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Preliminary Feasibility Study for Introducing 4th Industrial Revolution Technology to Nuclear Plant

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1. Introduction

These days, the 4th industrial revolution technology widely spread out in various fields. This technology has been developing to improve safety and economy of systems including human society. In this study, the characteristics of this technology and adoptability to the nuclear power plant are feasibly examined. Although this technology has some weakness in the viewpoint of the nuclear field, it has lots of advantages to keep the plant safer and more economical. It can provide precise status information of plant to operator, make preventive maintenance, give better operational aid and eliminate human errors. In the near future, this technology will be introduced to nuclear power plant through overcoming some weakness.

2. State of Art of 4th Industrial Revolution Technologies

In this section some of the techniques used in the 4th industrial revolution are described. The widely used technologies are IoT (internet of things), big data, machine learning, deep learning network, industry 4.0 and so on.

2.1 IoT (Internet of Things)

The Internet of Things (IoT) is the inter-networking of various physical devices, other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data.[1,2] The IoT allows objects to be sensed or controlled remotely across existing networks, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit in addition to reduced human intervention. The IoT is expected to offer advanced connectivity of devices, systems, and services that goes beyond machine-to-machine communications and covers a variety of protocols, domains, and applications.

2.2 Big Data

Big data is a term for data sets that are so large or complex that traditional data processing application software is inadequate to deal with them.[3] Big data challenges include capturing data, data storage, data analysis, search, sharing, transfer, visualization, querying, updating and information privacy. Lately, the term "big data" tends to refer to the use of predictive analytics, user behavior analytics, or certain other advanced data analytics methods that extract value from data, and seldom to a particular size of data set. The characteristics of big data are high-volume, high-velocity and/or high-variety information. Also, big data uses inductive statistics and concepts from nonlinear system identification to infer laws (regressions, nonlinear relationships, and causal effects) from large sets of data with low information density to reveal relationships and dependencies, or to perform predictions of outcomes and behaviors.

Fig. 1. Architecture of IoT

2.3 Machine Learning

Machine learning is a type of artificial intelligence (AI) that allows to infer outcomes without being explicitly programmed. The basic premise of machine learning is to build algorithms that can receive input data and use statistical analysis to predict an output value within an acceptable range.

Machine learning tasks are typically classified into three categories, depending on the nature of the learning relationships between inputs and outputs. These are;

- Supervised learning: The system is presented with example inputs and their desired outputs, given by experts, and the goal is to learn a general rule that infer inputs to outputs.

- Unsupervised learning: No labels are given to the learning algorithm, leaving it on its own to find structure in its input. Unsupervised learning can be used to discover hidden patterns in data or a means towards a feature.

- Reinforcement learning: A computer program interacts with a dynamic environment in which it must perform a certain objective such as winning a game or safe operation of system. The program is provided feedback in terms of values to obtain better solutions in the system.

Fig. 2. Concept of big data

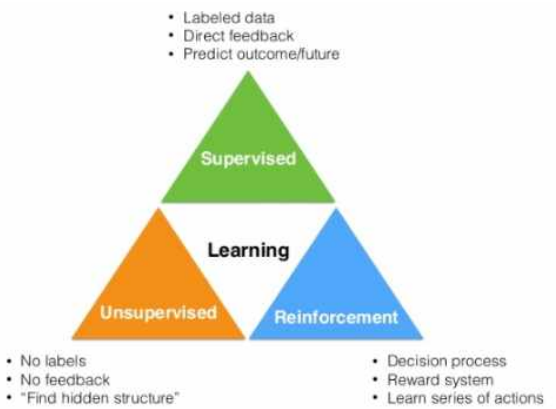

Fig. 3. Three categories of machine learning

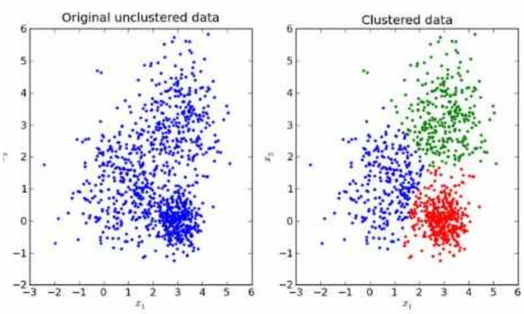

Fig. 4. Unsupervised learning result (clustering)

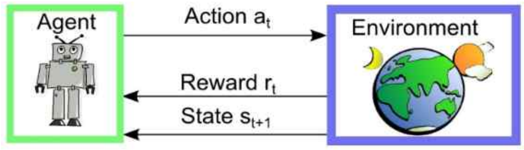

Fig. 5. Reinforcement learning algorithm

2.4 Deep Learning

Deep learning is a new neural model which overcomes the learning problems of old neural networks and a class of machine learning algorithms that use a cascade of many layers of nonlinear processing units for feature extraction.[4] Each successive layer uses the output from the previous layer as input. The algorithms may be supervised or unsupervised and applications include pattern analysis (unsupervised) and classification (supervised). Deep learning was developed to overcome old neural model such as convergence, over-fitting, computing cost etc.

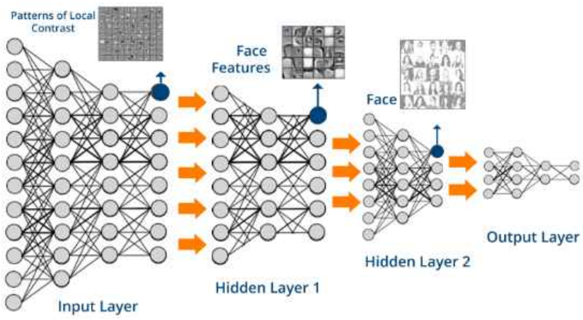

Fig. 6. Face recognition using Deep Networks

2.5 Industry 4.0

Industry 4.0 is a best example using 4^{th} industrial revolution technology in the plant and presented in Germany. Industry 4.0 is defined as the digital transformation of manufacturing such as big data, IoT and OT (Operational Technology), robotics.[5] Otherwise, it is a the information-intensive transformation of manufacturing in a connected environment of data, people, processes, services, systems and production assets with the generation, leverage and utilization of actionable information. There are 4 design principles:

- Inter-operability: The ability of machines, devices, sensors, and people to connect and communicate with each other.

- Information transparency: The ability of information systems to create a virtual copy of the physical world by enriching digital plant models with sensor data.

- Technical assistance: The ability of assistance systems to support humans by aggregating and visualizing information comprehensibly for making informed decisions and solving urgent problems on short notice.

- Decentralized decisions: The ability of cyber physical systems to make decisions on their own and to perform their tasks as autonomously as possible. Only in the case of exceptions, interferences, or conflicting goals, are tasks delegated to a higher level.

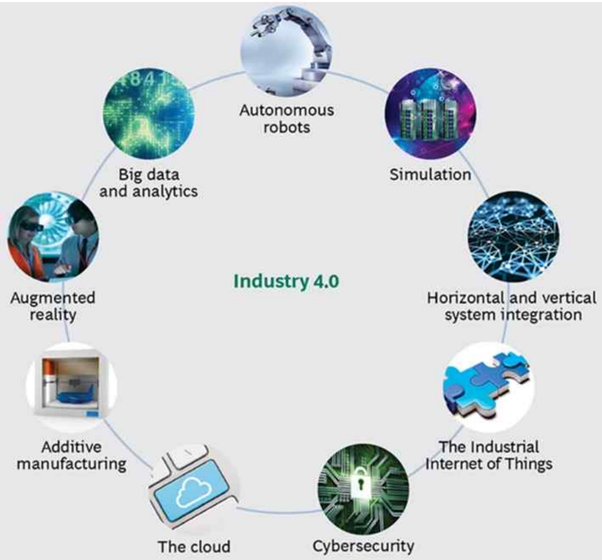

Fig. 7. Configuration of industry 4.0

3. Adopting 4th Industrial Revolution Technology for Nuclear Power Plant

The nuclear power plant should be changed by adopting the new technologies to improve the safety, economy and public acceptance. By adopting 4th industrial revolution technologies to a nuclear power plant, lots of strength can be obtained as followings:

- More precise status identification of plant in real time in all conditions of plant including normal, abnormal, accident and severe accidents by using big data with machine learning and cyber physical system.
- Safe accident mitigation even if some sensors or equipment are failed through guiding better success path using sound sensors and equipment by inference with machine learning with big data.
- Better operator aid with big data and machine learning to keep the plant safe and efficient by making appropriate safety measures during accident.
- Predictive maintenance to keep healthy condition of equipment and to eliminate the possibility of advertent incidents and accidents.
- Improvement of both safety and economy which are contradictory to each other in current technologies.
- Elimination of human errors through autonomous operation.

However, there are some weaknesses of 4th industrial revolution technology in the viewpoint of the nuclear power plant as followings:

- Some new sensors to examine the status of equipment and plant.
- Needs for more complicated and dependable network systems to introduce IoT to nuclear power plant.
- Design changes to introduce cloud, fog and edge computing system for efficient operation of the plant in real time
- Verification and validation of machine learning algorithms because most of current machine learning algorithms are based on the statistical processing. These are less deterministic techniques which must be required in the nuclear field.

  - Completeness of training in the viewpoint of convergence of machine learning including over-, under-fitting possibility of machine learning.
- Problems of cyber security and physical protection of the plant. Sometimes these characteristics can be strength with appropriate administrative procedures.
- Difficulties to set up redundant and diverse features.

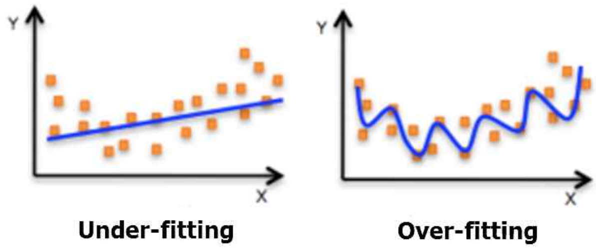

Fig. 8. Fitting Problem

3. Conclusions

In this study, current status of art of 4th industrial revolution technology and the strength and weakness of its technology when introducing them to the nuclear power plant. Although the current 4th industrial revolution technology has some weakness, they are widely used and being developed in various industrial fields and society to improve safety and economy. Therefore they may be introduced to the nuclear field in the near future by overcoming some weakness through further studies related to the licensing requirements in the nuclear industry.

REFERENCES

[1] "Internet of Things (IoT)". gatewaytechnolabs.com.

[2] "Internet of Things Global Standards Initiative". ITU. Retrieved 26 June 2015.

[3] Mayer-Schöberger, V., & Cukier, K. Big data: a revolution that will transform how we live, work and think. London: John Murray, 2013.

[4] David Silver, "Mastering the game of Go with deep neural networks and tree search,"

[4] David Silver et al, "Mastering the game of Go with deep neural networks and tree search," nature, Vol. 529, 28, Jan., 2016.

[5] https://en.wikipedia.org/wiki/Industry_4.0.