Building on belief

Neural plants: Building autonomous factories

Equipping manufacturing setups with contextual intelligence

Abstract

Manufacturing firms are constantly on the lookout for new ways to boost operational efficiency of their factories. Stringent regulations and safety measures enforced to curb the spread of COVID-19 have compelled manufacturers to reduce dependencies on human labor. Though industrial internet of things (IIoT) technologies have been instrumental in boosting manufacturing efficiency over the last few years, these still require some amount of human intervention. The technologies have enabled manufacturers to progressively automate more than 80% of factory operations. But critical and contextual decision-making requires human intelligence for preventive as well as corrective action. This limits technological evolution and hampers the setups from becoming fully autonomous systems.

With connected infrastructure across assets, operations, and workforce, manufacturers can build a neural plant using the tenets of the Neural Manufacturing™ framework. Such a plant is built using intelligent devices, artificial intelligence (AI), and machine learning (ML). This paper outlines how neural plants can be equipped with self-diagnostic and self-healing capabilities to redefine their operations not only to make them autonomous but also enable them to be resilient, adaptable, and sustainable.

Evolution of manufacturing plants

Over the years, manufacturing plants have evolved from using paper-based systems (with siloed functions) to completely digitalized and fully automated setups, as shown in Figure 1. Developments in digital technologies, robotics, and automation have reduced human intervention in routine and repetitive tasks. The systems still need human involvement in converting data—accumulated from various connected assets, operations, and workforce—into information. These are largely reactive in nature, and corrective action depends on the ability and availability of the human workforce.

However, armed with real-time information, such as customer demand, production capacity, operational performance, and product quality, next-generation manufacturing plants can assist in operations and asset management with self-learning capabilities. These lay the foundation for neural plants, the future of manufacturing, in which factories are enabled with contextual intelligence and, eventually, autonomous operations.

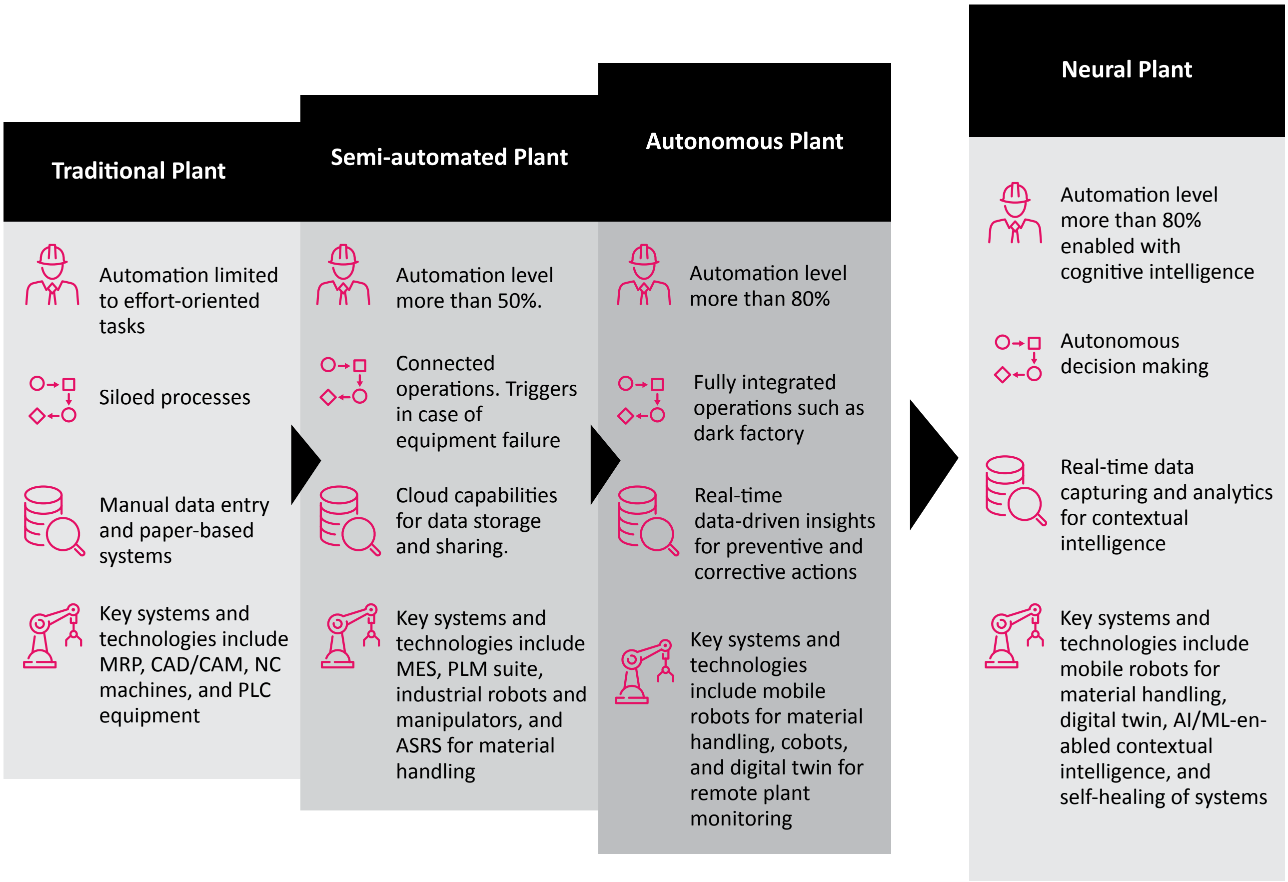

Figure 1: Evolution of manufacturing plants

Mimicking human intelligence in machines

Neural plants draw inspiration from the human nervous system in the way they respond to external stimuli. By sensing, perceiving, and acting on signals, they self-heal or adapt to shocks. All these aspects of the neural plant are based on the tenets of Neural Manufacturing. In these futuristic plants, the physical and digital worlds and the workforce are interconnected through wearable and handheld devices. The interaction between these elements generates data, which is stored as knowledge. The historical learning is processed by edge computing devices to exhibit intelligence, which is relayed to the executional systems, such as robots, automated guided vehicles, and drones in the form of decisions for the desired actions. Neural plants are built on three pillars, as shown in the Figure 2:

1. **Central command center:** Equipped with AI and cloud computing capabilities, the central command center is the brain of the plant. It analyzes interactions among the various internal functions and external events to derive actionable insights based on historical learning.

2. **Peripheral systems:** These perform various functions including planning, internal logistics, production, quality control, and maintenance. Equipped with AI and edge computing capabilities, these systems analyze situations and make critical decisions for the functionality they represent.

3. **Technological structure:** This lays the foundation to achieve the desired neural capabilities. It is built on the 5G++ network architecture for seamless connectivity across the plant and its external ecosystems. AI and ML platforms enable continuous learning and autonomous decision making. Intelligent devices such as robots, cobots, and cyber-physical systems execute tasks sent by the AI and ML systems, and the blockchain platform ensures security and transparency in the chain of operations. A web of these technologies supported by smart sensors and cameras spread across the plant, helps in replicating a biological system to continuously perform the sense-perceive-act cycles.

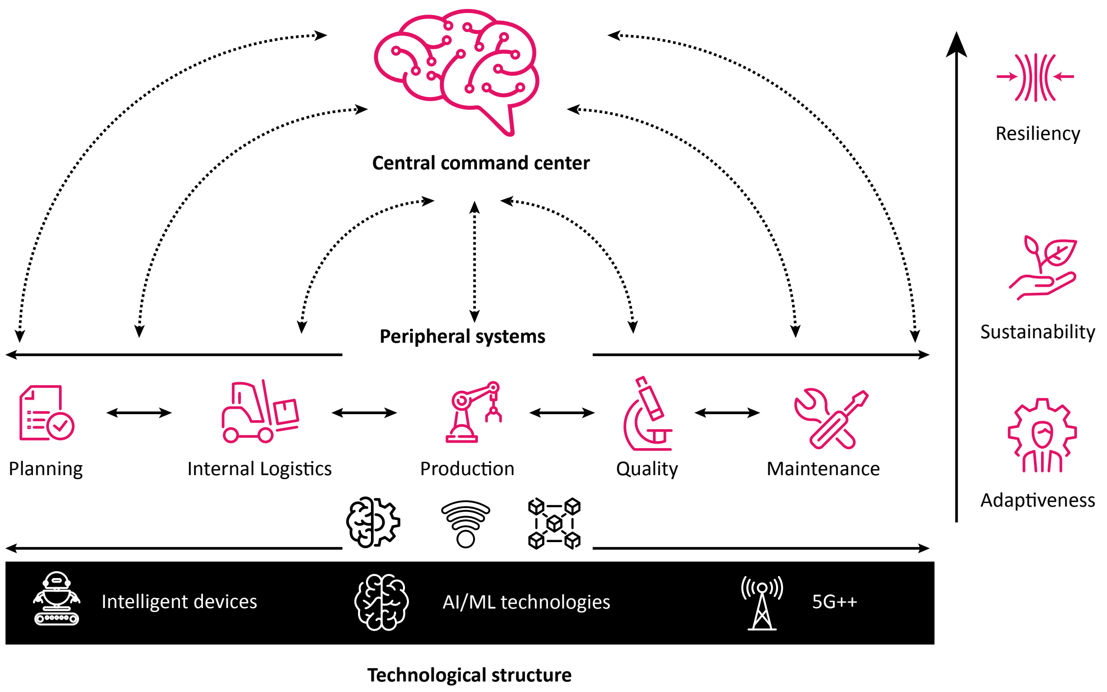

Figure 2: A neural plant framework

Designing a neural plant

Figure 3 depicts a functional architecture for neural plants. Intelligent systems in the neural model comprise the supporting systems for effective functioning of the plant. These include energy management systems, digital twins and environment, health, and safety (EHS) systems. Intelligent networks interconnect peripheral systems and are supported by connected assets, operations, and workforce. A neural fabric lays the foundation for data transmission, accumulation, and analytics, which drive the functioning of the plant. Intelligence built in the system improves efficiency by taking timely action without waiting for human intervention. For example, in case of a power outage due to unavoidable reasons, the central command center checks for alternate sources through power trading platforms and ensures that the required power for the functioning of the plant is sourced. Similarly, when the system senses a sudden reduction in demand for a particular product, it identifies the peripherals allocated to the manufacturing of that product and reshuffles operations accordingly to maintain the desired productivity levels. Moreover, when a manufacturing firm plans a new product launch, corresponding data can be fed into the digital twin of the plant to evaluate manufacturing feasibility. Through a virtual trial and error process, without even entering the plant premises or building prototypes, manufacturers can test the new product and avoid huge investments. Once the design is finalized, the central command center analyzes the given data and releases action commands across all the peripheral zones. The operations will then accordingly align themselves to accommodate the new processes.

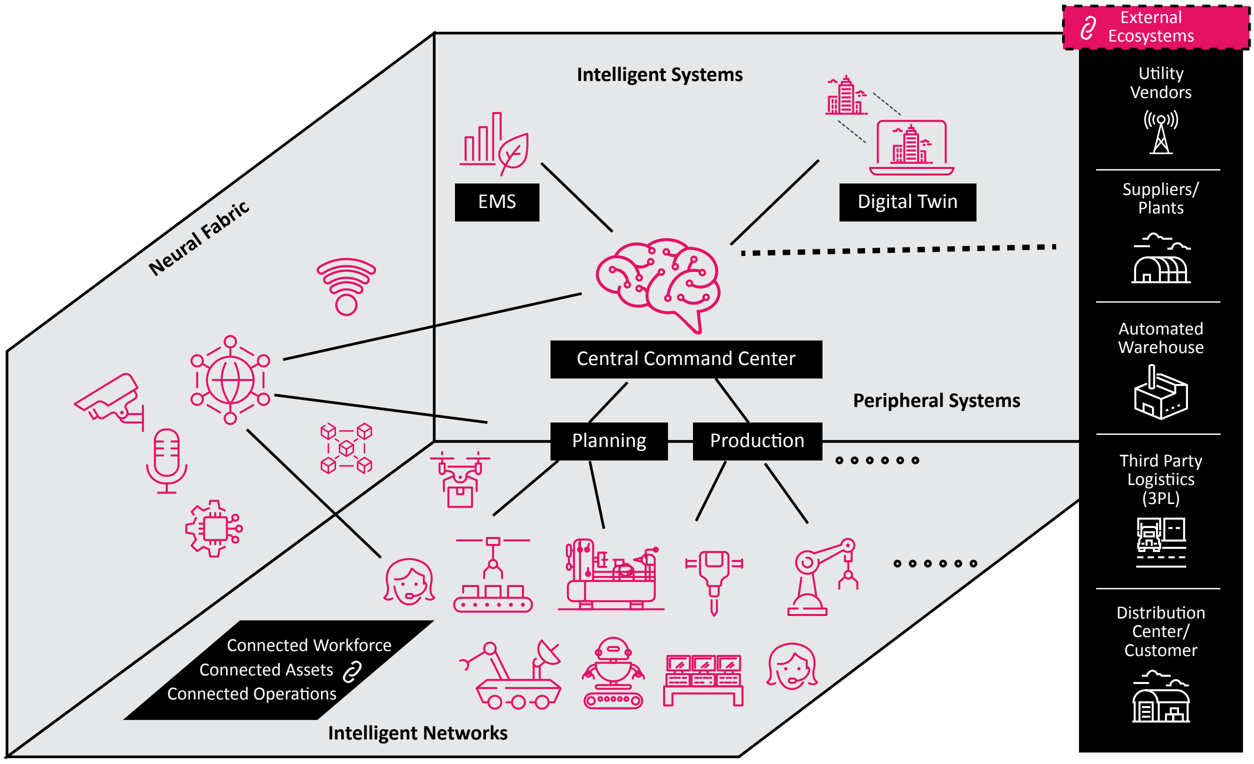

Figure 3: Architecture of a neural plant

The neural advantage

The following use cases illustrate how neural plants and their architecture function:

Use case 1 – New product introduction

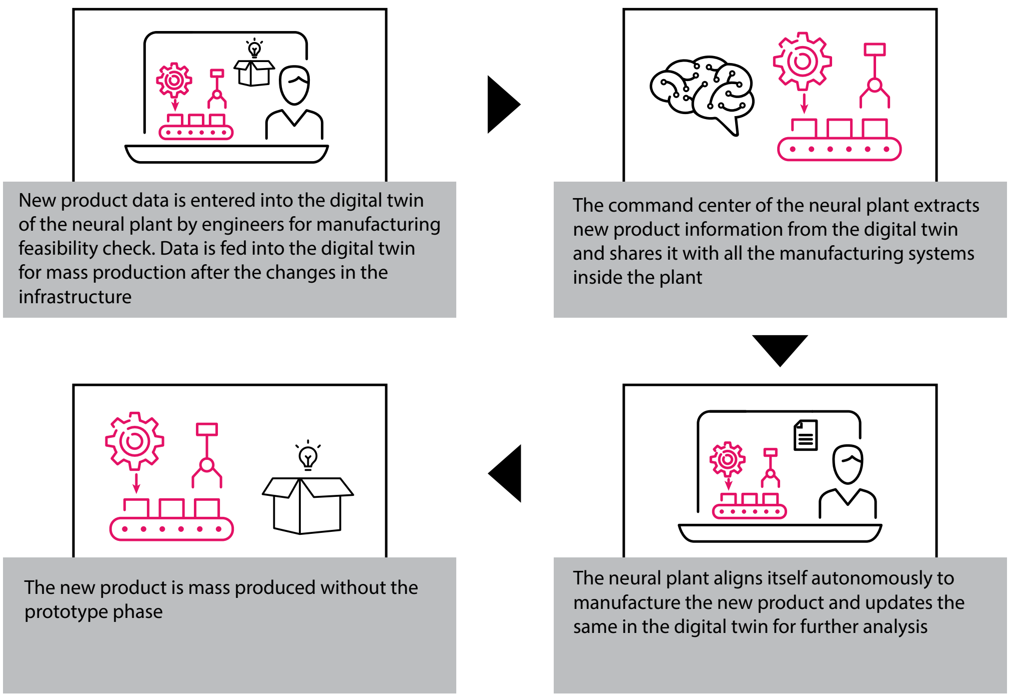

Figure 4: Use case 1

Use case 2 – Self-healing

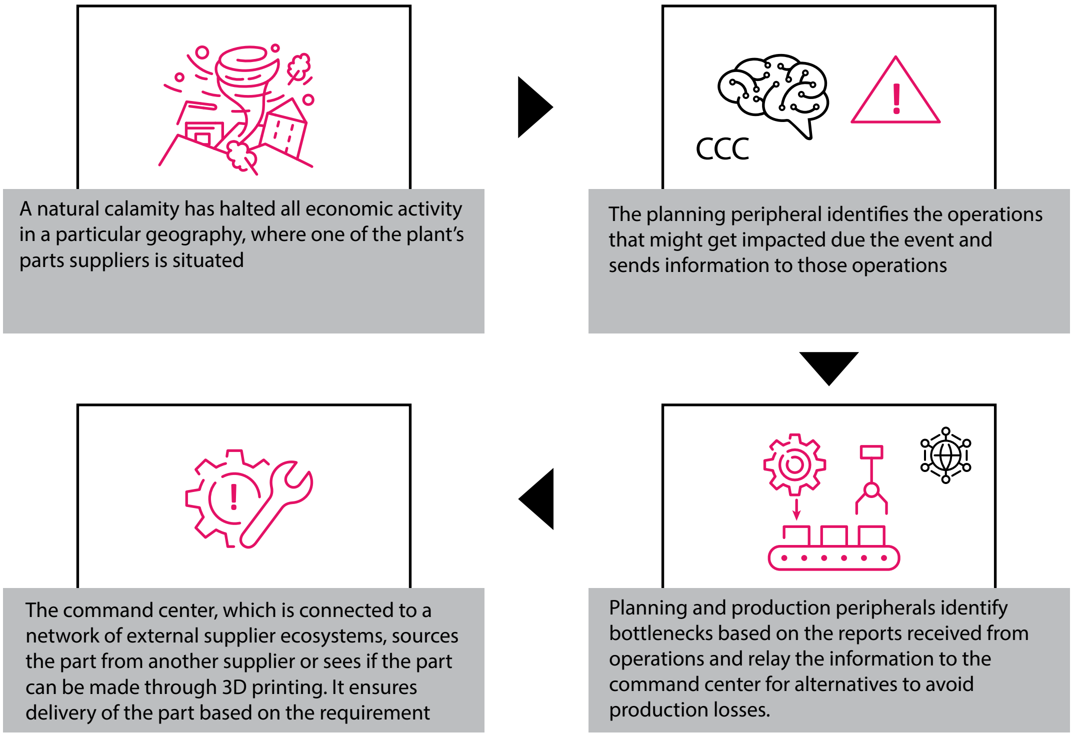

Figure 5: Use case 2

A roadmap for building neural plants

Because neural plants are built on a network of intelligent systems with the 3Cs—connected assets, operations, and workforce—at its core, it is relatively easier to set up greenfield projects than retrofitting solutions in existing plants. The 5G++ technological framework, which is a foundational technology, requires a compatible sensor network to achieve the speed and latency required to exhibit neural features. Also, neural plants need to be fed with huge data sets from various plants across the globe for the intelligent systems to learn and transform themselves to self-healing factories.

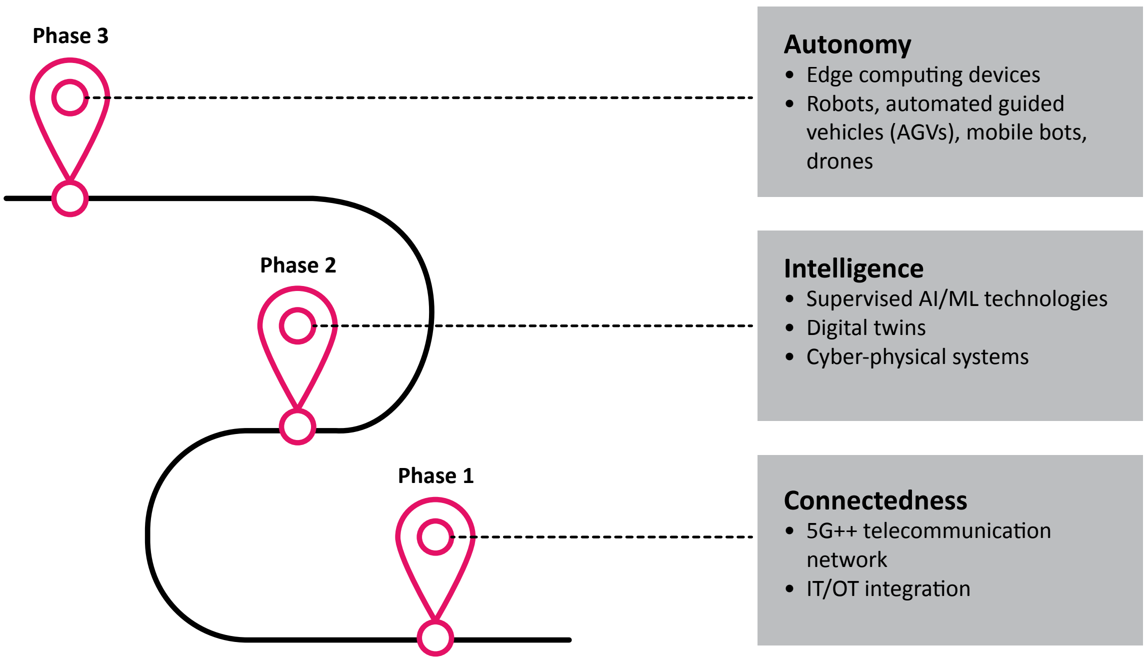

Figure 6: Roadmap for building neural plants

Brownfield projects can be used as proof of concepts to gain confidence before building neural plants from scratch. A potential roadmap for building neural plants includes:

- **Enabling connectivity:** Next-generation telecom networks such as 5G++ or satellite communication boost the capacity, agility, speed, and robustness of data workflows. Facilitating the integration between information and operation technologies is critical during this phase for acquiring data from operations and enterprise systems. Data is converted into actionable intelligence in real-time to bolster operational efficiency. This lays the foundation to enhance the capabilities of edge computing devices to facilitate intelligence at the edges.

- **Building contextual intelligence:** The central command center and peripheral systems are equipped with AI technologies to analyze cloud data and generate intelligent recommendations based on historical patterns. These insights are further fed into autonomous systems to execute tasks, thereby exhibiting contextual intelligence.

- **Gaining autonomy:** Edge computing enables data analysis in distributed devices, servers or gateways, away from corporate data centers or cloud servers. This reduces the data management and storage overhead because only the necessary data is analyzed or sent on for further analysis. Equipping automated and networked robots and guided vehicles with the data achieves autonomy in operations.

Enabling the transformation

Though automation technologies have improved efficiencies of manufacturing units, these are still leveraged only in select industries, such as electronics and microchips. Several manufacturing firms, including heavy industries, continue to rely on manual processes, which affect their competitiveness and sustenance. The neural model is the future of manufacturing, but the industry is still a long way from reaping the full benefits of its capabilities. Beyond improving efficiencies, it will also allow manufacturing firms to explore new revenue-generating opportunities. It enables the most sustainable operations with optimal utilization of energy and resources. However, the shift to fully automated systems requires change beyond implementing new technologies. It necessitates a shift in attitude, organizational culture, and skill development. Moreover, organizations must set priorities, evaluate automation levels, analyze cybersecurity concerns, and make necessary investment decisions to fully leverage the neural model.

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