A model of Cyber Physical System for Smart Machine

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Abstract- As requirements of manufacturing industries continue to grow, whether for electrical systems or mechanical systems, improved mechanical efficiency must be found. Integration of computing, network and physical process, or so called Cyber Physical System (CPS) is proposed way of managing an industry. This paper describes a model of CPS in traffic management system in detail. It also provides basic information about the basic structure, standards, applications and some recent developments in CPS. . The paper also presents a detailed analysis of a CPS implemented in a bending machine. A model is established to propose the solution to improving efficiency and lifespan of a bending machine. The research results are very important for future works that might upgrade industries to Industry 4.0.

Index Terms- Cyber physical system, Industry 4.0, Smart sensors, Bending machine

I. Introduction

Competition in machine development has been taking place all over the world. Interconnection between information has been blooming in a skyrocketing rate, which has a major affect in development of an industrial environment. At this rate, forecasting of the world development is uncertain. Artificial Intelligence (AI) which has just been flourishing is completely astounding as it has given the scientists and engineers a new view point towards machines. In Industry 4.0, sensors, machines, work pieces, and IT systems will be connected along the value chain beyond a single enterprise. This connected system is Cyber Physical System (CPS). Versatile results can be expected with the innovation of AI and CPS.

The performance boundary of a bending machine is ever expanding, and the components involved in the bending are no exception. So, use of CPS in a manufacturing system helps to attain the maximum performance of a system. The term CPS refers to a new generation of systems with integrated computational and physical capabilities that can interact with humans through many new modalities [1].
These connected systems can interact with one another using standard Internet-based protocols and analyze data to predict failure, configure themselves, and adapt to changes. Industry 4.0 makes it possible to gather and analyze data across machines, enabling faster, more flexible, and more efficient processes to produce higher-quality goods at reduced costs. [2] The advantages of Industry 4.0 are: increase in manufacturing productivity, shift in economics, foster in industrial growth, and modification of the profile of the workforce—ultimately changing the competitiveness of companies and regions.

The world has been through different stages in development. Firstly, it was industrial revolution, which is regarded as steam power and hydroelectric technology, the second revolution was regarded as a technology of mass production with the help of electric energy, the third revolution was regarded as an electronic and IT technology for advanced automation in production. It is now expected that the 4th industrial revolution will be based on the Cyber Physical System (CPS). So, CPS is very important in development of smart machines. Smart machines are an integral part of Industry 4.0. Industry 4.0 simultaneously shows characteristics that represent the challenges regarding the development of cyber-physical systems, reliability, security and data protection [3].

Manufacturing industries get many benefits from CPS. Smart prognostics and diagnostics in CPS can help to utilize big data from different networked sensors, machines, and systems, which can improve productivity and quality. Each physical component and machine will have a twin model in cyber space. Each component and machine can predict and prevent potential failure and further with self-aware, self-predict, self-compare, and further self-reconfigure, and self-optimize for robust intelligence and performance. Both producers and academics are predominantly involved in the acquisition of significant activity related to the digitalization and intelligent of manufacturing processes [4]. All these can be attained without manual intervention.

II. Literature Review

Industry 4.0 is the concept and revolutionary idea introduced by Germany in 2011, which has created intense interest in the industry world since then. Industry 4.0 is not a single technology, but rather a combination of IoT [6], Big Data [7], Robotics, advanced

analytics [8], and Human machine interfaces [9], CPS systems [10]. It is a concept where these technologies will integrate with our existing technologies and will completely change the industrial landscape. Customers do not have to shop for hours anymore when they want to buy a product in an ideal Industry 4.0 world. The client will be able to personally design a product using the designer software of the organization, which is part of the common corporate platform [11]. The product is designed, verified, and verified by the software. The virtual image of the customized product will be sent to the 'smart' factory and built by the CPS, requiring minimal human control. Subsequent storage, logistics and after-sales customer service are part of the digitized value chain and the product status can be tracked and tracked from start to finish. [6]

According to Deloitte (2015), Industry 4.0 should have four features. [12]

- Vertical network of intelligent production system: Cyber-Physical Production Systems (CPPS) are autonomous, self-directed and self-sustaining. Information on stock levels, resource utilization rate and quality will be part of the feedback loop.
- Integration of the next generation global values chain networks: Everything is digitized until after sales support. His decision is made in real time, and elements such as quality, time and price are treated differently from our current model.
- An engineering in the chain of all values: A rapidly changing landscape, and new business synergies in value chains need to be discovered and designed.
- Acceleration with exponential technology: Emerging technologies such as artificial intelligence, nano materials, 3D printing and advanced robotics can greatly accelerate the capacity of the CPPS, making it cognitive and flexible.

CPS can lead the world to Industry 4.0. There are many papers related to defining Cyber Physical System. Wan Jiafu [5] has described CPS in relation with the intelligent machines. He has stated that CPS is an evolution of machine-to-machine (M2M) by the introduction of more intelligent and interactive operations, under the architecture of IoT. Also, the paper has demonstrated how M2M systems with the capabilities of decision-making and autonomous control can be upgraded to CPS and has identified the important research challenges related to CPS designs. Sztipanovits [13] has analyzed the challenges to integrate CPS in an industry. The major challenge in CPS integration emerges from the heterogeneity of components and interactions. The paper has also described the solutions to overcome those challenges. CPS has encouraged industries to move towards Industry 4.0. According to Lee [14], many challenges exist in designing a CPS. Lee also concluded that, based on designs that are built on today's abstractions, it is not sufficient to improve design processes, raise the level of abstraction, or verify designs. Lee [15] also says that, the relation between physical system and the cyber system can be blurry and quite complex to understand. And there is no doubt in the development and research to go wildly in the topic of CPS system. In agreement with Sha [16], the report generated by the President's Council of Advisors on Science and Technology (PCAST) has the primary focus on CPS to research and invest for federal research investment. Moreover, as presented by Derler [17], concept of relation between computer science and physical world should be clear enough to design the CPS system as this is the study of joint dynamics that sets this topic apart. In accordance with Zanero [18], our civilization has been depending more and more on the successful relation between computer science and physical world, also known as CPS, to accomplish task related to automation and control. Previous research papers of CPS have provided us with many information needed to perform this research. CPS is very important for the industries to advance to Industry 4.0. As per the researches done till now, the world is slowly advancing to Industry 4.0. However, even with increase in CPS in many industries, it is very difficult for all the industries to upgrade to Industry 4.0.

III. METHODOLOGY

Normal bending machines have no intelligence. No CPS. So here we want to define a cps for the bending machines.

3.1 A CPS for bending machine

Cyber Physical System is the next generation of embedded information and communications technology (ICT) system that is becoming widespread in every aspect of our daily life. CPS is a mechanism that is tightly integrated with the Internet and its users and is controlled or monitored by computer-based algorithms. In CPS, physical and software components are connected, each operating on different spatial and temporal scales, showing multiple and distinct behavioral modalities, and interacting with each other in many different ways.

Figure 1 A model of CPS for smart machines

As described in figure 1, smart machine tools can be used to run the entire cyber physical system. Smart machines such as cameras, machine controllers, data acquisition devices, and so on, are embedded with some communication services such as XML data model, STEP Data model and MT connect data. They are used to send the information to the smart visibility services or devices. Such smart visibility service displays Real-time machine status, Statistics report, AR-based visualization etc. All these technologies are finally used by end users such as engineers, data scientists, economists and other technological experts.

CPS is engineered system that is built from, and depends upon, the seamless integration of computational algorithms and physical components. Advancement in CPS has led to increase in capability, adaptability, scalability, resiliency, safety, security, and usability in the simple embedded systems. CPS technology is a revolution in the world. Just as the Internet has transformed the way people interact with information, advancement in CPS can also transform the way people interact with engineered systems.

Computers are embedded in many systems to monitor and control physical processes: cars, airplanes, automotive highway systems, air traffic management, etc. In the past, research on embedded systems focused on the design optimization problems of these computational devices. In recent years, the focus has shifted towards the complex synergy between the computational elements and the physical environment with which they interact. The term Cyber-Physical Systems (CPS) justifies to refer to such interactions. When embedded computation and communication devices, together with sensors and actuators of the physical system, are federated in heterogeneous, open, and systems-of-systems, the system is called Cyber Physical System. Examples of CPS include smart cities, smart grids, medical devices, production lines, automotive controllers, and robotics.

Industry 4.0 has new concepts like: Internet of Things (IoT), Industrial Internet, Cloud Based manufacturing and Intelligent manufacturing. All structures, internet and support technologies, human and machine agents, materials, products, production lines and processes, serve as the backbone to create new organizational boundaries and process the intelligent, connected and elegant value of the latest technological developments.

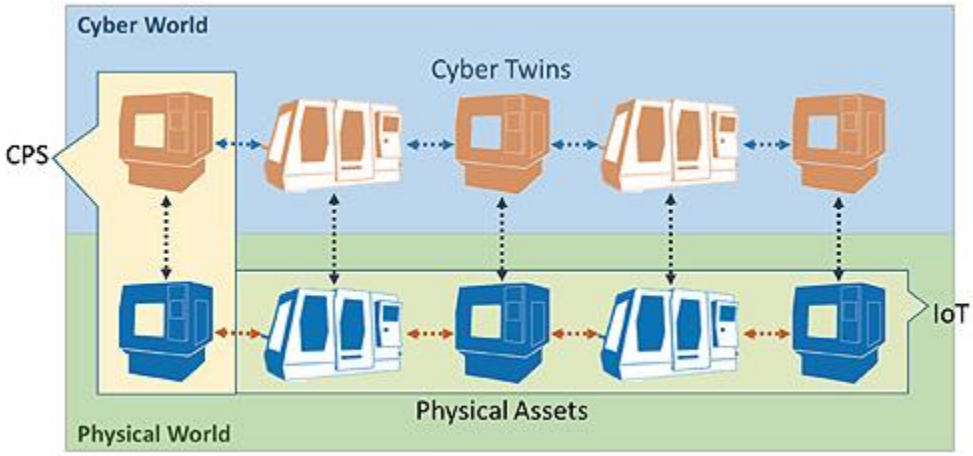

Figure 2 Cyber Physical System

Cyber Physical System can be developed by using smart sensors in smart machines. Even the traditional bending machines can be made smart by using smart sensors. According to Ralph [19], the primary objective of the bending machine is to make profile bends of variable radii or multiple radii in stock with the bending occurring in either a clockwise or counter-clockwise direction in a single operation or pass of the machine.

An embedded system consists of standalone devices for input and output. Whereas, CPS is a network of interacting elements with physical input and output. With the advancements in technology, computational and physical elements are linked by intelligent mechanisms. CPS helps to increase adaptability, autonomy, efficiency, functionality, reliability, safety, and usability of machines. CPS can be used in various tasks that seem to be impossible for a standalone device with embedded system. For example: CPS can be used in dangerous environments like fire, deep-sea, and so on. It can be used in robotics.

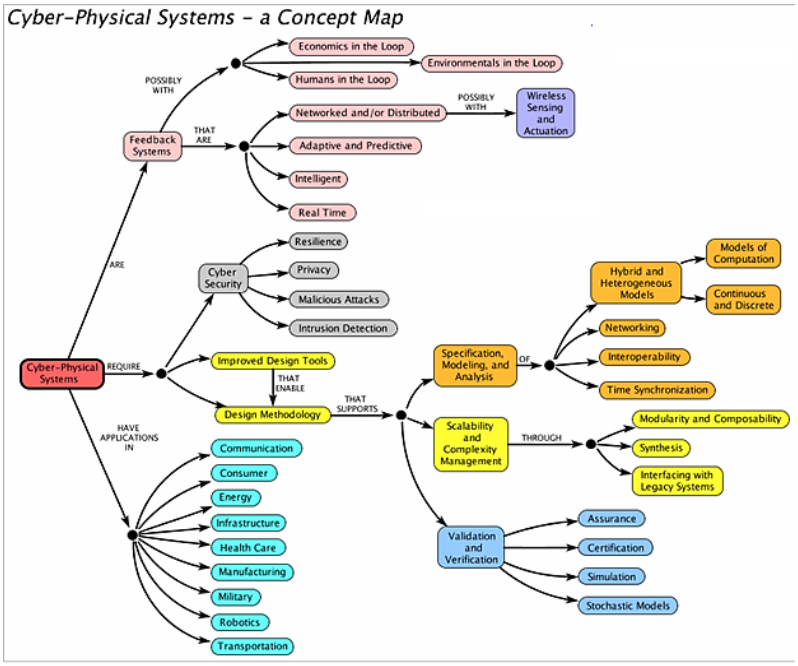

Figure 3 CPS- A Concept Map

There are large differences in the design practice between the various engineering disciplines involved, such as software and mechanical engineering. This is the challenge faced in the development of embedded and cyber-physical systems. In today's world, where rapid innovation is very important, engineers from all majors need to be able to explore system designs collaboratively, allocating responsibilities to software and physical elements, and analyzing trade-offs between them. Cyber Physical System allows all the engineers working at their respective field come together to achieve a single mission.

Use of CPS in a machine provides the user with real time outputs so that the user can take real time decisions. Embedded computers and networks monitor and control the physical processes, with feedback loops where physical processes affect computations and vice versa. CPS can be implemented to develop a smart machine. It is also an important aspect of Industry 4.0.

Use of smart sensors in machines have made machines smart. Such smart machines when linked together in a system in an industry, makes up a CPS. A bending machine also needs to be a smart one to develop a CPS of the bending machine. The paper presents a smart bending machine used in a Cyber Physical System.

IV. Case Study: Cyber Physical System in bending machines

Bending machine often consists of parts that need to be monitored once in a while. Some of them are brake fluid in a braking system, Engine oils, hydraulic fluids, air filters, engine oil filters, and so on. And when it comes to expensive machinery equipment with expensive parts, information on each part is very crucial. Cyber Physical System which has been a dominating topic in this era can play a huge role in maintaining the condition of such expensive system. Many information regarding the condition of the machinery parts might be hidden to the machine operators which in the end might result in system failure and degrade the efficiency of the entire system. CPS system can come in handy when such situation are being felt.

Challenges:
So far, bending machines or any machines used for manufacturing purposes which are similar to bending machines, such as punching machines, blanking, drawing, hole making, forming, dyeing, and so on are most likely to be using open loop control system. Which means, they lack the feedback qualities. Data on very important parts are hidden to the operators which results in undesirable outcome or damage to the system. Some vital details of the machinery includes

1. Time to change the engine oil.
2. Time to change the hydraulic fluid.
3. Time to change the brake fluid.

The machines need to operate in a desirable manner. And by that, it means without any troubles at all. So in order for a machine to run smoothly, an operator has to make sure that the machines are in overall good condition. But Since the Automation has taken a high rise during the information age, people are more likely to leave all those actions to the machine itself.

Figure 4 A Bending Machine

As the computer technology has taken over the world, mechanical labor has been fading away drastically. People don't have time to do a routine check on something that requires once in a month check. So for that reason, many things which need to be monitored once in a while are getting neglected, which in turn result in poor performance and finally system failure. Operators tend to be unaware of such situations. People need to be notified only when the problem is getting close to them, unlike been poked everyday which is not desired by the operator. But assurance must be made on getting informed at the specific time, i.e. the time when the awareness has to be passed on to the responsible person. If the man in charge is not aware at the time of replacement of some certain equipment in the machine, the factory has to suffer the loss caused by it. Many such problems have been seen so far in many industries. They refer this to be the problem because of untrained man power or in the case now a days, lack of innovation. A new approach has to be made in order for the factory to know each and every crucial details about their own machines. As long as the factory is aware of the current situation of their machines, they need not to worry about anything.

In some situations, the operator seems to neglect the situation of their machines. They tend to run the machines more than they should even when the replacements of some things should be done. Or in case of fully automated machines, even in the presence of closed loop system, the operators are likely to not consider such conditions. They think that it can run a bit longer than the specification and ignore the timely checkup. This is why servicing of machines are performed on a daily basis. But in some cases, the factory owners would much appreciate if the machines company do it by themselves. But how do the company of that machine determine whose factory's which machine needs to be serviced, and which parts need to be changed or repaired? This is the part where cyber physical system plays its role.

In bending machine, since the use of hydraulic system is one of the most important part, focus on hydraulic fluid must be made in order to avoid any undesirable actions in the future which might cause a big loss to the company. Neglecting such small details might lead to poor performance and eventually to system failure. These small information has to be taken into consideration while running the bending machine.

Solution: Machine companies being informed directly.
As the increment of automation, not only the machines are run automatically, but also the data generation can be done in a same manner. In the figure below, it shows how the machines are linked with the factories and factories to the company where those machines are manufactured.

In here main machine factory sells its machines to the factories. Factories run the machines in automatic mode. Now the problem was the replacement of some equipment. So in this case, cyber which means the computer generates the data of the physical system. In our case the machine. The data generated is transferred not only to the factory, but also to the company which made that machine. One Main company can sell one or more machines to a certain factory. And each and every data accumulated by the machines and the computer can me analyzed thoroughly to getter a better sense on how the condition of the machines are.

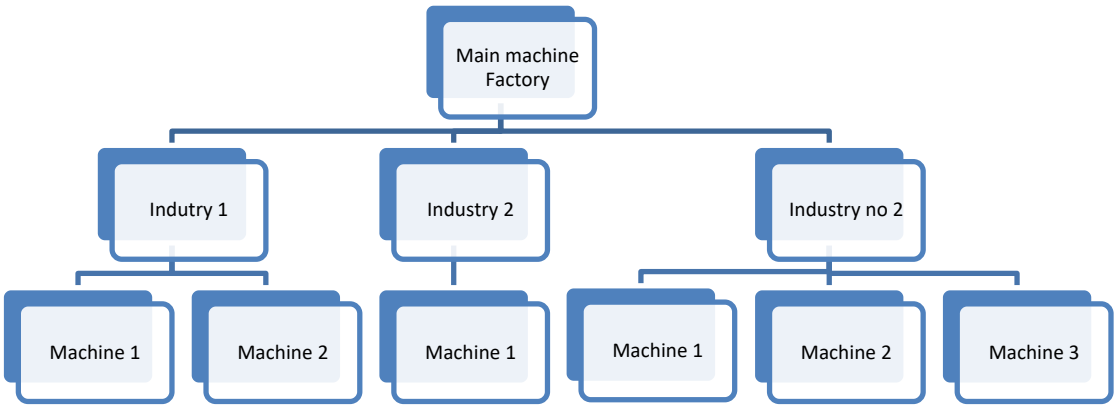

Figure 5 CPS system in the Machines of main machine factory

In order to understand the problem and solution more rationally, consider bending machine which needs its hydraulic fluid to be replaced. Hydraulic fluid needs to be replaced once every 5000 hours of operation. But the factory might not be aware on how long the machines have been running. So in this case, if the Cyber Physical System, CPS is implemented, the data can be generated and be analyzed in the factory along with the main machine company, the company who manufactured the machine. The machine company, after getting informed of the condition of the machine, May able to go to the factory directly if possible and repair or service the product. The companies will keep track of how long the machines have been working and share the information to their customers and go to the related factory and replace the hydraulic fluid or inform the operators of that factory to replace the hydraulic fluid by themselves.

In this way, the factory who are using the machines will not have to worry about the machine performance and keep track of each and every details which might affect the machine from running smoothly. As the information is directly passed to the main machine factory itself, the factory owners and the operators will have less things to worry about and more time to spend on the production of machines like bending machines.

V. CONCLUSION

The case study confirmed the need of CPS in heavy machinery like bending machines. The use of CPS not only provides real time information, but also helps to extend the life of machines. When a company gets to know many parameters of the machine in real time, the company can then decide what is beneficial for the machines, and eventually for the company. Moreover, CPS is a foremost factor to be used for Industry 4.0.

Future work remains to reconcile the computational and experimental results. The parameters that are analyzed using CPS can be automatically used to make decisions, without human intervention. This way, Artificial Intelligence (AI) can also be embedded in the system along with CPS, to obtain Industry 4.0.

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