To,
IITD-AIA Foundation of Smart Manufacturing

Subject: **Weekly Progress Report**

Dear sir,

Following is the required progress report to the best of my knowledge considering relevant topics to be covered.

What happened last week:

- MATLAB
- Machine Learning
- Simulink
- Deep Learning

What's happening this week:

- Digital Twin Introduction
- Going through some lectures
- Webinars online
- Research papers
- Reference materials
- Books

My understanding about IP30: Digital Twin of Smart Lathe Machine in MATLAB

Data-driven product design of lathe machines. Digitization of design processes, supported by computer-aided tools for product design, such as computer aided design (CAD), finite element analysis (FAE), computer-aided engineering (CAE), computer-aided manufacturing (CAM).
In the virtual world, products are created in computers to visualize product structure, simulate product behavior, and validate product performance.
In the physical world, with technologies such as IoT, cloud, and AI, products' performance, behavior, and interaction with the users can be captured directly and analyzed in real time.
But generally, the virtual and physical products are built, analyzed, and upgraded, separately, which could lead to such problems as incomplete information support, cyber-physical inconsistency, and imperfect digital mapping.
Therefore, the *data-driven product design* calls for a new framework that can effectively integrate, synchronize, and converge the increasingly "bigger" data that are related to the virtual product, the physical product, and their back-and-forth interactions.

Different from CAD that exclusively focuses on the digital world and IoT that heavily concentrates on the physical world, **digital twin** (DT) is characterized by the interaction and convergence of the digital and physical worlds.

- physical product can be made more intelligent to actively adjust its behavior in real time according to the simulation by the virtual product
- the virtual product can be made more realistic to accurately reflect the real states of the physical product

Weekly Progress:

June 12:
IP allocation - Digital Twin of smart lathe in MATLAB.

- Going through video lectures and online webinars regarding Digital Twin
- Brushing up the basics of ML to more effectively implement it in real-life scenarios
- Visualizing data, evaluating its skewness
- Cleaning data, occupying valid values for missing data

June 13:
Searching for resources across the internet. It was quite difficult because practical implementation of DT is not very common at this time.

- Went through lectures
- Demonstration by ANSYS and Thingworx
- Why digital twins?
    - Increasing productivity
    - Easy maintenance
    - Future of manufacturing
- Tried to understand how to implement DT in real life, but couldn't gather good evidences for the same

June 14:
Referring to research papers. How these authors have implemented or theorized DT gave me greater insights and better understanding of what I am supposed to look for.

- These papers seemed little difficult to understand but shaped my idea of DT from multiple point of views
- Could not really get into the depths of subject for it is vast to grab at the first read

June 15:
Revising ML. After going through different materials available with me, I could easily infer that it is greatly dependent on data and how we interpret that data into meaningful information. Hence, I started with what I had the most to at least one topic associated with DTs.

- How do humans make decisions?
- Basic terminologies
- Supervised: classification, regression | Unsupervised: clustering

- Predictive maintenance
- ML approach, when, why and how?

June 16:
Going through ML basics, I realized one thing that is in my control at this moment is learning how to use the Lathe machine. Knowing the basics could offer me a great deal of up-front in understanding how to make it's Digital Twin

- Challenges operator face
- Precision required
- Delicate parts, prone to frequent maintenance

June 17:
Started reading a book - Twin Control, a digital approach to improve machine tools lifecycle
Topics covered to the best of my understanding:

- Digital twins to CPS
- Virtual machining and machining tool
- Local monitoring and data management
- Data analytics
- CPS in machine tools

June 18:
Referring to later reference materials - A relatively new application of digital twins, theory and methodology in the chapter: Digital twin driven smart product design framework.
Most of my time was spent in reviewing previous week's work and learning to write the report for the same but this revision made me realise the changes in my perspective of DT throughout the week. More confident and energetic.

References:

1. Digital Twin driven smart design (edited by Fei Tao, Ang Liu, Tianliang Hu, A. Y. C. Nee
2. Twin Control, a digital approach to improve machine tools lifecycle by Mikel Armendia, Mini Ghassempouri, Erden Ozturk, Flevien Peysson (editors)
3. Xie, Y., Lian, K., Liu, Q., Zhang, C., & Liu, H. (2020). Digital twin for cutting tool: Modeling, application and service strategy. Journal of Manufacturing Systems. doi:10.1016/j.jmsy.2020.08.007
4. Damjanovic-Behrendt, V., & Behrendt, W. (2019). An open-source approach to the design and implementation of Digital Twins for Smart Manufacturing. International Journal of Computer Integrated Manufacturing, 1–19. doi:10.1080/0951192x.2019.1599436
5. Lu, Y., Liu, C., Wang, K. I.-K., Huang, H., & Xu, X. (2020). Digital Twin-driven smart manufacturing: Connotation, reference model, applications and research issues. Robotics and Computer-Integrated Manufacturing, 61, 101837. doi:10.1016/j.rcim.2019.101837