Contextual visualizations for debugging collaborative robots

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SDU Software Engineering
Development cycle

Cognitive Distance

Robotic development process is long & slow
Development cycle

Errors! => + Cycles => + Complex
Development cycle

Cognitive Distance

Errors! => - Cycles => - Complex

Meaningful Feedback
Collaborative Robot: Cobots

Direct human-robot interaction
Close proximity with humans

Evaluation
Continuous visual inspection
Long working shifts
Collaborative Robot: Cobots

Direct human-robot interaction
Close proximity with humans

Evaluation
  Continuous visual inspection
  Long working shifts

Inspect data a posteriori
Meaningful feedback

Dev programs, but…
Robot behavior fails

Robot presents data…
Data is difficult to follow

Put data into context…
Dev has information
Dev can debug the behavior
Meaningful feedback

Dev programs, but…
Robot behavior fails

Robot presents data…
Data is difficult to follow

Put data into context…
Dev has information
Dev can debug the behavior
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Methodology

Record: EDDE → Process → Display
Methodology

Record: EDDE -> Process -> Display

Data to Information
Interactive visualizations
Cobot application: pick-and-place

Pick-and-Place
One of the most (if not the most) common application

Machine Tending
Assembly
Material Handling
Palletizing
...

...
Experimental set-up

Context
Pick-and-place application
UR5 + vacuum gripper

Data
Execution time
Runtime state
CSV file: 244 x runtime state
## Experimental set-up

### Data

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<th>Date/Time</th>
<th>Execution Time</th>
<th>Current Thread</th>
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### Context

- **VGC10 Gripper**
- **UR5e Cobot**
- **Gripper example: successful pickup**
- **Gripper example: partial pickup**
- **Laptop receiving runtime data**
- **Teach pendant**
- **Tile (object) layout**
Visualizations: Objects and Robot

2D Position of objects
  Current / Past / Future
  Success / Error / Warning

3D Robotic arm configuration
Visualizations: Vacuum level

Success pick-up

Partial grasping

Error pick-up
Visualizations: Source code

Source code

Together with all visualizations

Highlight current execution line
Visualizations: Interactive through time

Choose Cycle
Step within cycle

Visualizations update with time
Robotic arm

https://youtu.be/FffedGoe-fU
Conclusions
Conclusions

Visualizations in context: quickly assess the behavior of the robot
Quickly assess if the robot is behaving correctly

Debugging via meaningful feedback and interaction
Future Work

Evaluation
  Try with real users/operators
Use cases: more contexts
  Different (common) cobotic applications
Data Management
  Handling large data volume (7.4MB / 1 min)
External sensors
  Cameras, …
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