ZEUS 2017 - Lugano, Switzerland
2017-02-13

Closed-Loop Control of 3D Printers via Webservices

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Computer aided product development

Additive Manufacturing applications

Additive Manufacturing/3D Printing

Additive Manufacturing/3D Printing:

- Creates physical objects from digital models
- Layer-wise addition of material
- Variety of material (e.g., plastics, metals, ceramics)
- Summarises technologies:
  - Electron Beam Melting (EBM)
  - **Fused Deposition Modeling** (FDM, also Fused Filament Fabrication FFF)
  - Laminated Object Manufacturing (LOM)
  - Stereolitography (SLA)
  - Selective Laser Sintering/Melting (SLS/SLM)
  - 3D Printing (3DP)
- Uses STL (STereoLithography) files, tesselated object description

Motivation

- Lacking quality in results
- Errors and failures during fabrication
- Material and component wastage
- Lacking quality control

Lacking Quality in Results

- Objects detach
  - ← vibration
  - ← collision
- Material cut-off
- approx. 22 mm/s movement speed

Proposed System

- Externalised intelligence (service)
- Control by service via adaptor
- Direct machine-code streaming

Basics – CPS

- ▷ Cyber-physical system = real world object
- \+ digital representation
- → Influencing object via actuator(s)
- ← Acquiring information via sensors

Benefits

- Extensible $\rightarrow$ new 3D printer
- „Profiles“ (fast, expert user, ...)
- Shared data (collaboration)
- No modification of hard- or software
- Re-manufacturing, non-planar surface
- Adaptive slicing/manufacturing

Drawbacks

- Requires uninterupted Internet connectivity
- Low latency
- Fast roundtrip (within one instruction: 0.14s)
- False positive (robustness)

Closed-Loop Control

- Positional/state data from 3D printer
- Accurate position data: expensive, requires modification
- Sensor data: requires analysis and statistical models

Components

- 3D printer (requires controllable interface)
- Service (storage, processing, management)
- Adaptor (mediator between service and 3D printer)
- Sensor nodes
- User (distinction in proficiency)

3D Printing Model

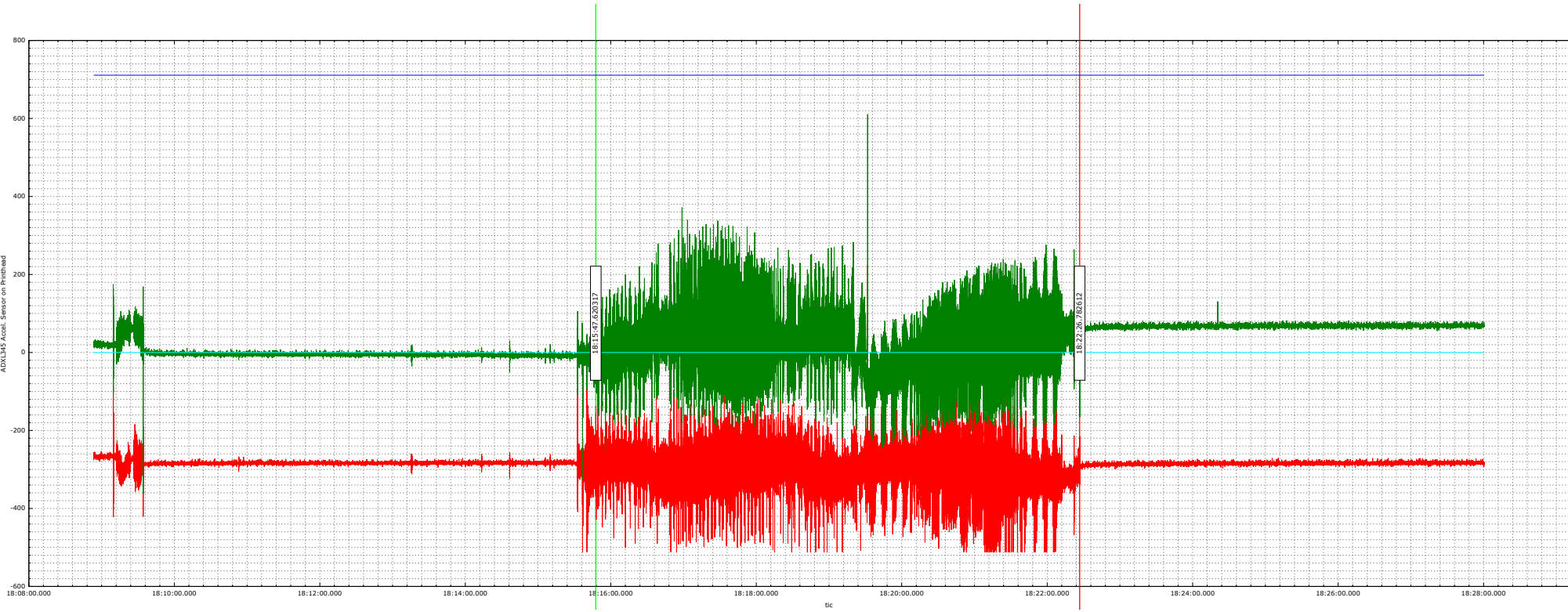
- ▷ CAD model, STL model, machine code

  - vs -

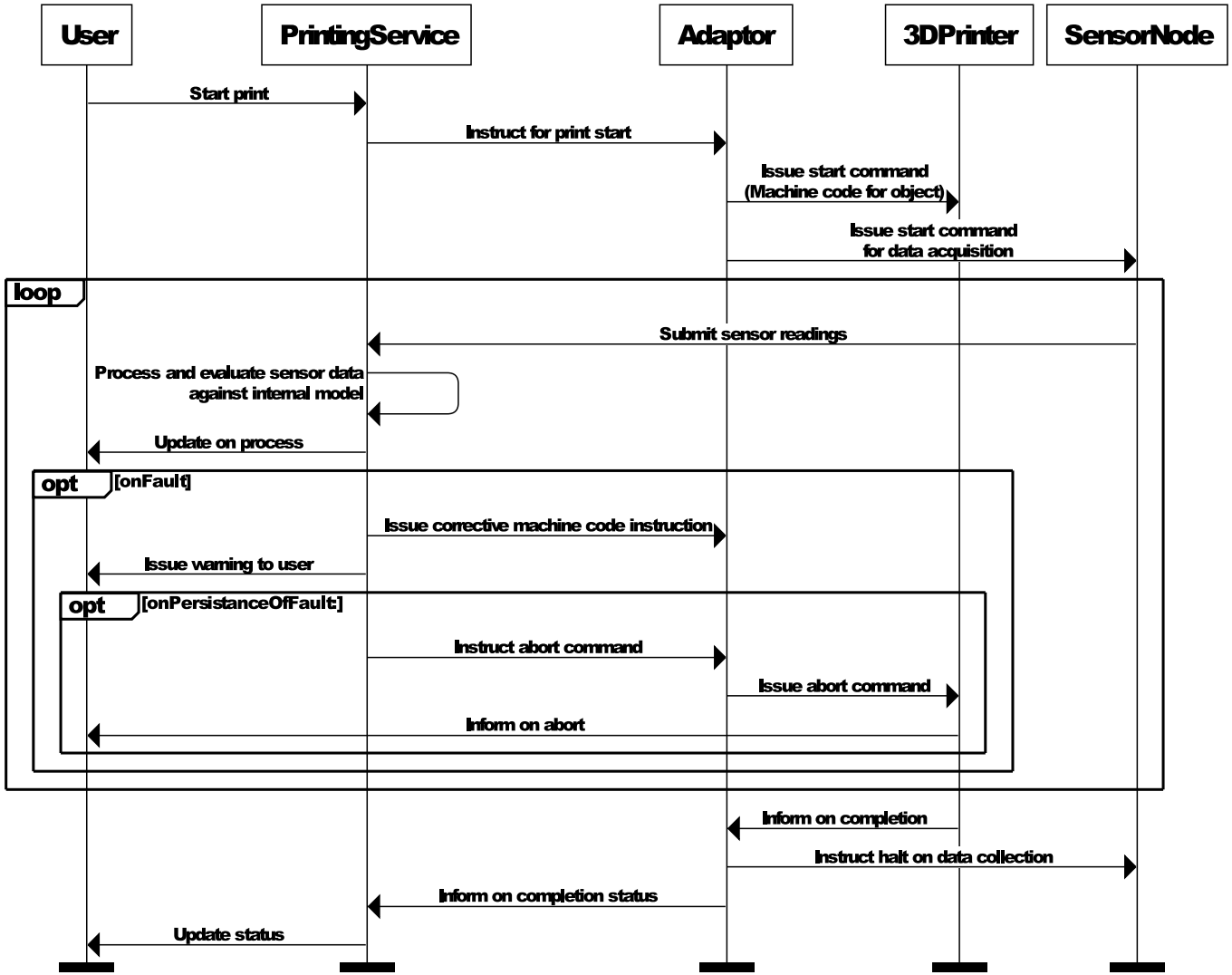
- ▷ (Expected) sensor reading

- ← User input (quality rating)
- ← Machine learning

Example Sensor Data



Processing Flow



Challenges

- Latency in communication
- Auto-connection (user-friendly)
- Loss of control for customer

Future Work

- Model creation (requires more data)
- Testing and evaluation
- Predictive maintenance

Summary

- Outline of work-in-progress of 3D printer control with REST
- Motivation
- Architecture based on REST API
- Advantages and disadvantages

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- **Q & A**