Requirements for digital twinning

1. Functional Requirements

A. Basic Tasks

- **Simulate Production Processes:** The DT should replicate the complete paper folding process, including all steps executed by the three robots.
- **Data Collection and Analysis:** Gather and process real-time data from physical production line to assess operational efficiency.
- **Sensors and IoT Devices**: Collect real-time data from the physical entity, such as folding accuracy, queue length, speed, or operational status.
- ~~**Alignment with Physical System:** Ensure the DT mirrors real-world performance by sharing and validating design data, such as workpiece tolerances, properties, and force limits.~~

B. Disturbances and Resilience

- **Disruption Detection:** Identify and signal common production disturbances, such as:
  - Paper misalignment or jams.
  - Deviations in robot movements.
- **Recovery Protocols:** Simulate actions for recovery:
  - Reset robots to safe positions.
  - Suggest manual interventions or automated corrections.
  - Model alternative workflows to bypass affected components.

C. Adaptation and Extension

- **Scenario Flexibility:** Adapt simulations for new paper plane designs requiring different folding sequences or material properties.
- ~~**Scalability:** Allow integration of additional robots or components, maintaining real-time simulation fidelity.~~
- **Modular Design:** Ensure each system component (e.g., grippers, robots, paper feeders) is modeled independently to facilitate easy updates and modifications.

D. Collaboration with External Team

- **Incorporate Gripper Models:** Collaborate with UT Twente to integrate detailed models of the grippers, reflecting physical behavior in the DT.
- **Joint Testing Protocols:** Develop shared validation procedures to ensure consistency between the DT and the physical production line.
- **Dynamic Feedback Loops:** Use performance data from the DT to suggest improvements in the gripper design, which UT Twente can implement.
- **Regular Sync Meetings:** Conduct regular meetings to align development timelines, discuss challenges, and refine goals.
- **Workshops and Demos:** Host hands-on workshops to showcase the current state of the DT and gather feedback from both teams
- **Documentation Sharing:** Share detailed documentation of each team's work, such as DT architecture and gripper design blueprints.
- **Unified Software Tools:** Use a common platform for data sharing and simulation modeling (e.g., CAD software or cloud-based systems).
- **Collaborative Digital Workspace:** Employ a shared repository (e.g., GitHub) for storing project files, test results, and documentation.
- **Physical-to-Digital Testing:** After UT Twente develops a physical gripper prototype, run synchronized tests where the DT mimics the real-world operations.
- **Feedback Loop Testing:** Use the physical test results to refine the DT and, conversely, use DT simulations to suggest optimizations for the physical grippers.

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2. Nonfunctional Requirements

A. Performance

- **Simulation Accuracy:** Achieve less deviation in outputs (e.g., folding angles, gripper positions) compared to real-world operations.
- **Fault Detection Accuracy:** The DT's ability to correctly identify disruptions.

B. Reliability

- ~~**Robustness:** Ensure the DT operates under network disruptions by caching the last known state and predicting short-term outcomes.~~

- **Error Handling:** The system should recover gracefully from invalid inputs or unexpected behaviors.

C. Scalability and Extensibility

- **Scalable Architecture:** Support simulations with additional robots or additional production steps for complex folding methods.
- ~~**Future-Proof Design:** Ensure the DT can integrate with other DTs or systems as part of larger manufacturing ecosystems.~~

D. User-Friendliness

- ~~**Accessible Interface:** Provide an intuitive dashboard for monitoring, analyzing, and controlling the production process.~~
- ~~**Training Simulations:** Include training scenarios for operators to learn using the DT.~~
