Human Model For Industrial System And Product Design In Industry 5.0: A Case Study

Arnaud Allemang--Trivalle, Jérémie Donjat, Gaëlic Bechu, Gilles Coppin, Oliver W. Klaproth, Andreas Mitschke, Arnd Schirrmann, Mathieu Chollet, Caroline G.L. Cao

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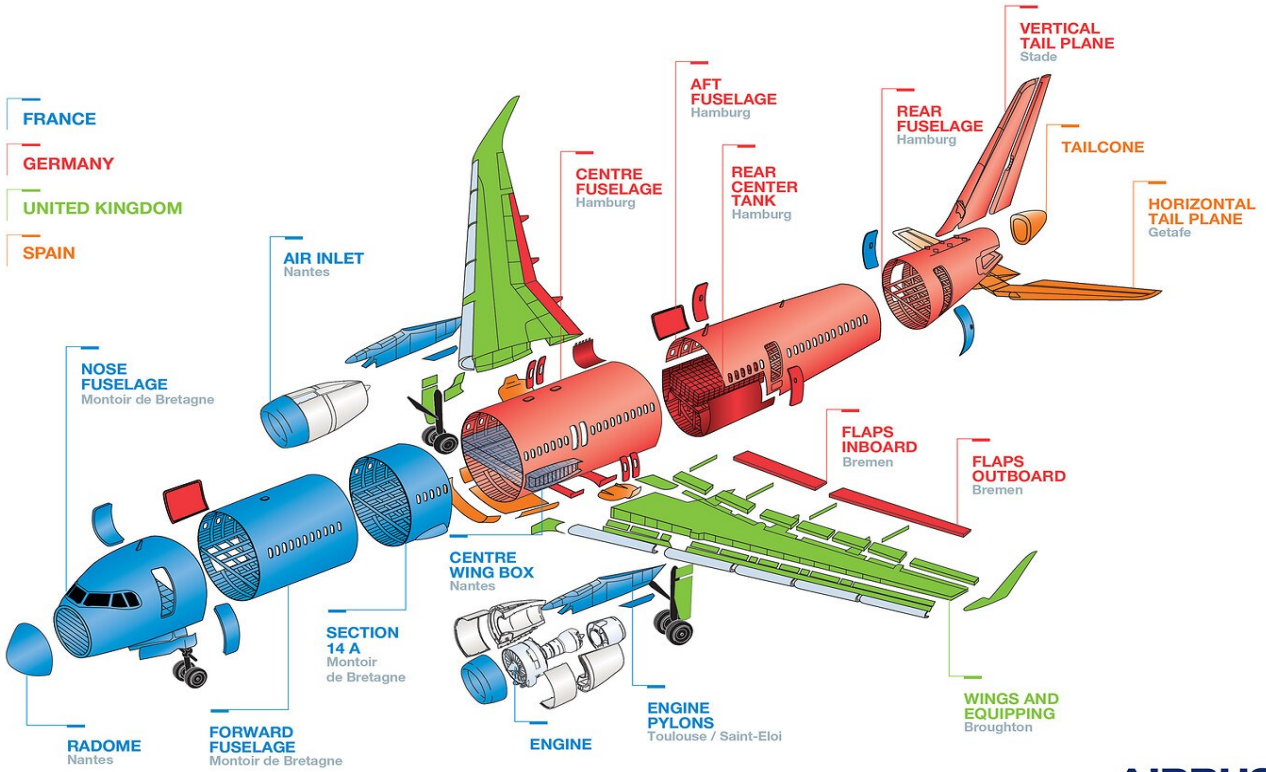
Industry 4.0 → Industry 5.0

Workers Wellbeing → positive symbiosis between workers and technological augmentation in future smart factories

European Commission, Directorate-General for Research and Innovation, Industry 5.0 – Human-centric, sustainable and resilient

Aviation industry - Airbus

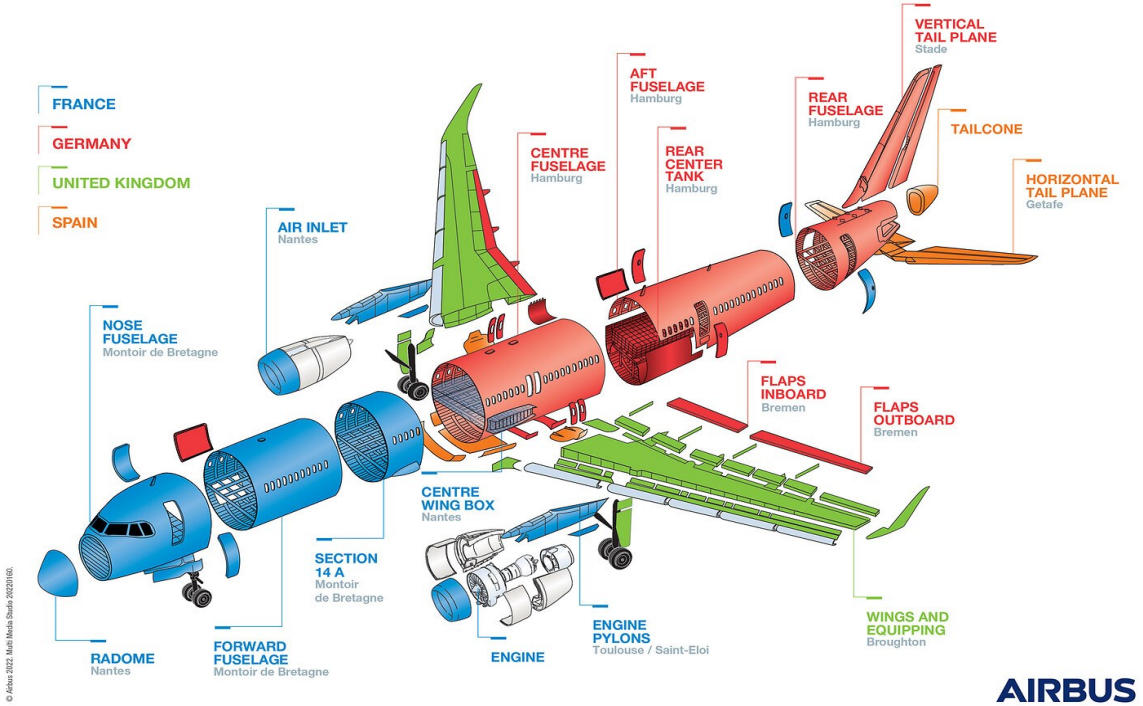


Building an aircraft is complex

- Many factories
- Many workers
- Many sub tasks
- Different processes for the same task
- Different level of automation

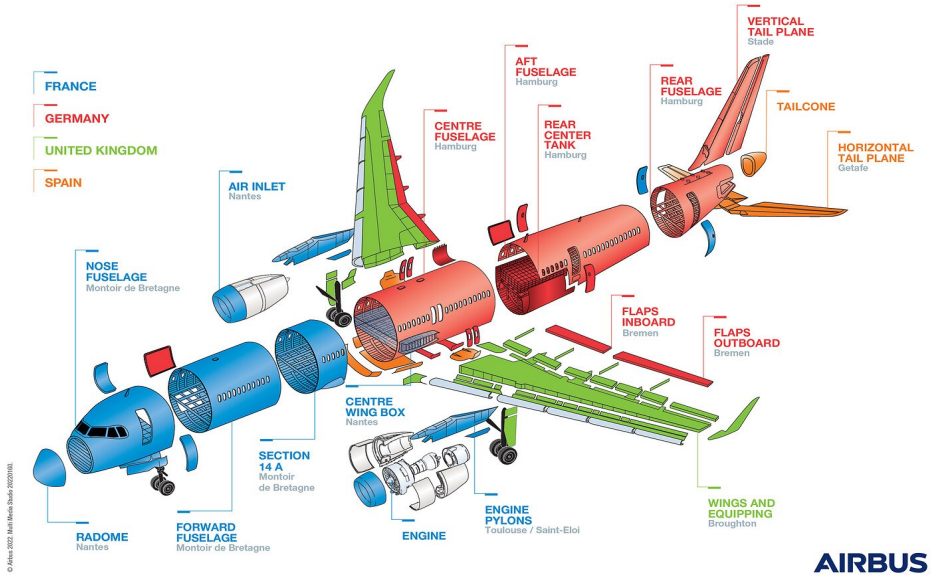
AIRBUS

Aviation industry - Airbus



How to design efficient factories and task processes focusing on workers wellbeing ?

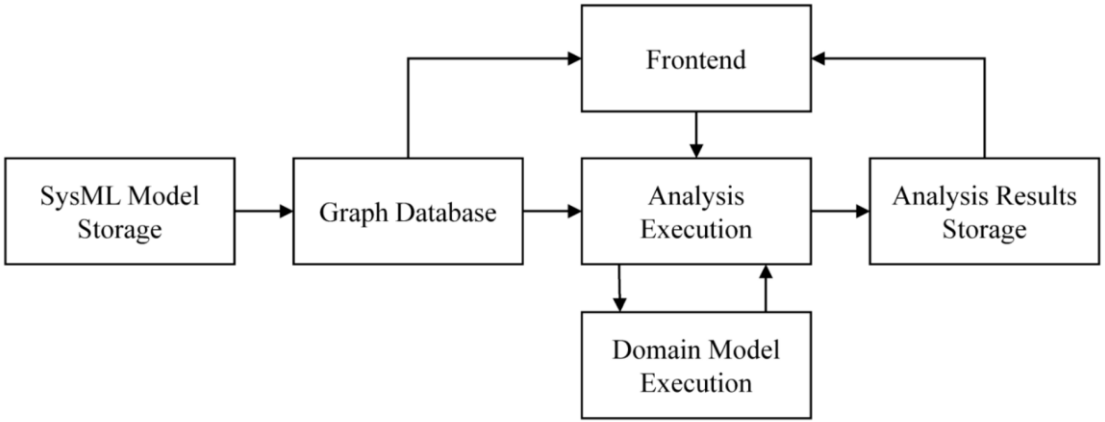
Aviation industry - Airbus



Objective: Demonstrate that by including workers performance we can enhance overall performance model

Proof of concept: Focus on fatigue

Existing Airbus DISM platform

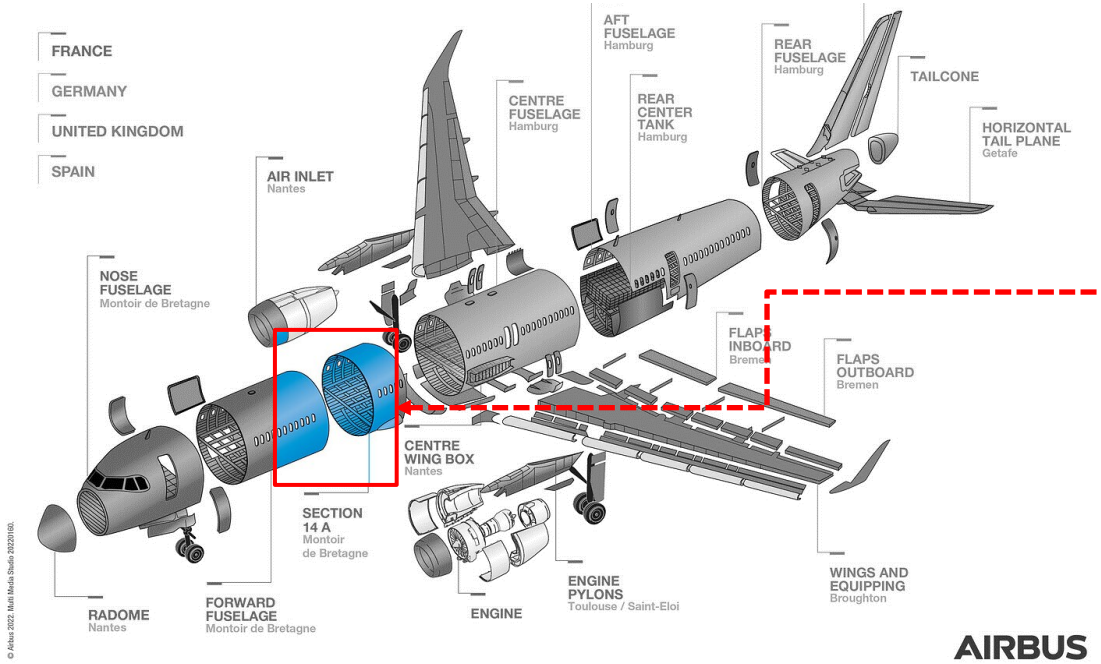


Model-based systems engineering to balance between airplane and production line constraints

➔ **Add human performance models**

Disruptive Industrial System Modeling (DISM) platform overview ***(Helle et al., 2022)***

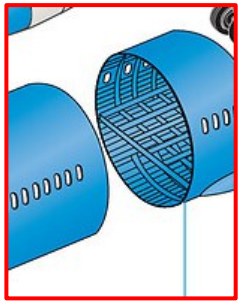
Use case – Orbital joint



- "Orbital" junction of 2 sections
- Occurs several times at major component assemblies and at final assembly line
- ≃ 1,200 riveted joints along the circular connecting line

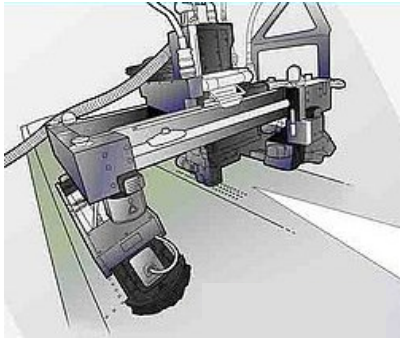
Use case – Orbital joint

Different levels of automation



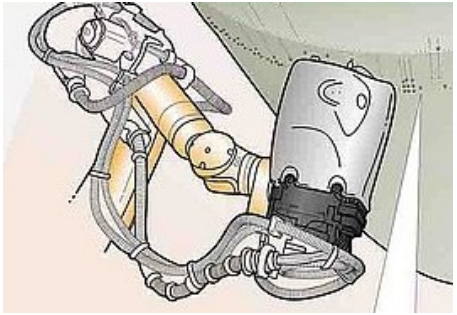
Fully manual

Semi automated



Light Flex Track robot

Fully automated



KUKA robot

Existing literature

Worker fatigue and system performance are affected by numerous factors:

These factors are associated with: **process, task, environment designs and individual characteristics** ***(Kolus et al., 2018)***.

experience, age, general cognitive abilities, physical work capacity, learning and forgetting, reaction time and motivation considerably impact the performance ***(Abubakar & Wang, 2019; Katiraee et al., 2021)***

Observations, interviews and data

- **Field observations and semi-structured interviews** at different Airbus plants (France: Nantes, Saint-Nazaire; Germany: Hamburg): understand the work performed by Airbus employees on the production lines and the different types of workforce **(super workers, average workers, basic workers)**

- **Activity distribution programs** for specific production lines: list of tasks, expected duration of each task and sequence in the process.

  For each task was provided an **ergonomic rating injury risks**: postures, physical loads, and environmental conditions

Our model

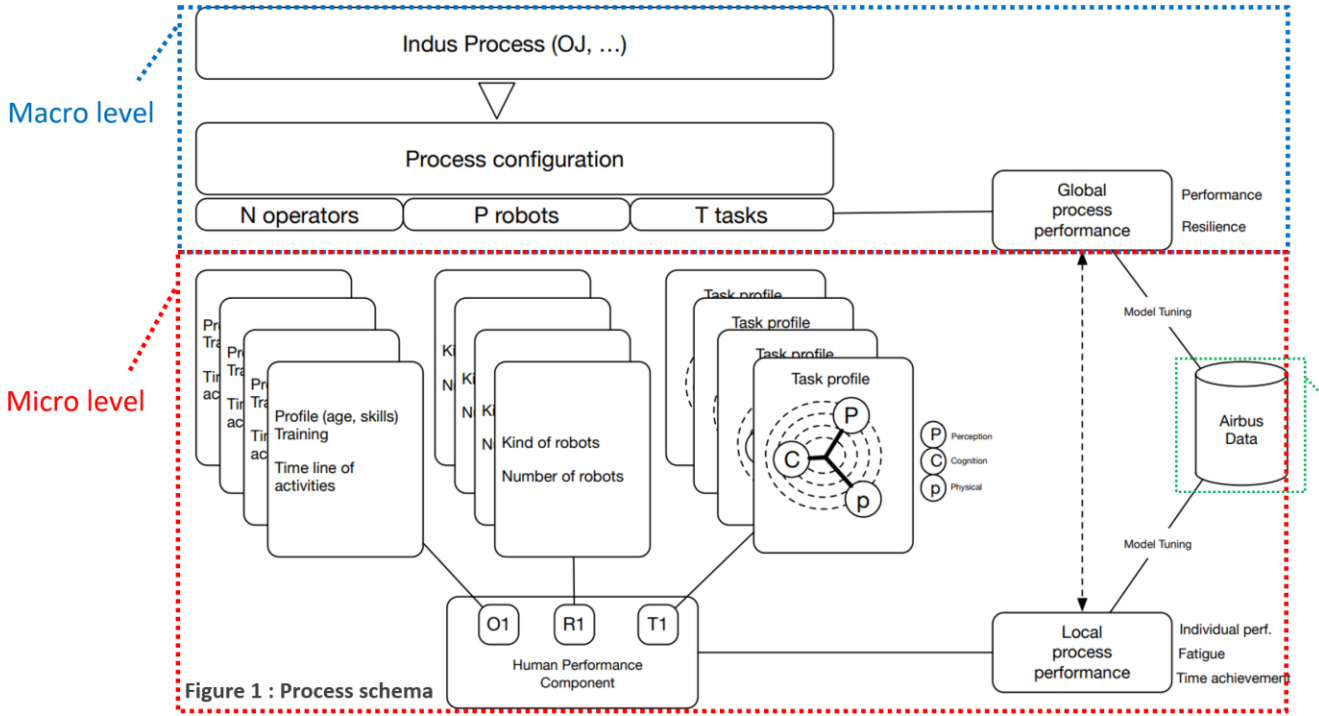


Figure 1 : Process schema

Discrete-event **Worker Fatigue Model** integrating:

- **Workers characteristics**: age, motivation, skills
- **Tasks characteristics**: physical, cognitive and perceptual loads
- **Robots**

Our model

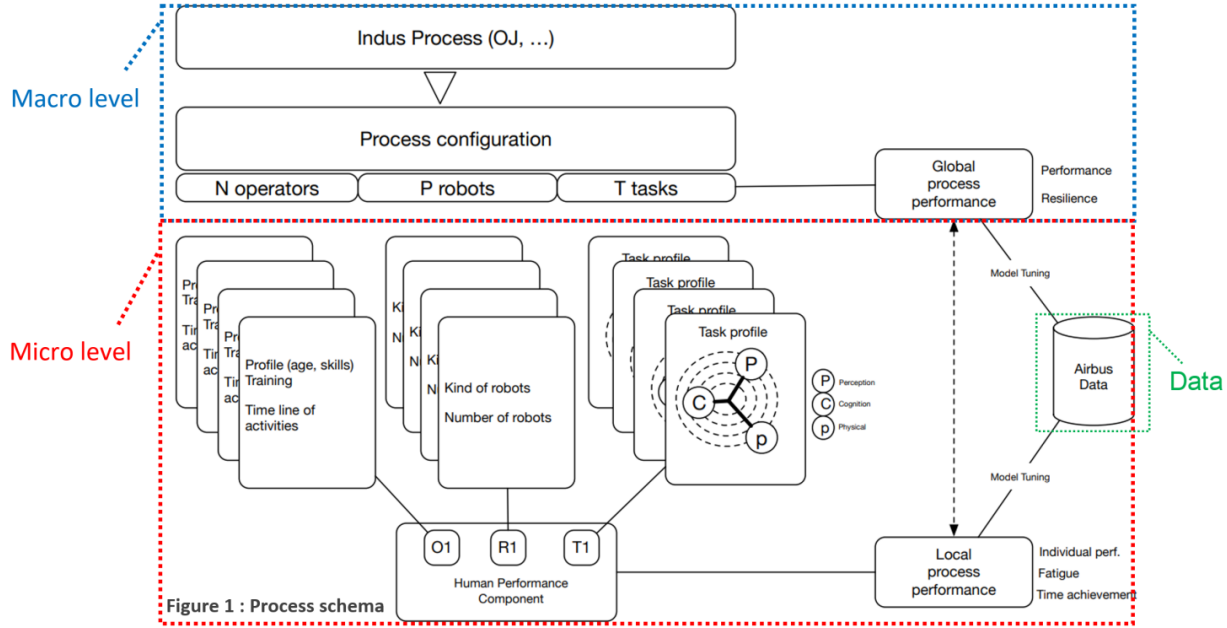


Figure 1 : Process schema

Discrete-event **Worker Fatigue Model** adapting and incorporating :

- **Human fatigue model by *Jaber et al., 2013***
- **Workforce aging model from *Boenzi et al., 2015***

Two scenarios of the Orbital Joint Assembly process were simulated

(240 tasks performed by 5 teams working simultaneously)

Fully manual

- **Mix of super workers, basic workers, and average workers in various combinations in each team**

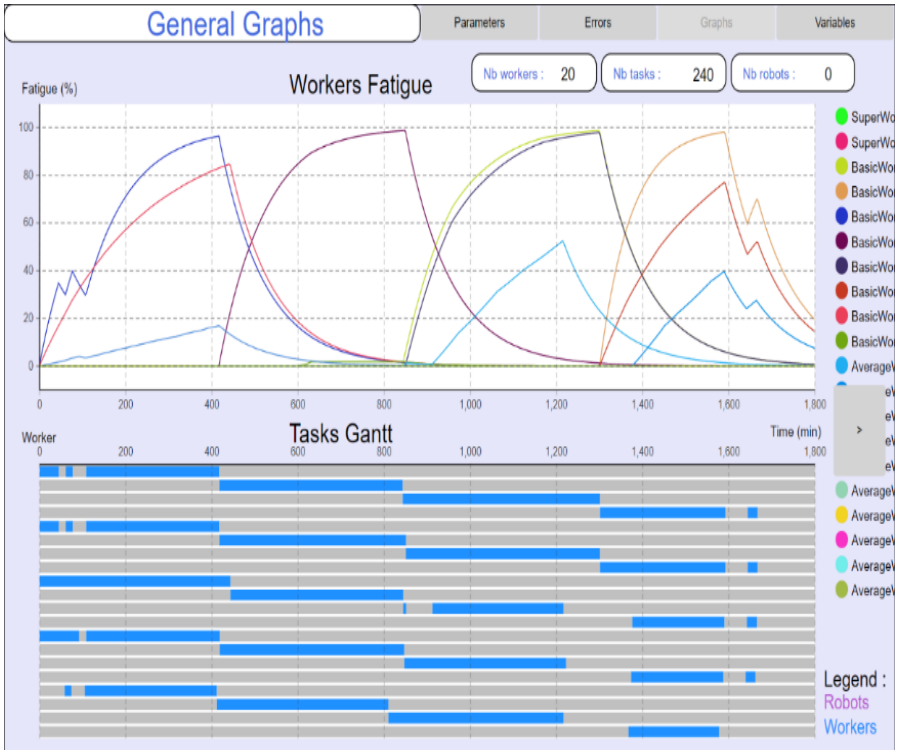
➔ **Demonstrate the effect of low-skill teams versus high-skill teams.**

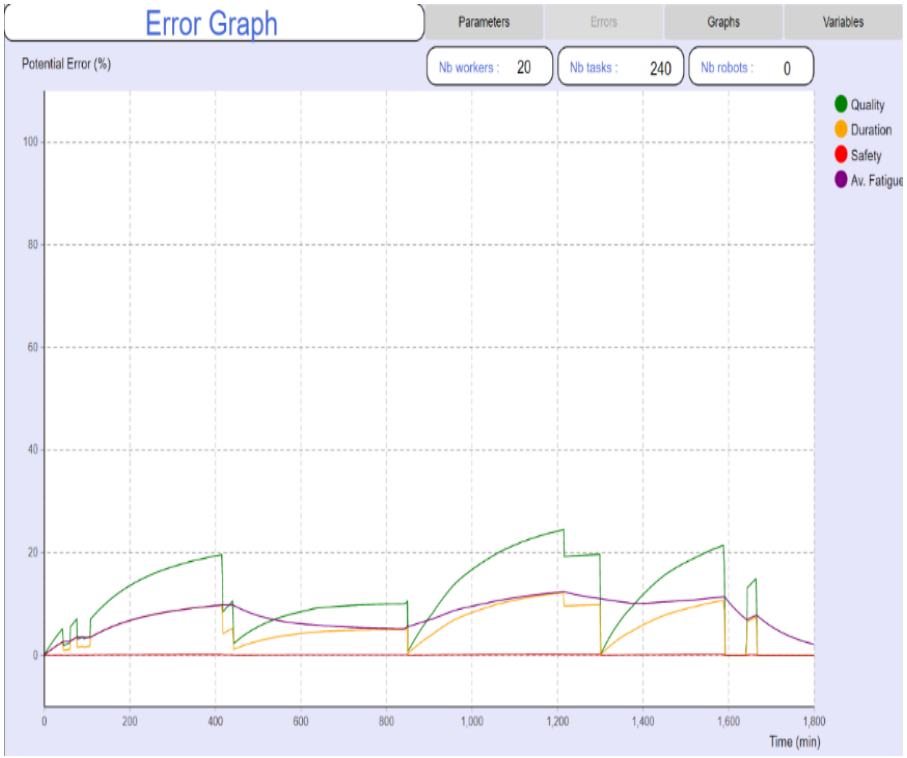
Semi automated

- **In each team, a worker is replaced by a robot during the last shift**

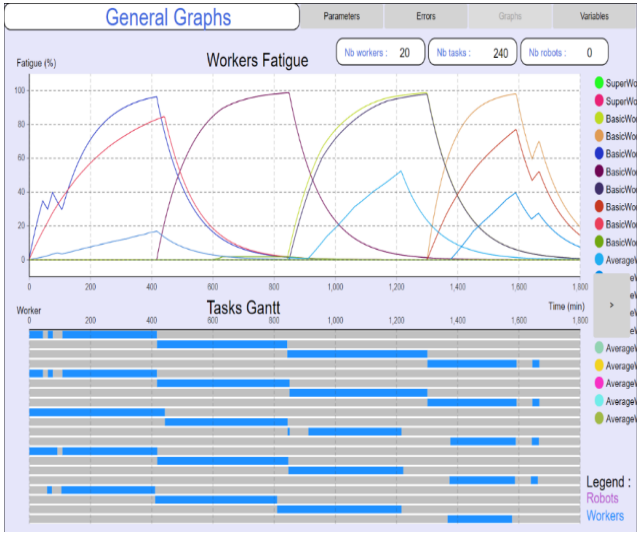
➔ **Demonstrate how automation can help decreasing fatigue**

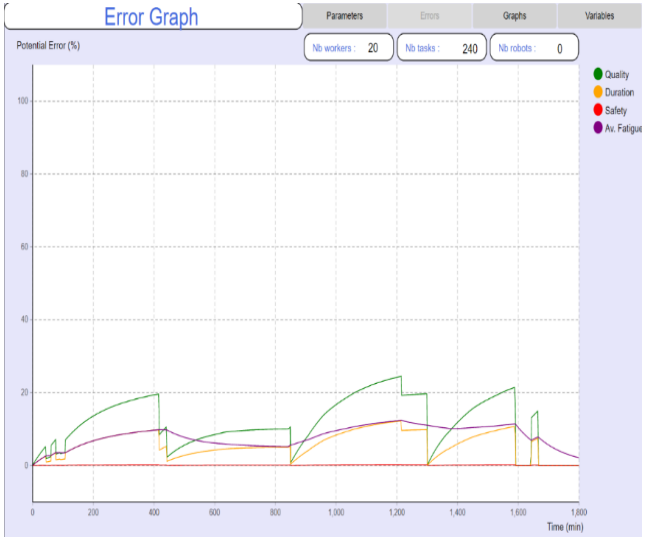
Fully manual



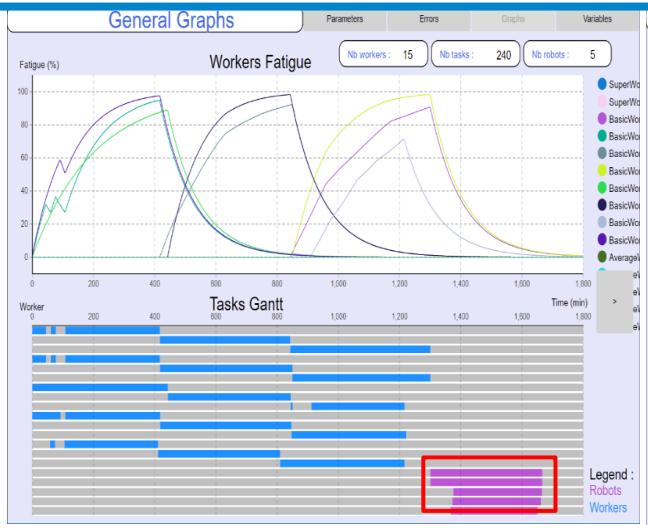


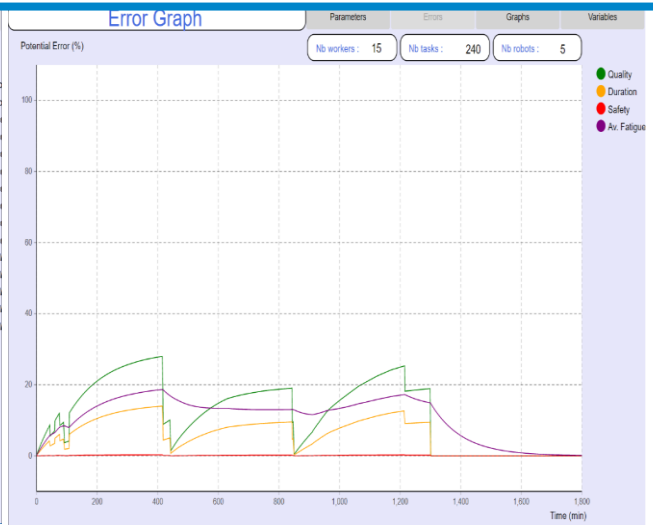
Fully manual





Semi automated





Strong potential

The Worker Fatigue Model was sensitive to variations in:

- Type of workers (Super worker, average worker, basic worker)
- Team composition (Mid-Career and Early Career)
- Task demands (manual vs. robot-assisted).

Limitations

The adapted fatigue model is for illustrative purposes…

- It does not include learning-forgetting effects
- It requires validation data to verify and calibrate the model
- It does not consider operational costs for workers while robots are active and engaged and the human work necessary to setup, calibrate, operate, monitor, and recover in case of failure.

Summary

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Problem **How to design efficient factories and task processes focusing on workers wellbeing ?**

Observations ➡ Implementation ➡ Evaluation

Observations

Highly complex environment:

- **Different level of automation**
- **Different types of workforce**
- **Different types of tasks**

Implementation

Discrete-event fatigue model integrating:

- **Workers characteristics**: age, motivation, skills
- **Tasks characteristics**: physical, cognitive and perceptual loads
- **Robots**

Evaluation

Orbital-joint use case with different level of automation and workers teams

➔ **The model behaves as expected**

Need verification data

Acknowledgements

- The production line workers and managers at Airbus Hamburg
- The Region Bretagne, FEDER and the University of South Australia for funding the Chair for Industry of the Future (Prof. G.L. Cao)
- The International Max Planck Research School for Intelligent Systems (IMPRS-IS) and the AI@IMT program (Arnaud Allemang--Trivalle).

Funding: Airbus Contract SP2104350 DISM

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