known that, as already mentioned above, the human population is still rapidly increasing at the rate of 80 million per year. It can obviously be guessed that, sooner or

Figure 4. Asian Agriculture Growth Strategy

Later, the food issue will become a serious problem. Fortunately, Asia is producing a huge number of bio-resources, especially food resources, however the quality is not well controlled and managed. As far as food production is concerned, the priority should be to secure the safety. It should be noted that there are two kinds of countries in Asia: one kind is resource-oriented countries, and the other kind is technology-oriented countries, called ASEAN, plus three like China, Japan and South Korea. To secure the quality, especially food safety, higher technology is needed and applied. The author's proposal is based on the collaboration and mutual competition among these two types of countries. One needs the resources and the other needs the technology. Both need them mutually and interactively. The best way is to collaborate and compete to promote a stable economy in Asia. In addition, two things should be done on the process of final goal achievement. They are: 1) Technology transfer and 2) Human Resources Development. Both should be desirably promoted in parallel, however, due to some inconvenience of laws and regulations, it is hard to achieve in practice. Which one should be started first? That is the human resources development, especially for universities. The extension must be followed through the process of technology development and its validation; therefore, it takes time for final technology transfer to extension. Even for the human resources development, it takes time until the effective result could be found, therefore, the academic mobility program should be started earlier and promoted in the regional area. It is required that highly educated human resources will be absolutely needed by the mature global society. Two stages of goal achievement are shown towards the final one. The first step is to make Asia one of the world food pantry in huge amount of food resources production. Secondly, the most reliable Asian brands of foods should be created enough to guarantee both quality and safety. Following the process based on this proposed concept, the Asian economy can be developed and promoted stably, and regional peace can also be kept. Both resource-oriented and technology-oriented countries can get mutual prosperity to survive together contributing a lot in safe food production and supply all over the world (Figure 4).

II. SMART AGRICULTURE

The Ministry of Agriculture, Forestry and Fisheries of The Government of Japan defines smart agriculture as "new agriculture that enables hyper labor saving and high-quality products production by utilizing cutting-edge technologies such as robotic technology and ICT". According to the Ministry, the materialization of smart agriculture can achieve hyper labor saving and large-scale farming production by automatic control of agricultural machinery, high-yield, high-quality products production that makes full use of sensing technology and large data, and heavy labor by using robot technology. It can be expected to have more merits such as CO_2 mitigation and labor saving, simplification of agricultural operation by combining know-how with data and assisting operating function and providing important and necessary information to consumers by providing final products information (traceability) [6].

A. *Precision Agriculture*

Precision Agriculture has variable rate control function for reducing loss and saving materials and energy. The concept of this farming system is similar to the TOYOTA car manufacturing system named “Kanban (or Kaizen)" system mainly consisting of the three conditions listed below. In the car manufacturing industry, the parts must be prepared in advance and supplied timely based on the production plan and schedule.

1) The required parts must be prepared in advance based on the production schedule
2) Provide just enough amount required
3) Provide them timely when required

In actual farming, three conditions of “What”, “How many or How much” and “When” must be decided from time to time knowing the data provided by GIS is specifically matched with site by site.

B. *Robotics*

There are two kinds of robots. One is something like an industrial robot set and used to complete the work for the post-harvest products, such as selection, weighing, grading, sorting, packaging etc. in a specially prepared building or facility. The other is a mobile vehicle type, such as tractor, combine and transplanter doing the original operation while moving things, such as tillage, fertilizer application etc. The location of the robotic machine is autonomously guided by the GPS signal provided from the satellite. The optimal operation can be done under the variable rate control based on the final decision derived from the data collected and provided by GIS continuously from time to time while moving. A laser scanner is mounted in front of the vehicle (tractor, in this case) to detect the obstacle and it functions to stop the machine immediately. The other direct contact type sensor is also mounted for a double check in safety. Three-way sway of the vehicle, namely pitching, yawing, and rolling, reduces accuracy. It is also possible to control the automatic guidance operation of a group of vehicles consisting of multiple vehicles while maintaining a master-slave relationship. Figure 5 compares agricultural and industrial robots.

Difference between Industrial and Agricultural Robots

No.	Item	Agricultural robot	Industrial robot
1	Robot motion	Move to work Search, Find, Identify, Off road	Stay and wait for the work
2	Objective work	Non standardized Size, Color, Shape, Maturity Hardness, Location	Standardized Designated set position
3	Operation	Autonomous	Program based
4	Function	Learning	Teaching
5	Structure	More complicated	Comparatively simple

Figure 5. Difference between agricultural & industrial robots

C. *Green Factory*

This type of farming is different from the conventional one mainly focusing on the mass production of fresh market crops such as lettuce, mini tomatoes etc., which is similar to the industrial crop cultivation under completely controlled conditions of the environment. This is basically managed on hydroponic system, therefore, water is normally used for fertilizing and circulated for saving. Disease infection is tightly controlled. Workers are strictly forced to wear special work clothes, masks and caps, in addition to special work boots and gloves. The environment is similar to the clean room of semi-conductor industry plants. They are also strictly forced to take air showers when getting in and out of the facility.

Figure 6. Various types of Green Factory.

Figure 7 shows the advantages of green factories in terms of materials and costs, including future business prospects.

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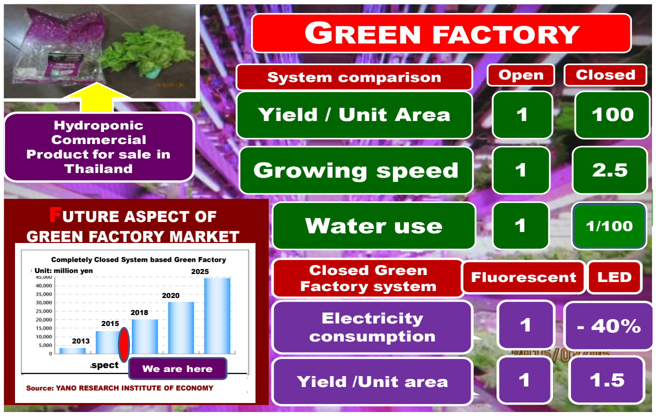

Figure 7. Green Factory, present and future.

D. Drone

Recently, the number of possibilities of drone application to the agricultural sector have grown rapidly. One of the most important merits of applying drone is to get a wide bird eye view photo which enables to find how the crops are growing. Farmers can find what and how they can do from the image sent to their device, such as a smart phone They can make decision regarding how much fertilizer should be applied from the green color image (NDVI, Normalized Difference Vegetation Index).

$$NDVI = (NIR - RED) / (NIR + RED)$$

where NIR – reflection in the near-infrared spectrum
RED – reflection in the red range of the spectrum
According to this formula, the density of vegetation (NDVI) at a certain point of the image is equal to the difference in the intensities of reflected light in the red and infrared range divided by the sum of these intensities. This index defines values from -1.0 to 1.0, basically representing greens, where negative values are mainly formed from clouds, water and snow, and values close to zero are primarily formed from rocks and bare soil. Very small values (0.1 or less) of the NDVI function correspond to empty areas of rocks, sand or snow. Moderate values (from 0.2 to 0.3) represent shrubs and meadows, while large values (from 0.6 to 0.8) indicate temperate and tropical forests. Crop Monitoring successfully utilizes this scale to show farmers which parts of their fields have dense, moderate, or sparse vegetation at any given moment. Simply put, NDVI is a measure of the state of plant health based on how the plant reflects light at certain frequencies (some waves are absorbed, and others are reflected). Chlorophyll (a health indicator) strongly absorbs visible light, and the cellular structure of the leaves strongly reflect near-infrared light. When the plant becomes dehydrated, sick, afflicted with disease, etc., the spongy layer deteriorates, and the plant absorbs more of the near-infrared light, rather than reflecting it. Thus, observing NIR changes compared to red light provides an accurate indication of the presence of chlorophyll, which correlates with plant health. Drone can be used for many other ways, such as seed broadcasting, fertilizer and chemicals application. In these cases, the payload is the problem, namely, how much it can carry and fly. More applications are under consideration; however, the challenges are security, privacy, various regulation and the standards. Hackers can break into seemingly safe remote-controlled engines and networks that control brakes and steering.

III. TECHNOLOGY APPLICATION IN AGRICULTURE

A. Nano Technology

Carbon Nano Fiber is famous and well know for its light weight and strength. It is already used for the aircraft and car industry. Recently, the bio-based Cellulose Nano Fiber is attracting a lot of interest. It is a newly developed material by Professor Hiroyuki Yano, Humanosphere Research Institute, Kyoto University, Japan from bio-resources equipped with unique physical properties, namely, 5 times stronger and 1/5 lighter than metal, in addition to higher heat resistance. The Cellulose Nano Fiber may take the application area and replace CNF (Carbon Nano Fiber) in the future. In addition, it costs 1/6 of the cost of carbon nano fiber. Cellulose Nano Fiber can be produced not only from trees, but also from various popularly known cellulose materials such as wood, rice straw, cassava and potato.

Various Nano Bubble water provides other hopeful possibilities, such as

- Oxygen Nano Bubbles
- Ozone Nano Bubbles
- Nitrogen Nano Bubbles

The applied industrial sector is shown below.

- Food safety – Vegetable sterilization
- Aquaculture (Fishery) – Oyster sterilization
- Dentistry – Periodontology / Periodontics
- Medical science - Cancer cell control

Oxygen nano bubble water has higher effect of promoting plant growth and shortening the total growth period. Ozone nano bubble water functions effectively for sterilization for various bacteria and fungi. In case of washing out the chemicals attached to agricultural products, 80% are removed by using ozone nano bubble water, whereas only 20% can be removed at one time with ordinary water. Toothpaste water using ozone nano bubble water has been commercialized. Periodontal bacteria in the mouth can be sterilized just by gargling without brushing your teeth.

B. Plasma Technology

Plasma technology can be used to treat waste and change to energy because under high temperature treatment hydrogen can be produced. On the other hand, if the plasma treatment was done under low temperature, waste oil can be changed into fuel. According to the news currently televised, it is said that around 4,000 workers are working everyday at Fukusima nuclear power plant, however it will take 40 years more to remove the debris left in the reactor. The use of plasma is promising for treating highly radioactive debris.

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C. Pattern / Face Recognition

The combined technology of image processing, pattern recognition and Artificial Intelligence (AI) is getting popularly applied to recognize and identify the individual person quickly. This technology can be used even for the individual livestock management. Two kinds of memory can be found and considered: one is a tag attached to a part of the body like a ear, and the other is the chip type to be embedded in the body. The pedometer, the route traveled, the distance, etc. are automatically recorded and sent to the data center for recording. These data can be used for observing the health status of individual livestock and managing the amount of food to feed.

The net pattern of melons is unique and original to each individual and resembles a human fingerprint. By recording and memorizing this net pattern as an image, the historical background of the melon can be known such as the place and when it was harvested and how it came from the production site. This is one of the areas called Agribiometrics or Bioinformatics.

IV. PROJECTS AND BUSINESS

In this section, we list some of the ongoing projects and businesses.

A. Blue fin tuna, Kinki University

Blue fin tuna is one of the most popular big thick fishes served at higher class restaurants in Japan. However, to meet the customers demand, fishermen must live away from home for months in remote pelagic fisheries. Sometimes the weather is unseasonable, and they sometimes encounter storms and typhoons. Some of them will also encounter a fatal accident. If they do not have to live away from home for fishing, it will make them more relaxed and even their family will feel more at ease. Fisheries should be changed from going away and fish for months to keeping put and growing fish. The Kinki University succeeded in the cultivation of blue fin tuna to grow from the stage of egg up to the final stage for shipment. Currently, blue fin tuna cultivated in this way is delivered to large cities and rural areas and is also served in the cafeteria on the university campus [4].

B. Osaka Prefectural University

Osaka Prefectural University is one of the first universities in Japan to succeed in researching and commercializing a Green (plant) factory. Just like Kinki University mentioned above, it can be said that this university has demonstrated the industrialization of agricultural products production. The cultivation shelves lined up in an environmentally controlled building are fully covered with LEDs of various colors, and the workers working inside seem to be working in the clean room of a semiconductor manufacturing plant, and they are nervous about bringing in pathogens from the outside. Harvested lettuce and other fresh vegetables are delivered not only to university cafeterias, but also to large cities and regions on order. One of the important factors to keep in mind is that producers have a clear and reliable relationship with consumers [3].

C. EUGLENA Project

This is a joint venture project already launched few years ago. The author does not know how much they have been successful up to now unfortunately, however, this business model is one of the few successfully launched examples the author knows about. The main product is an alga. Euglena has many characteristic features, but it is noteworthy that it absorbs a large amount of carbon dioxide. Electric power plants discharge a large amount of carbon dioxide, which can be absorbed by Euglena to promote its own growth. The produced Euglena can be sold as a raw material or resource for food, feed and fertilizer, while also contributing to aircraft jet fuel as bio-fuel. The problem with business operations is that they need technology to produce a large amount of Euglena in a short period of time, and the company founders have also proven this technology. Since it is a bio-based fuel, it contributes a lot to a low carbon society and decarbonization from the viewpoint of carbon neutral concept [5].

D. Good Harvest Plan

This is also a business model proposed by Toyota. It is a contractor-type business model for small-scale farmers or farmers who have no successor, but own farmland. The farmer will contact the contracted center and request the dispatch of machine together with driver to carry out the necessary operations timely. The center will respond to the request by dispatching an appropriate driver according to the type of farming operation. The main operation is tilling, transplanting and harvesting, but the farmer is the owner of the farmland, however, does not physically work directly. The number of such contractor-type farmers is increasing in Japan due to no successor. Agriculture in the high-tech and information era has the potential to significantly increase the entry of industries from completely different sectors that are not closely related to agriculture [7].

E. Animal Factory

This is an animal version factory of a plant factory. The target livestock are dairy, beef cattle, pig farming, and poultry farming, but unlike growing in a limited space, this is a project to give time to walk around freely in a wide space and to carry out breeding management of livestock with high quality meat. Individual management using small device and equipment incorporating information and communication technology is extremely needed. The necessary information is sent as data from sensors attached to dairy cows and beef cattle grazing in the pasture to the central center and used for individual health management.

F. Beef Traceability

It was already mentioned above how important the mutual liability between producer and consumer. Food security has four important keywords such as 2QSL consisting of

Quantity, Quality, Safety and Liability. One of the most important problems, but difficult one to negotiate, is the mutual liability issue. No matter how famous and well-known companies are, if they do not manage well, they will disperse false information. They can cheat the place of production, fake the contents of the product, rewrite the expiration date, and do embarrassing acts without hesitation. The other three conditions except mutual liability are relatively easy to clear and satisfy. This is because there is no problem as far as the standard code level is cleared.

G. International Collaborations

Asia can be qualified as a world food pantry in production and supply, however, farmers are still working in poor conditions due to various problems such as family labor and low income mainly caused by small scale farming. The ASEAN community based international collaboration is really needed in technology transfer and human resources development. Technology oriented countries should join and actively invest in Asia for further economic promotion and regional peace keeping. The author is making a proposal named FFA (Future Farmers of Asia).

V. Conclusion

Global tetralemma is a common issue not only in Asia, but also in the world, and these issues must be resolved urgently.

Asia is qualified as a world food pantry capable of producing and supplying huge amounts of food. However, although the production is large, the quality of the products is not constantly controlled. From the perspective viewpoint of food security due to the rapid increase in the world population, technology-oriented nations should actively invest in Asia through technology transfer and human resource development. A collaboration system in which technology-oriented countries provide technology and resource-oriented countries provide resources is effective in solving mutually common problems. In other words, avoidance of food crisis, escape from hunger and poverty, and promotion of regional economy bring regional peace keeping and its stability. Agricultural policy is not about providing farmers with financial support to increase their income. It is more important to have a policy to strengthen the agriculture industry rather than supporting farmers. If such a policy is continued, there can be no promotion of agriculture. In Japan, a rice production control policy was implemented for half a century, but, as a result of that, agriculture has declined significantly rather than being promoted. Although the aging of farmers will come sooner or later, looking down on the agriculture industry has brought about a serious situation where young successors are not interested in continuing in that sector. Given that industry is production-based, production control is not an option. Rather, the basic principle is to focus on developing new markets and increasing consumption.

Food is an indispensable resource for human survival, and the prosperity of agriculture-based Asia is important and necessary not only for Asia, but also for the world. The IT based high-tech agriculture provids the opportunity for many kinds of industries to join and invest in agriculture.

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Identification of Multilinear Forms Using Combinations of Adaptive Algorithms

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***Abstract*—The tensor-based adaptive algorithms represent useful tools for the identification of linearly separable systems. These algorithms are designed in the framework of multilinear forms and exploit the decomposition of rank-1 tensors. In this paper, we outline the idea of using different adaptive algorithms (with different performance features) for the individual filters, which represent the components of a rank-1 tensor. In this context, the global scheme based on such combinations could inherit some of the advantages provided by each category of algorithms, e.g., fast convergence rate and low computational complexity.**

***Index Terms*—adaptive filter; multilinear forms; least-mean-square (LMS) algorithm; recursive least-squares (RLS) algorithm; tensor decomposition**

I. Introduction

Many important system identification problems can be efficiently solved using adaptive filters [1]. The real-time features of these signal processing tools are advantageous especially in time-varying environments. In this context, the performance criteria mainly target fast convergence rate, accurate estimation, and low computational complexity.

A more challenging scenario appears in the framework of Multiple-Input Single-Output (MISO) systems. The adaptive filters developed for this purpose should cope with the existence of a large parameter space. However, some of these problems can be formulated in terms of linearly separable systems. Such an approach can be exploited in different applications, like array beamforming, nonlinear acoustic echo cancellation, channel equalization, and source separation, e.g., see [2] and the references therein.

In this context, the tensor-based adaptive filters [2] represent efficient solutions. These adaptive algorithms rely on the decomposition of rank-1 tensors, while the global solution results using a combination of shorter adaptive filters. As shown in [2], the tensorial approach can be applied using the classical adaptive algorithms, e.g., the Least-Mean-Square (LMS) and the Recursive Least-Squares (RLS).

In this work, we explore the idea of using different adaptation modes for the individual filters, aiming to inherit the advantages of each category of algorithms. In other words, the RLS algorithm is used for its fast convergence rate (paid by a higher computational amount), while the normalized LMS (NLMS) algorithm owns the low-complexity feature.

Following this introduction, Section II briefly presents the multilinear framework, while Section III describes the adaptive algorithms and their combination. An experimental result is provided in Section IV, followed by a conclusion in Section V.

II. Identification of Multilinear Forms

In the framework of a real-valued MISO system, the output signal (at discrete-time index n) is defined as

$$y(n) = \sum_{l_1=1}^{L_1} \sum_{l_2=1}^{L_2} \cdots \sum_{l_N=1}^{L_N} x_{l_1 l_2 \ldots l_N}(n) h_{1,l_1} h_{2,l_2} \cdots h_{N,l_N}, \tag{1}$$

where $\mathbf{h}_i = [h_{i,1} \ h_{i,2} \ \cdots \ h_{i,L_i}]^T$ are N individual channels, each one of length $L_i, \ i = 1, 2, \ldots, N$, and the superscript ^{T} denotes the transpose operator. The input signals can be described in the tensorial form $\boldsymbol{\mathcal{X}}(n) \in \mathbb{R}^{L_1 \times L_2 \times \cdots \times L_N}$, having the elements $(\boldsymbol{\mathcal{X}})_{l_1 l_2 \ldots l_N}(n) = x_{l_1 l_2 \ldots l_N}(n)$. Thus, the output signal from (1) becomes

$$y(n) = \boldsymbol{\mathcal{X}}(n) \times_1 \mathbf{h}_1^T \times_2 \mathbf{h}_2^T \times_3 \cdots \times_N \mathbf{h}_N^T, \tag{2}$$

where $\times_i, \ i = 1, 2, \ldots, N$ denotes the mode-i product. As we can notice, $y(n)$ is a multilinear form, since it is a linear function of each $\mathbf{h}_i, \ i = 1, 2, \ldots, N$, when the other $N-1$ components are fixed.

Let us consider the rank-1 tensor $\boldsymbol{\mathcal{H}} \in \mathbb{R}^{L_1 \times L_2 \times \cdots \times L_N}$, with the elements $(\boldsymbol{\mathcal{H}})_{l_1, l_2, \ldots, l_N} = h_{1,l_1} h_{2,l_2} \cdots h_{N,l_N}$, such that

$$\boldsymbol{\mathcal{H}} = \mathbf{h}_1 \circ \mathbf{h}_2 \circ \cdots \circ \mathbf{h}_N, \tag{3}$$

where $\circ$ denotes the outer product. In addition, we have

$$\text{vec}(\boldsymbol{\mathcal{H}}) = \mathbf{h}_N \otimes \mathbf{h}_{N-1} \otimes \cdots \otimes \mathbf{h}_1, \tag{4}$$

where $\text{vec}(\cdot)$ is the vectorization operation and $\otimes$ denotes the Kronecker product. Hence, we can rewrite (1) as

$$y(n) = \text{vec}^T(\boldsymbol{\mathcal{H}}) \, \text{vec}[\boldsymbol{\mathcal{X}}(n)]. \tag{5}$$

Furthermore, we can denote $\mathbf{x}(n) = \text{vec}[\boldsymbol{\mathcal{X}}(n)]$ and $\mathbf{g} = \text{vec}(\boldsymbol{\mathcal{H}})$. Here, $\mathbf{x}(n)$ is the input vector of length $L_1 L_2 \cdots L_N$ and $\mathbf{g}$ plays the role of a global impulse response (of the same length). Therefore, (1) finally becomes

$$y(n) = \mathbf{g}^T \mathbf{x}(n), \tag{6}$$

while the reference signal usually results as

$$d(n) = \mathbf{g}^T \mathbf{x}(n) + w(n), \tag{7}$$

where $w(n)$ is the measurement noise, which is uncorrelated with the input signals. The main goal is the identification of the global system $\mathbf{g}$. Equivalently, the identification problem can be formulated in terms of recursively estimating the individual components $\mathbf{h}_i, \ i = 1, 2, \ldots, N$.

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III. Combinations of Adaptive Algorithms

Let us consider the estimated impulse responses of the channels, $\widehat{\mathbf{h}}_i(n),\ i = 1, 2, \ldots, N$, and the estimated output, $\widehat{y}(n)$, such that the error signal result in N equivalent ways:

$$e(n) = d(n) - \widehat{y}(n) = d(n) - \widehat{\mathbf{h}}_i^T(n-1)\mathbf{x}_{\widehat{\mathbf{h}}_i}(n), \quad (8)$$

for $i = 1, 2, \ldots, N$, where

$$\mathbf{x}_{\widehat{\mathbf{h}}_i}(n) = \Big[\widehat{\mathbf{h}}_N(n-1) \otimes \widehat{\mathbf{h}}_{N-1}(n-1) \otimes \cdots \otimes \widehat{\mathbf{h}}_{i+1}(n-1)$$
$$\otimes \mathbf{I}_{L_i} \otimes \widehat{\mathbf{h}}_{i-1}(n-1) \otimes \cdots \otimes \widehat{\mathbf{h}}_2(n-1) \otimes \widehat{\mathbf{h}}_1(n-1)\Big]^T \mathbf{x}(n),$$

with $\mathbf{I}_{L_i},\ i = 1, 2, \ldots, N$ denoting the identity matrices of sizes $L_i \times L_i$. Using a multilinear optimization strategy based on the mean-squared error (MSE) criterion, the updates of the N adaptive filters result in

$$\widehat{\mathbf{h}}_i(n) = \widehat{\mathbf{h}}_i(n-1) + \mu_i(n)\mathbf{x}_{\widehat{\mathbf{h}}_i}(n)e(n), \quad (9)$$

where $\mu_i(n),\ i = 1, 2, \ldots, N$ are the step-size parameters, while the estimate of the global filter is obtained as

$$\widehat{\mathbf{g}}(n) = \widehat{\mathbf{h}}_N(n) \otimes \widehat{\mathbf{h}}_{N-1}(n) \otimes \cdots \otimes \widehat{\mathbf{h}}_1(n). \quad (10)$$

In nonstationary environments, it is advantageous to follow the line of the NLMS algorithm. In this context, the step-size parameters of the tensor-based NLMS (NLMS-T) algorithm are obtained as $\mu_i(n) = \alpha_i / \left[\delta_i + \mathbf{x}_{\widehat{\mathbf{h}}_i}^T(n)\mathbf{x}_{\widehat{\mathbf{h}}_i}(n)\right]$, with $i = 1, 2, \ldots, N$, where $0 < \alpha_i \leq 1$ are the normalized step-sizes and $\delta_i > 0$ are the regularization constants.

Alternatively, we can apply the least-squares (LS) error criterion [1] in the context of (7) and (8). Thus, the cost functions can be formulated in N alternative ways, following the optimization procedure of the individual impulse responses, Furthermore, the minimization of these cost functions with respect to $\widehat{\mathbf{h}}_i(n),\ i = 1, 2, \ldots, N$ leads to a set of normal equations, which result in the updates of the individual filters:

$$\widehat{\mathbf{h}}_i(n) = \widehat{\mathbf{h}}_i(n-1) + \mathbf{k}_i(n)e(n),\ i = 1, 2, \ldots, N, \quad (11)$$

where $\mathbf{k}_i(n)$ are the Kalman gain vectors and $e(n)$ is evaluated based on (8). The Kalman gain vectors are

$$\mathbf{k}_i(n) = \frac{\mathbf{R}_i^{-1}(n-1)\mathbf{x}_{\widehat{\mathbf{h}}_i}(n)}{\lambda_i + \mathbf{x}_{\widehat{\mathbf{h}}_i}^T(n)\mathbf{R}_i^{-1}(n-1)\mathbf{x}_{\widehat{\mathbf{h}}_i}(n)}, \quad (12)$$

where λ_i ($i = 1, 2, \ldots, N$) are the individual forgetting factors. Finally, the matrix inversion lemma [1] is used to update the matrices $\mathbf{R}_i^{-1}(n)$, i.e.,

$$\mathbf{R}_i^{-1}(n) = \frac{1}{\lambda_i}\left[\mathbf{I}_{L_i} - \mathbf{k}_i(n)\mathbf{x}_{\widehat{\mathbf{h}}_i}^T(n)\right]\mathbf{R}_i^{-1}(n-1), \quad (13)$$

for $i = 1, 2, \ldots, N$. Summarizing, the tensor-based RLS (RLS-T) algorithm is defined by the relations (11)–(13).

In order to take advantage of the particular features of the algorithms, we propose a combination of adaptive filters that uses the RLS-T for the longest filter, while the rest of them are updated as in the NLMS-T algorithm. In this way, the resulting algorithm (namely RLS-NLMS-T) would inherit the fast convergence features of the RLS-T algorithm, while reducing the overall complexity due to the $N-1$ filters that are based on the NLMS-T algorithm.

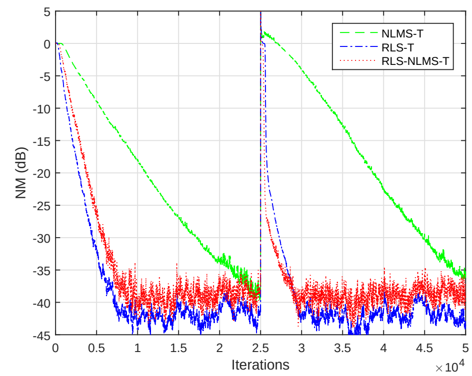

Figure 1. NM of the NLMS-T, RLS-T, and RLS-NLMS-T algorithms.

IV. Experiment

In the following experiment, the input signals are AR(1) processes, which are generated by filtering white Gaussian noises through a first-order system with the pole 0.99. The additive noise $w(n)$ is white and Gaussian, with the variance equal to 0.01. The order of the system used in the experiments is $N = 4$, while the individual impulse responses $\mathbf{h}_i,\ i = 1, 2, \ldots, N$ are generated as in [2], but using $L_1 = 32$, $L_2 = 8$, and $L_3 = L_4 = 4$. Thus, the global impulse response $\mathbf{g}$ has the length 4096. The performance measure is the identification of the global impulse response using the normalized misalignment $\text{NM}\left[\mathbf{g}, \widehat{\mathbf{g}}(n)\right] = \|\mathbf{g} - \widehat{\mathbf{g}}(n)\|_2^2 / \|\mathbf{g}\|_2^2$, where $\|\cdot\|_2$ is the Euclidean norm. In Figure 1, the main parameters of the algorithms are set to $\alpha_i = 0.25$ and $\lambda_i = 1 - 1/50L_i$, for $i = 1, 2, \ldots, N$. As we can notice, the RLS-T and RLS-NLMS-T algorithms perform very similar, in terms of the convergence rate/tracking and misalignment.

V. Conclusion

In this work, we have explored the idea of using a combination of adaptive filters for multilinear forms. The proposed RLS-NLMS-T algorithm achieves a fast convergence rate, while having a lower computational complexity as compared to the RLS-T algorithm. Future works will investigate computationally efficient versions of the RLS-NLMS-T algorithm, which could be based on the coordinate descent iterations [3].

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