Engineering IoT-based Software Systems for Forestry: A Case Study

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1. Introduction

- The Internet of Things (IoT) is a rapidly growing technology that offers huge possibilities for optimizing processes and increasing productivity in various domains.

- **Ensuring the quality of the IoT** is a complex challenge for software engineers and requires new development skills as well as coordination of third party service providers.
1. Introduction

- Forestry domain actors still operate with traditional non-digital practices.
- IoT technology provides numerous opportunities for improvement and ways to improve productivity and increase level of automation.
- Forest machines are intelligent but the support and maintenance of forest machines includes a large number of manual work activities.
Research problem:
How quality aspects should be taken into account while designing and implementing IoT-based software systems for forestry?

3 research questions:
• What types of IoT monitoring needs does a forest machine operator company have?
• How quality attributes are visible in building IoT solutions?
• How IoT monitoring shall support forest operations?

Research data: Empirical data on two IoT cases conducted in the case organization (Device specs, interviews with IoT providers, work meetings, field visits, data records etc.)
Figure: The context of the case study

CASE: IOT-Based Monitoring

Applications:
Mobile app TILHI, IoT dashboard, cloud-based IoT services

Processes:
Inventory management of forestry supplies

IoT cases:
Embedded single case design with multiple units of analysis

Embedded Unit of Analysis 1: Liquid level monitoring
Embedded Unit of Analysis 2: Weight monitoring

Strategies:
Respect environmental values, cost efficiency, high productivity

Devices:
Ultrasonic sensor, industrial scale, analog signal transmitter

Infrastructure:
Mobile & web & cloud

Communic. architecture:
Cloud architecture for IoT LoraWAN

Data analysis
Case comparison
3. Results

- Case study results are presented by using Situation, Task, Action, Results (STAR) approach.

- The STAR approach includes four steps:
  1. **Situation** describing the context within the IoT development was performed,
  2. **Tasks** describing responsibilities or tasks to be done in that particular situation,
  3. **Action** describing how the task was completed or how the challenge was resolved, and
  4. **Results** describing the outcomes or results generated by the action.
3.1. Case A: IoT-based liquid level monitoring

- **Situation:** the company lacks an accurate view of their forestry liquid inventories -> drivers of forest machines do not receive required.

- **Task:** The EU funding from DIH World enabled the research consortium to design, implement, test and validate the monitoring solution. The company can order refilling of containers proactively.

- **Action:** LoraWAN sensor modules installed into IBC containers, a mobile app development “digital twin”

- **Results:** IoT-based monitoring system that enables monitoring liquids (Adblue, marking dye) in remote storage areas.

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3.2. Case B: IoT-based weight monitoring

- **Situation:** Need to monitor & measure mass of forestry supplies such as oil canisters (identified in the end of Case A)

- **Task:** The main task was to design a continuous mass measurement system using smart sensors and AWS cloud services -> An industrial class “scale” under the monitoring target

- **Action:** Monitoring target was changed to the oil canister pallet, PCE RS 2000 scale purchased, meetings with Amazon, the system provider was selected after Solver X pitching event

- **Results:** the system architecture established, services selected, the prototype 80 % completed
### 4. Analysis of results

<table>
<thead>
<tr>
<th>Category</th>
<th>Case A</th>
<th>Case B</th>
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</thead>
<tbody>
<tr>
<td><strong>Monitoring needs</strong></td>
<td>- Monitoring liquid containers</td>
<td>- Continuous mass monitoring</td>
</tr>
<tr>
<td></td>
<td>- Proactive orders for liquids</td>
<td>- Proactive orders for supplies: oil canisters</td>
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<tr>
<td></td>
<td>- Sending alerts on low levels</td>
<td>- Sending alerts on low levels</td>
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<tr>
<td></td>
<td>- Ordering refilling containers in time</td>
<td>- Oil orders in time</td>
</tr>
<tr>
<td><strong>Quality</strong></td>
<td>- Accurate view on liquid level</td>
<td>- Number of oil canisters</td>
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<tr>
<td></td>
<td>- Data conversion on distance to percent</td>
<td>- 4-20 mA to kg</td>
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<tr>
<td></td>
<td>- Data frequency 6 hours</td>
<td>- Data frequency 1 hours</td>
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<tr>
<td></td>
<td>- Install sensor to cap of container</td>
<td>- Scale under pallet</td>
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<tr>
<td></td>
<td>- Calibration of sensors</td>
<td>- Calibration of scale</td>
</tr>
<tr>
<td><strong>Benefits</strong></td>
<td>- Check liquid levels remotely</td>
<td>- Number of oil canisters</td>
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<tr>
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<td>- Setting alerts on critical liquid levels</td>
<td>- Setting alerts on only few oil canisters left</td>
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<td></td>
<td>- Proactive way to ensure availab. of liquids</td>
<td>- Enables monitoring any tangible items</td>
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<td></td>
<td>- Provides data on liquid consumption trends</td>
<td>- Consumption of oil canisters</td>
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<td></td>
<td>- May reveal container leaks</td>
<td>- May detect that items are stolen</td>
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5. Conclusion

1. What types of IoT monitoring needs does a forest machine operator company have?
   - Various types and sizes of containers (fuel & water & oil & fungicide & diesel exhaust fluid & marking dye containers)
   - Various types of tangible supplies such as grease tubes, oil filters, oil canister pallets, chain blades and chains (mass monitoring needed)

2. How quality attributes are visible in building IoT solutions?
   - Devices and network: Selecting right sensor and data network solution
   - Data: Performing data conversion, defining data storage mechanism for IoT data
   - Calibration & installation: installing the sensors correctly, calibration of scales and sensors is very important to ensure quality of measurements

3. How IoT monitoring shall support forest operations?
   - Proactive ordering, alerts on low inventory levels, reduced traveling to remote sites...