Safe human-robot interaction in logistic applications for highly flexible warehouses

Title: Prototype demonstrator of 2D/3D-GUI interaction concepts

Deliverable: D4.5

Prepared by:

<table>
<thead>
<tr>
<th>Name</th>
<th>None</th>
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<tbody>
<tr>
<td>Organisation</td>
<td>SLA</td>
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<td>Date</td>
<td>December 24, 2018</td>
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</tbody>
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Approved by:

<table>
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<tr>
<th>First Reviewer</th>
<th>Jana Jost</th>
</tr>
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<tbody>
<tr>
<td>Second Reviewer</td>
<td>Ivan Marković</td>
</tr>
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1 Summary

This deliverable builds upon the concepts presented in deliverable D4.2 Concepts of intuitive 2D/3D interaction with the system [M18], and gives the first prototype implementations of various components. In summary, here we are exploring extensions to the CO009: Fleet Manager Terminal to allow better interaction between the Supervisor and the Picker/Service Technician inside the warehouse and extend it to be able to monitor the new components introduced inside the warehouse e.g. the CO001: Safety Vest.

As current tests with the Hololens proved it’s robustness, the interface modalities of the mobile picking station/fleet manager terminal that are not already part of the AR-interaction paradigms will be implemented as part of the AR-interface. As such they will be discussed in the deliverables concerned with AR-based interaction. In case of failures the implementation can easily be adapted to use on a tablet-like device. More on that is discussed in Section 2.
2 Extentions to the Fleet Manager Terminal

In short, the following points were presented as possible extensions to the fleet manager terminal:

- Display **CO001: Safety Vest** status
- Display positions of humans inside the warehouse
- Stream audio data - intercom modality
- Stream video data

For a more detailed descriptions of the concepts please refer to the previous deliverable *D4.2 Concepts of intuitive 2D/3D interaction with the system* [M18]. Currently, most of the code is implemented in separate programs/windows for easier testing and debugging.

Implementation of the **CO001: Safety Vest** status is still in progress as we await for the finalisation of the safety vest components, which would allow direct tests with the safety vest. Allowing the communication however is just a matter of implementing a client-server architecture between two Linux Ubuntu 16.04 systems, which we already demonstrated with the implementation of the **CO011: Location Server**. The communication in question will not go through the **CO011: Location Server**; however, the solution can be reused in this case.

It is already possible to display the correct position of the human worker inside the warehouse as seen in Figure 1. The solution uses the **CO011: Location Server** developed by partner CVUT as a client of the **CO011: Location Server**, which handles the positions and paths of all the components inside the warehouse. On the other side we have a VR application emulating the **CO003: AR Device**/**CO001: Safety Vest**. We use a VR setup as it allows large-scale tests in big warehouses with large **CO006: AGV** fleets. On the software side we use unity for both VR and AR applications and both devices run a Windows 10 OS, thus the solutions are easily interchangeable between the two.

The capture and streaming of audio and video data (one way, from Hololens to a PC) is already enabled in the Hololens through the mixed reality capture/streaming capability in the device portal, a webservice provided by the Hololens itself. One thing to note is that this method produces significant lag even when the access point is devoid of any other traffic (usually around 4s). These tests where done with included video streaming as no other option is available at this time. Tests conducted with Microsoft’s Hololens App show much better results with almost no lag (less then 1s even when the access point is shared with devices streaming pointclouds, videos etc.). The prototype implementation using the Microphone Listener protocol implemented in the Mixed reality toolkit (MRT), a toolkit developed by Microsoft for Unity development implementing classes and libraries for easier interaction with the Hololens, show a lag in between the two aforementioned lags, which is currently too high for seamless audio communication. We used a standard websocket interface to communicate between the Hololens and a PC. Efforts are on the way to mitigate it, testing other connection options and reverse-engineering the code provided in the MRT to try to improve it on the sender side of things.

Similarly to audio, we implemented a one-way streaming program for the video. On the Hololens side a ScreenGrabing server is implemented that continually grabs frames from the camera. Other processes can then request frames from it. This is done as only a single process is able to access any sensor at a given time. As we use the cameras also for, e.g. object detection, this was the only possible method. The communication is again using a websocket. Although it shows solid performance it is still prone to lag spikes. The implementation can be seen in Figure 2. Another problem detected is that sometimes video frames arrive out of order. Again efforts are under way to mitigate this in form of Sender and Receiver buffers.
Figure 1: Visualisation of the position of the human in the Fleet manager terminal.

Figure 2: Streaming of camera data from the Hololens
3 Mobile Fleet Manager/ Picking Station

The main functionalities of the Mobile Fleet Manager as described in the deliverable D4.2 Concepts of intuitive 2D/3D interaction with the system [M18] are:

- retrieving new maintenance task from the Fleet Manager Operator,
- retrieving status data for CO006: AGVs and racks,
- calling CO006: AGVs and racks for maintenance to Maintenance Area,
- retrieving additional technical data about components to maintain or repair,
- marking future maintenance area on a warehouse layout.

Likewise the functionalities of the Mobile Picking station are:

- Support for picking with similar interface as on the picking station,
- Support for inventory control and filling the racks,
- Connection to handheld barcode reader device.

As stated in the introduction some of these modalities already exist in the AR-interaction or can be easily added. As the AR was proven more robust and is an innovative solution that should be researched further, priority was given to implement all mobile interaction in AR rather than a hand-held tablet.

Regarding the mobile fleet manager, points one, two, and four are already in the AR-interaction with the other components now added to the workflow.

In regards to the mobile picking station the first two points have been added to the interaction modalities. The connection to a barcode scanner can also been implemented. Presently a camera based barcode/QR-code reading algorithm has already been implemented on the Hololens to supplement the object detection product recognition for products in featureless boxes. The implementation can be seen in Figure 3. This should be compared to a barcode reader and a connection between the Hololens and a portable barcode reader implemented is the barcode reader provides significantly superior. Similar implementations of a barcode reader bracelet and AR-glasses have already been implemented by other companies e.g. by Ubimax and Intel.

As a fallback strategy reimplementing the AR-based solution on a tablet would not be difficult as the Unity development environment supports development for tablets. Touchscreen control and a fixed camera view would be added. Especially if using a Windows tablet, communication protocols would not need to be changed at all.

4 Outlook and Summary

Here we presented the current proof-of-concept implementations of the various components described in D4.2 Concepts of intuitive 2D/3D interaction with the system [M18].

It was proven that the interactions capabilities described there are indeed possible and implementable. Some of the interaction capabilities were moved entirely to AR and therefore will be described in the relevant deliverables instead.

The future work includes optimisation of the streaming modalities to reduce lag, which at the moment renders both audio and video streaming somewhat impractical. Further testing on a system where other components are also running and communicating will also be needed to evaluate the viability of the streaming in the final system. Finally, if proven viable, the relevant programs and components should be integrated directly in the CO009: Fleet Manager Terminal, instead of stand alone programs as they are at the moment for testing purposes.
5 Consortium

**Role of KIT**

KIT has two roles:

1. KIT will be coordinator of SafeLog. Coordinating person will be Björn Hein. The department FORScience of KIT will handle all management issues (s. previous paragraph, section *Management structure and procedures* and *WP8 Project Management* in document Part 1).

2. Regarding research and innovation KIT will mainly focus on the human-system interaction and assistive technologies in the envisioned flexible and collaborative warehouse *WP4 Assisting technologies for a collaborative and flexible warehouse system* with the corresponding relations to the other work packages.

**Role of SLA**

Swisslog provides expertise in automation and logistics ranging from industrial robot applications, electrical overhead monorails, transport AGVs and goods-to-man systems. Swisslog will handle the demonstrator based on a fleet of mobile goods-to-man robots. For this system prior work exists comprised of fleet-manager, standard safety infrastructure and also a 2D emulation environment. Swisslog will take the lead of WP1 and WP6.

**Role of CVUT**

CVUT will lead *WP3 Planning and scheduling for a heterogeneous fleet manager*. The target of the workpackage is to realize a planning module that will provide coordinated plans for robots and humans in the warehouse CVUT will also significantly contribute localization activities in *WP2 Integrated safety*
concept for detecting and localizing of humans as well as specification and requirement analysis. WP1 Requirements and Specifications and integration WP6 Integration and Demonstration.

### Role of UNIZG-FER

UNIZG-FER will lead WP2 Integrated safety concept for detecting and localizing of humans. The target of the workpackage is development of a holistic safety concept that will allow safe collaboration of humans and robots in the warehouse. UNIZG-FER will also contribute in human aware planning in WP3 Planning and scheduling for a heterogeneous fleet manager, localization and human intention recognition in WP4 Assisting technologies for a collaborative and flexible warehouse system, specification and requirement analysis in WP1 Requirements and Specifications and integration in WP6 Integration and Demonstration.

### Role of IML

IML has a comprehensive knowledge about a multitude of interlogistic applications as well as a deep knowledge about development of embedded electronic components and robotic solution.

In this position IML will contribute to the overall integration of the different concepts by leading the WP6 Integration and Demonstration. Furthermore IML will bring in the expert knowledge in embedded systems and communication technologies to contribute majorly to the safety concept and hardware development of the vest as part of WP4 Assisting technologies for a collaborative and flexible warehouse system.

### Role of KEEI

KEEI will lead WP5 Development of a Safety Vest. The goal of this work package is to develop a Safety Vest which enables humans to safely enter and work in a flexible warehouse system with AGVs. Special attention shall be given to safety certification of the safety vest and the Safety Concept developed in WP2 Integrated safety concept for detecting and localizing of humans. KEEI will contribute to the Project with its experience in embedded systems design and in development and certification of safety critical control systems for railway applications.
6 Glossary

AGV
Automated Guided Vehicle: An Automated Guided Vehicle is a mobile robot that follows markers or wires in the floor, or uses vision, magnets, or lasers for navigation. They are most often used in industrial applications to move materials around a manufacturing facility or warehouse. Application of the automatic guided vehicle has broadened during the late 20th century. 5, 7–9

AR
Augmented Reality: Augmented reality is a visualization technique where a direct (e.g., through glasses) or indirect (through a camera and screen) view of the real world is supplemented by sensory input and data to achieve a better and more informative understanding of the scene. 4, 5, 7
References