CPS: An Architecture for Integrating the 5 Technological Elements of Industrial Intelligence

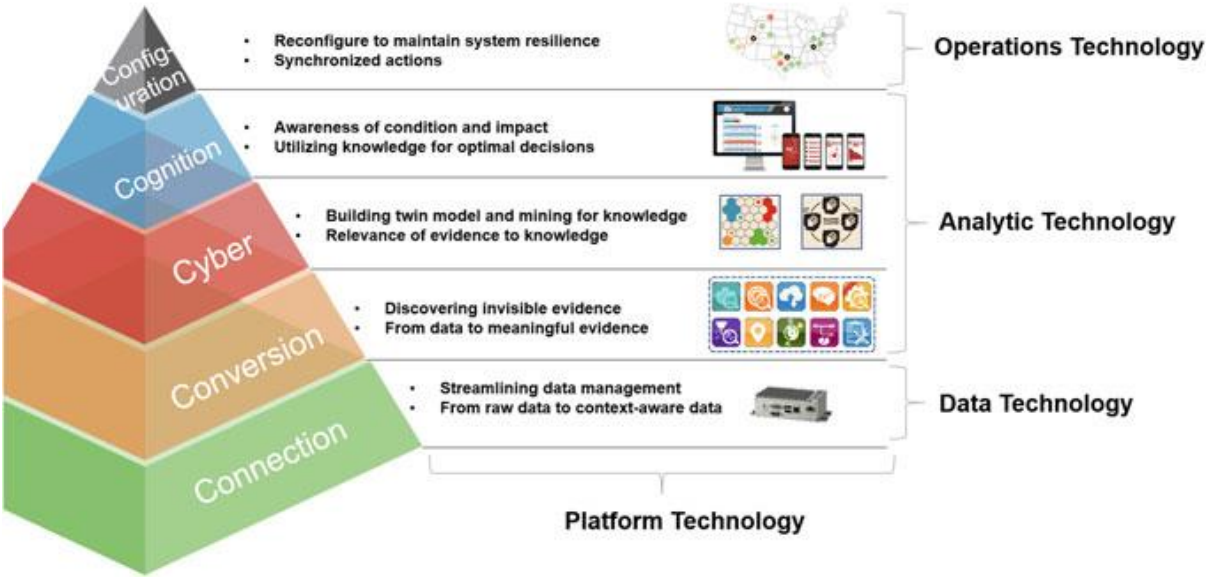
The 5C architecture of a CPS is the core framework to integrate the above five technological elements. The German Industry 4.0 strategy and the American CPS plan each regard CPS as the core technology of implementation and use it in their strategic goals. So, what is CPS? CPS is a smart industrial technology system to address the whole process of data collection, aggregation, analysis, sorting, prediction, decision-making, and distribution, and can analyze industrial data in a streamlined and real-time way. During analysis, the characteristics and requirements of logic, relationships between processes, and business activities are each fully considered. Therefore, CPS is the core of building an intelligent system through the analysis of large industrial data.

In the process of production, lots of data is generated. The essence of Industrial Intelligence is to extract logical relations and knowledge from production data by using big data and AI, and to formulate decisions and appropriate actions to avoid invisible problems and transmit manufacturing knowledge. For example, for a machine tool that processes molds, the worker is controlling the machine, and the cutter is cutting. The equipment is generating a lot of vibration signals. In the cutting process, the tool can be stabilized at the optimal speed and angle without resonance and flutter using intelligence, and it can consider the processing characteristics of the material to ensure the final product quality. If the tool isworn out after cutting for a period of time, the machine should be able to find out by itself and stop automatically before breakage occurs. Nearby workers should be notified that they need to replace the tool, but newcomers to the factory might not know how to replace the tool. In this case, the machine should be able to demonstrate this process to prevent unnecessary errors. At this point, the industrial domain is practically intelligent.

To build a smart factory, it necessitates a large amount of data and building a closed-loop system to transform data into knowledge and then into execution. In past work, I have put forward the 5C architecture of CPS as the functional framework to realize this closed-loop process. 5C represents connection, conversion, cyber, cognition and configuration. Their more specific meanings is below (Fig).

Connection: The connection layer is about smart sensing. The quality and comprehensiveness of data are guaranteed from information sources, collection methods,and management methods. The data environment foundation supporting CPS is established. In addition to the

establishment of interconnected environment and data acquisition channels, another core of intelligent sensing is to independently select and focus on data acquisition according to the objectives of activities and needs of information analysis.



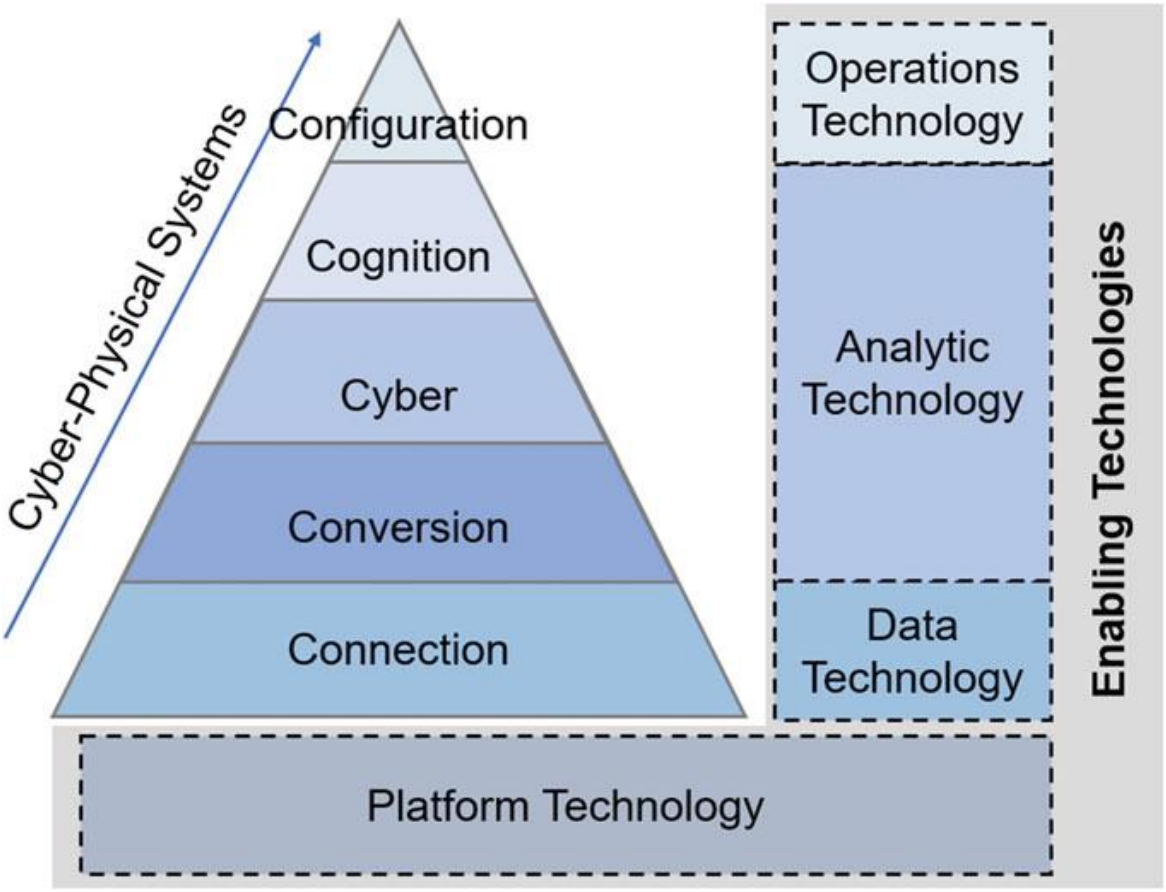
The '5C' architecture for cyber-physical system (CPS) [4]

Conversion: The conversion layer transforms low-value-density data into highvalue- density informationwhich can extract features, filter, classify, and prioritize the data, ensuring interpretability and allowing for data segmentation, decomposition, classification, and analysis.
Cyber: They cyber layer focuses on the cyberspace modeling in the network environment. A modeling and analysis environment can guide the entity space, including accurate synchronization, association modeling, records of change, analysis, and prediction.
Cognition: In complex environments and conditions with multi-dimensional data, evaluation and prediction of multi-source data is carried out according to different evaluation needs in order to recognize the operational patterns of systems and the relationships between objects, environments, and activities. Data visualization and decision optimization tools provide users with the support to make decisions.
Configuration: According to the objective of an activity and the analysis parameters in the cognitive layer, the operational decision is optimized and the optimization results are

synchronized with the execution of the system to ensure the timeliness of information utilization and system operations synergy.

The reason why CPS can improve the core competencies of manufacturing is because it integrates the ever-expanding growth of computing power within the information world and the manufacturing capacity of the physical world into an integrated system. It breaks through the limitations of the traditional production system and greatly develops it. Therefore, if we rethink the technology of the Industrial Internet and AI from the perspective of CPS 5C architecture, we will find that smart manufacturing is not simply equivalent to production process monitoring or the application of deep learning. At most, these are components of CPS. Fig. illustrates how four enabling technologies of Industrial AI (DT, AT, PT and OT) act as enablers for achieving success in the Connection, Conversion, Cyber, Cognition and Configuration steps of 5C architecture.

In order to fully integrate these smart technologies in the industrial domain to solve industrial problems, it is necessary to systematically and structurally establish the link between the information and physical worlds, to find the most important impact parameters for problem solving rather than blindly accumulating data, and finally to form closed-looped systems.



Enabling technologies for realization of CPS in manufacturing