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DESIRABLE WORLD WITH CPS AND IOT

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Abstract- The desirable world in the future is undoubtedly the world in which the Virtual World and the Physical World interact in any field. In today's world, the communication of the virtual and physical world is applied in many areas. The communication of the virtual and physical world means Cyber Physical Systems. In the future, these systems will be further developed and will help to realize the desirable world with the help of many other technologies. These ancillary technologies, especially Artificial Intelligence, Autonomous Robots, Digital Twin Technology, etc. can be. One of the most important technologies is the Internet of Things, which is one of the main components of the Cyber Physical System. Thus, the joint application of CPS and IoT promotes and will continue to promote high-quality development. The article discusses the concept of the IoT and CPS. However, the main differences between them were noted, as well as some of the areas in which these two technologies are used together. Finally, some examples have been considered.

Keywords: Cyber Physical Systems, Internet of Things, Society 5.0, Virtual World, Physical World, Smart Cities, Digital Twins, Smart Factory, Autonomous Robots.

1. INTRODUCTION

Because of technological development, the transition from the physical world to the virtual world is accelerating with each passing day. According to the statistics, today 65.6% of the world has access to the Internet. And this percentage is undoubtedly growing every day. Technological development is reviving not only the virtual world, but also the physical world in digital form. People entrust much of their work to technology. Although the pros and cons of technological development are the subject of discussion by experts, it is no longer possible to stop this development. In this regard, people should simply try to adapt to the times. Therefore, they should make the Internet a part of their way of life. Although more than half of the population of world will do so, about 30 percent will no doubt continue to do so.

Technologies presented to people by recent technological developments: CPS and IoT. Although the periods of emergence (CPS-2006, IoT-1980s) are somewhat distant, the years of development and widespread application allow us to mark them among the new technologies of the period.

Recently, joint projects of CPS and IoT have been of great interest. This aspect is the main essence of a scientific article. Note: Hierarchically, first the basics for a CPS | IoT program are outlined. After the foundations, the areas of application are noted. After that, examples are noted. Thus, the technologies mentioned as an example depend on these foundations, are create on its basis and are apply in the mentioned areas. Of course, it is clear that without exemplary technologies, their use in these areas will not be possible. And those areas cannot develop in this direction. In this regard, the areas of application and examples should be interdependent.

Finally, the last layer is experiments and tests, which depend on all three previous layers.

2. CYBER PHYSICAL SYSTEMS AND THE INTERNET OF THİNGS - MAIN DEFINITIONS

As part of a joint project on CPS and IoT, let's look at the basic concepts of these two terms:

2.1. Cyber Physical Systems (Definition)

CPS are systems that connect the physical world with the virtual processing world. CPS have different components. These components include modern preventive information technologies.

In other words, CPS collects information in the real (physical) world, analyzes this information using digital technology in the virtual (cyber) world, facilitates the use of information and knowledge, and returns that information to the physical side to create added value [1].

In a cyber physical system, various information in the real world (physical space) is collected by IoT devices and processed and analyzed in the virtual world (cyberspace) [2].

CPS can be encountered in many areas to some extent. Mainly on the eve of the 4th industrial revolution, CPS began to be applied in production and other fields. For example, the leading areas where CPS is applied are: aviation, automotive industry, chemical processes, civil infrastructure, energy, health, manufacturing, transport, entertainment and consumer goods, etc.

2.2. Internet of Things (Definition)

"It would be even more useful if one smart device was connected to another smart device." This idea is a transition to the concept of the Internet of Things in a broad sense. That is, the Internet of Things is an ecosystem created by the interaction of smart devices. In other words, "the Internet of Things is not necessary for the existence of smart devices, but smart devices are necessary for the existence of the Internet of Things. Rather, smart devices with Internet access and even artificial intelligence are key factors in the availability of this technology."

The Internet of Things (or IoT for short) is an environment where objects, each with a unique identifier, can send information over a network. There is no need for a human-to-human or human-computer relationship to exchange this information. The Internet of Things is created by combining wireless technologies, micro-electronic systems and the Internet. Therefore, this concept can be called the "Internet of Everything".

3. MAIN DIFFERENCE BETWEEN CYBER PHYSICAL SYSTEMS AND INTERNET OF THINGS

Cyber Physical System is a system that provides communication between the virtual world and the physical world. Simply put, this system aims to act as a bridge between the world with the Internet and the world without the Internet. It is clear that this system consists of two parts: the virtual world (with Internet) and the physical world (without the Internet).

Here, given that the term Internet of Things refers to the virtual world, we can note that the Internet of Things is one of the subsystems of the Cyber Physical System. At this point, the idea may arise that "if a system is a subsystem of another system, many of the characteristics of the underlying system will also exist in the subsystem. In fact, all the features of the subsystem will belong to the main system and there will be no difference between them". However, along with the similarities between CPS and IoT, there is a fundamental difference. And this difference is the main factor that separates these two technologies.

We can note this difference as follows:

Internet of Things - guarantees that any smart device with Internet access is part of the Internet of Things Ecosystem. In other words, any smart device with Internet access can create an Internet of Things Ecosystem. This is the basis of Internet of Things technology.

Cyber Physical Systems - unlike the IoT, one of its main goals is to make not only devices with Internet access, but also devices without the Internet interact with each other.

It is this factor that makes the fundamental difference between CPS and IoT.

4. A JOINT PROJECT OF CYBER PHYSICAL SYSTEMS AND THE INTERNET OF THINGS

Although the IoT is a subsystem of Cyber Physical Systems, joint projects are being implemented. In the virtual world of cyber physical systems, smart devices need an Internet of Things Ecosystem to interact.

We can consider a joint project of CPS and the Internet of Things - "CPS | IoT program". In general, we can present the hierarchy of this joint project as follows:

Foundations → Areas of application → Examples → Experiments and Tests (Far Eastern Practices)

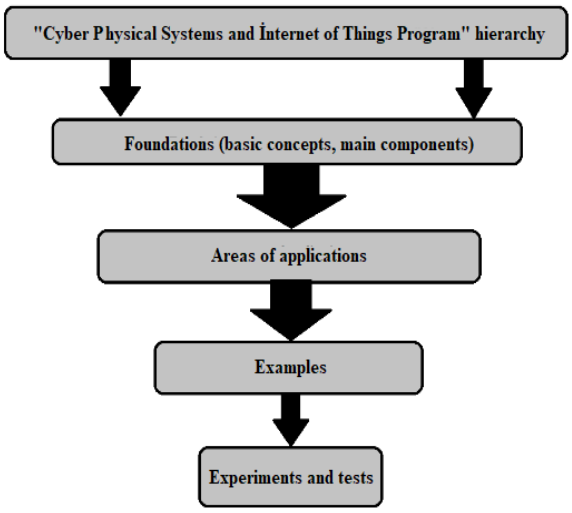

Figure 1. "CPS | IoT program" hierarchy CPS | IoT program hierarchy

4.1. Foundations (Basic Concepts, Main Components)

The Cyber Physical System generally includes many subsystems. These subsystems can be called the foundation of CPS. However, it is possible to describe in more detail the foundation of CPS, which includes concepts that include these subsystems, as shown below.

The components that make up the foundations of CPS are as follows.

- Foundations of CPS: [3]

✓ *Applied computing*
✓ *Computers in other domains*
✓ *Organization of the computer systems*
✓ *Cyber-physical systems and embedded systems*
✓ *Real-time systems*
✓ *Computing methodologies*
✓ *Simulation and modeling*
✓ *Model development and its analysis*
✓ *Theory of computation*
✓ *Logic*
✓ *Models of computation etc.*

We can also note the following for the Internet of Things.

- Foundations (or main components) of IoT [4]

✓ *Smart devices*
✓ *Hub*
✓ *Cloud*
✓ *Remote device management*
✓ *Remote software update etc.*

4.2. Areas of Application

CPS and IoT are applied in many areas where smart technologies are available. Some of these areas can be described in Figure 2.

Figure 2. Cyber Physical Systems (CPS) and Internet of Things (IoT) application areas

4.3. Examples

The recent combined use of CPS and IoT technologies has led to the development of many systems in which they are shared. Within the main topic of the article, the main examples of the joint project of CPS and IoT can be noted in Figure 4.

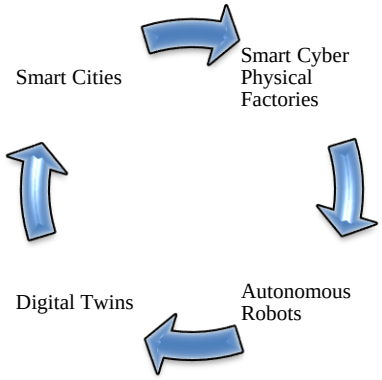

Figure 3. Basic application examples of CPS and IoT

4.4. Smart Cyber Physical Factories

Industry is perhaps one of the main areas in which the virtual world and the physical world work together. Smart factories are an example of this. The foundation of smart factories is the connection between human work and machine work.

While man represents the physical world, the machine represents the virtual world. In this regard, smart factories are one of the areas of use for CPS and IoT, especially in the general industry.

In smart factories where smart technologies (devices) are applied, it is possible to establish communication between such devices, exchange information with each other, and so on. The IoT ecosystem is a must for factors such as on the other hand, IoT-based CPS is important for the proper relationship between machine and human.

A smart factory is an IT-based factory.

The smart factory collects information such as factory equipment and work content, making full use of IoT. By transmitting the analyzed data to in-house and out-of-factory systems and to the head office, it is possible to optimize production efficiency and provide high quality products.

The smart factory was first proposed in Germany. In Germany, based on the concept of "factory, thinks of efficiency", there is a practical use of factories that provide equipment that can connect to the Internet [10].

On the other hand, Japan, one of the countries of the Far East, offers the concept of "Connected Industries". Connected Industries is an initiative similar to Industry 4.0 in Germany. The concept aims to further reduce the burden on humans by transferring labor power from humans to robots using the Internet [12].

Implementing smart cyber physical factories is a rather difficult process. Because these systems are expensive. Nevertheless, many economically developed countries are investing heavily in this area. There are several reasons for this as example:

✓ Smart factories are expected to solve the shortage of workers by replacing manual work with machines such as robots.

✓ It is possible to reduce costs by reducing energy consumption and increasing work efficiency by optimizing work [9].

However, it should be noted that smart factories may not show results immediately after presentation [11]. Of course, this factor applies to every new project used.

4.5. Autonomous Robots

Robot technology has been evolving for a long time. It is known that robots are somewhat dependent on humans. Of course, unlike the initial versions. One of the most notable technologies of recent times is autonomous robots.

Autonomous robots belong to the category of developing devices, including unmanned aerial vehicles (aerial robots) that can be programmed to perform tasks without human intervention or interaction [10].

Like a human, a robot that will move instead of a human. Although this sounds a bit different, the idea that robots will completely replace human workers in the near future is still relevant.

However, if we look at the current era, such robots are expected to be useful in places where people cannot enter in a disaster, or to overcome labor shortages. If robots try to perform even simple and unconscious actions for humans, they will be a very advanced technology [3].

Another feature of autonomous robots is that they can think and cooperate on their own. For example, for large loads that a robot cannot carry, more than one robot must work together to move the load and move in the same direction. Such a situation requires learning to "cooperate" in order to communicate with other robots [6].

Autonomous robots are expected to play an active role in various areas such as the service industry, healthcare and education.

It is expected that autonomous robots will be used more in smart hospitals, which will be widely used in the future. Autonomous robots can be used for various purposes in healthcare. The robot as a medical assistant, as a cleaning robot, and so on.

Autonomous robots can be more useful by interacting with other technologies (such as Big Data). Robot doctor assistants, replacing human medical assistants, allow the

doctor to visit the patient, examine, and so on. may accompany the doctor in such cases. In other cases, the robots can be used in patient rooms, dormitories, etc. can also perform the cleaning process [11].

Two concepts related to autonomous robots can be confused with each other: Self-contained and autonomous robots. Robots belonging to these two categories are somewhat different from each other. In this regard, we can look the description of Figure 4.

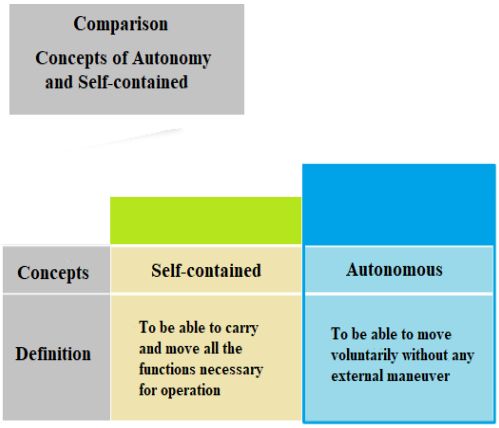

Figure 4. Comparison of "Self-contained" and "Autonomous" robot concepts [16]

In other words, a robot that can move without receiving energy from the outside, as well as a robot that thinks and makes decisions on its own, seems to be called an "autonomous robot." [6].

Robots can vary significantly in size, functionality, mobility, agility, artificial intelligence, and cost, from process automation to high-quality imaging and data-gathering aircraft.

Autonomous robots are expected to evolve over the next five years, especially within supply chain operations involving lower-cost, potentially hazardous, or high-risk tasks [4]. In other words, autonomous robots are expected to be further developed in the future and will help such people in many areas, even in everyday life.

4.6. Digital Twins

Digital twins are a technology that creates a twin (copy) of any being in the physical space, based on the information it receives from the physical space [5]. This technology is one of the most important concepts for CPS because it acts as a bridge between the physical world and the virtual world.

The construction of factories and manufacturing facilities, in all areas, such as urban planning, increases the physical space in the digital space, refers to the whole mechanism that performs simulation, analysis and optimization in advance, and returns it to the physical space [8].

Working Principle of Digital Twins Technology - First, intelligent components that use sensors to gather information about a real-time situation, working condition, or position are combined with a physical substance. The components are connected to a cloud-based system that receives and processes all the information tracked by the sensors. This input is then analyzed with case studies and other contextual information [8].

Examples of technologies that make up digital twins [9, 10]:

- Product Design / Product Information Management: CAD / PLM (Product Lifecycle Management)
- Product Simulation Engineering: CAE (Computer Support Engineering)
- Factory / Production Line Simulation: 3D Factory / Plant Simulation Software
- Returning digital data to physical space with 3D information: AR (augmented reality) / VR (virtual reality)
- Sending physical space data to digital space: AI / 3D scan

4.7. Smart Cities (Smart Home, Smart Grid)

The Smart City system is one of the key technological innovations hosted by IoT and CPS. There are many different systems within smart cities. Smart homes, smart transportation, smart healthcare, smart management, smart store chains and more. The interconnectedness of smart devices within the Smart City, the availability of not only machine-to-machine but also human-machine connections, is a particular impetus for the development of IoT Ecosystem and CPS.

If we consider the smart city as a single research object, we can take a closer look at what can be done with IoT and CPS:

First of all, it should be noted that creating an ideal ecosystem for any infrastructure, especially for large spaces such as smart cities, consists of 4 main factors:

- ❖ Cyber Physical Systems,
- ❖ Internet of Things,
- ❖ Cloud Computing (cloud service)
- ❖ Artificial intelligence

In terms of the function and structure of the ICT system that builds a smart city, it can be said that it is the "Cyber Physical System (CPS)" itself. CPS is a system that optimizes activities in real space by collecting and analyzing information in virtual space that reflects the state and movement of real space, such as residential areas and streets. In addition to various data terminals, IoT devices must be used to collect data. Big Data analysis using cloud or artificial intelligence (AI) is required for analysis and optimization in virtual space. In addition, a data terminal is required to receive the analysis results and provide some information to the residents. In the future, control data will be transferred to infrastructure equipment, self-propelled (driverless) cars, robots, etc. will be returned and will become an autonomous system that operates optimally according to the conditions and movements of the city.

4.8. Experiments and Tests: Applied Models

Many countries use CPS and IoT technologies in a way that suits their economies and conditions. In this regard, let's look at several models in which CPS and IoT are applied. One of these models is the Digital Twins technology we mentioned earlier. Digital twin technology can also act as a bridge between the physical and the virtual worlds. Thus, a virtual model of any object is created by entering data.

One of the areas where digital twin technology is applied is the construction sector. Japanese company Komatsu is one of the implementers of this model. The company is doing this as part of the Smart Construction project.

Komatsu's smart machines – excavators, bulldozers and dump trucks - collect dynamic-time-based 3D geographic information about the areas where the excavations are being carried out, along with drone surveys. These data sources are used to create a Dynamic Digital Twins of the physical construction site to provide a more efficient and secure construction project.

Komatsu is currently cooperating with Cesium in this regard. Cesium provides users with a 3D platform and application to visualize and analyze virtual construction sites from anywhere in the world.

Until now, such research has been conducted manually, which was a time-consuming process. The implementation of the process within the framework of the Komatsu Smart Construction project has become much easier. This issue, which will be resolved in 4 days, can be implemented in 20 minutes.

Another model related to CPS and IoT is the use of autonomous robots. The most interesting event in this regard is a project called "Tsubuka Challenge", in other words, a challenge. The purpose of this project is to demonstrate the possibility of ensuring the coexistence of humans and autonomous robots. This project can be presented as an indicator of the main purpose of the Cyber Physical System. If the world of humans is a real (physical) world, the world of robots is a virtual world, and this project shows how advanced the interaction between these two worlds can be.

In the Tsukuba Challenge, robots are required to walk autonomously along a route 1 km or longer through a pedestrian street, park and square in Tsukuba. The Tsukuba Challenge has been held annually since 2007. In total, more than 500 teams from university laboratories, research institutes or companies are participating. Under this project, prototypes of autonomous mobile robots were developed and navigation experiments were conducted in the city to perform the given tasks. At the same time, many methods were tested to identify the necessary and effective technologies for the operation of robots in the real world, and the results of experiments and ideas for the design of robot systems were shared [7].

The Tsukuba Challenge is not a competition, but a "Challenge to Living with Robots in a Real Environment."

The Tsukuba Challenge, a very interesting project, will play a role in stimulating future development.

Another issue being studied in Japan is Cyber Physical Systems: Super City Concept and Society 5.0. KFS is also the core concept of Society 5.0, an ultra-smart city explored by Japan. Society 5.0 is a plan to bring the CPS concept to almost the entire city.

It is possible to note the following definition for Society 5.0:

Society 5.0 - A human-centered society that balances economic development through the solution of social problems through a system that combines cyberspace and physical space at a high level. This definition explains the main purpose of the Society 5.0 project.

This project was proposed in the 5th Science and Technology Master Plan as a future society that Japan dreamed of.

One of the main goals of Society 5.0 is to solve various modern social problems by incorporating innovations such as the Internet of Things (IoT), robotics, AI and big data into all industrial and social activities. To this end, intelligent technologies are being used to create a human-centered society in which everyone can live an active and enjoyable life, rather than a future controlled and monitored by artificial intelligence and robots In the context of increasing digitalization, communication and the widespread use of AI technologies, the Japanese government and the private sector have taken a number of steps related to this advanced concept. Society 5.0 can have a profound effect on societies at all areas, especially in terms of improving quality of life and sustainability.

Data-based urban planning is shaped by obtaining information from sensors installed here and there and analyzing that information in cyberspace. It will also be used to build a more conducive world, such as simplifying administrative procedures and controlling driverless cars.

Society 5.0 predicts that people's minds and behaviors will change. In such a situation, it is inevitable that the manufacturing industry will also need to change. As an ongoing Super City concept, it is important to adopt CPS with the awareness that the manufacturing industry is the leader in order not to lag behind the efforts of Society 5.0.

In general, there are many similar models of CPS and IoT in the world

5. CONCLUSIONS

The combination of CPS and IoT is common in many areas. We have looked at a few examples in this regard. These two concepts complement each other. Thus, as mentioned above, CPS acts as a bridge between the virtual world and the physical world. Moreover, it needs IoT devices to collect data from the physical world.

CPS and IoT are expect to be further develop in the near future. One of the applications of these two technologies, Smart Factories continues to be developed. It is costly to build a smart factory in a certain period, and it is not right to expect immediate results from it. Thus, many countries, such as Japan, reached the stage of virtualization in smart factories exactly 5 years ago. In addition, it should note that research in this area is still ongoing.

One of the technologies expected to be use in more areas in the future is autonomous robots. The use of these robots on a daily basis, as well as in various sectors, will facilitate human labor. Undoubtedly, robots, especially those that are less dependent on humans, are among the most loyal helpers of humans. Moreover, these loyal helpers will come to our homes and Smart Hospitals in the future. People will be able to entrust both their daily work and, in a sense, their health to these faithful helpers.

No matter how much artificial intelligence, CPS, AI or cloud services form the basis of a smart factory, it must be accepted that the human factor is as important today as smart technology. Although it is unknown whether this situation will change in the future, we must not forget that the human factor is important in any field. It would be more efficient for any intelligent machine to act as a helper than to replace a person.

Instead of the world of the future being the world of robots, it is more ideal to be a world where humans and robots can live together.

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