MR Immersive Telemanipulation

Mixed Reality Lab Project Proposal

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1. Project Description

Through robotic telemanipulation, robots are able to assist people in everyday tasks. Following this idea, we aim to build a system in which a user can remotely manipulate the ABB YuMi (a dual armed robot) while wearing the HoloLens 2.

HoloLens/MR makes different types of manipulation methods possible thanks to its capabilities. Mapping the environment in real time, seamlessly integrating holograms to the user's view, enabling interaction with these holograms and continuous hand pose tracking are several of them. Whereas, Computational Robotics Lab at ETH Zurich has built a comprehensive and versatile control system as well as a simulation environment for ABB YuMi and its stereo camera. Also, YuMi is able to interact with wooden sticks, e.g. by picking them up and assembling them into a given structure. Utilizing these extensive capabilities, we want to focus on two distinct manipulation methods, namely, external holographic operation and internal immersive operation.

2. Work Packages

The project can be split up into four separate work packages.

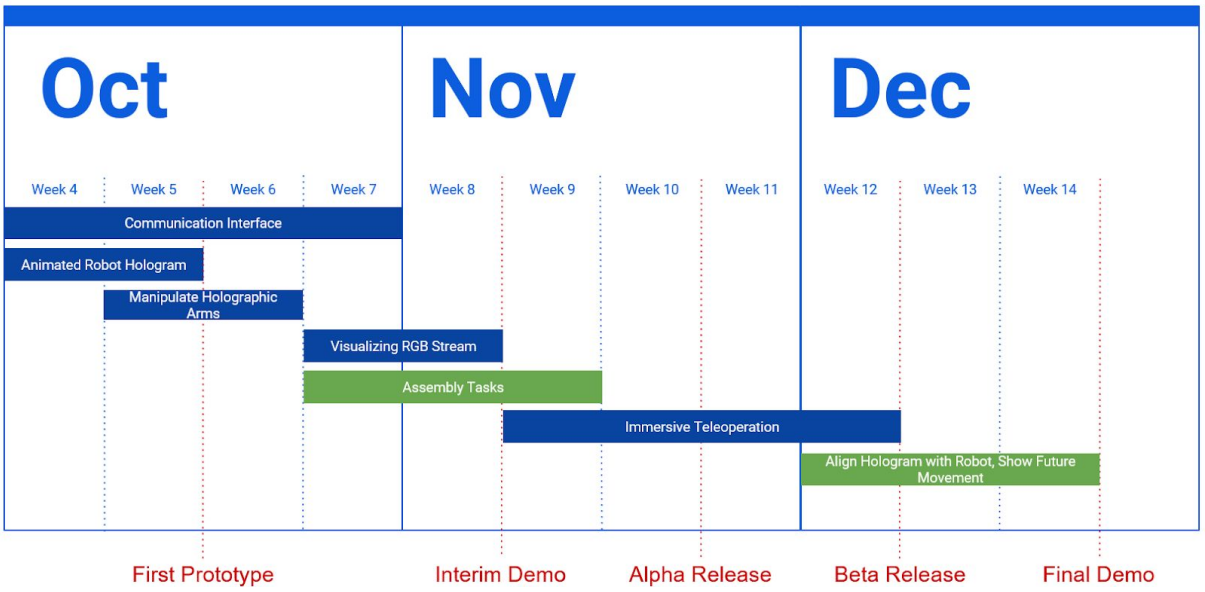
1. ***Communication Interface:***
   First, it is necessary to implement a custom communication interface between the ABB YuMi and HoloLens 2 in order to exchange all necessary information. Sub-tasks are, being able to send and/or receive,
   a. Simple position information of robot's end-effectors
   b. Robot's current pose
   c. Assembly tasks
   d. Robot's RGB stream
   e. Robot's planned trajectory/pose or similar information
2. ***External Holographic Operation:***
   In this manipulation method, the user is on the operating side and does not share the environment with the actual robot. A hologram of YuMi and its workspace is placed by the user in the environment to a location of his/her choice. The workspace represents the operating area of the robot (e.g. in our real world setup, the table in front of it). All interactions between the user and the robot happen through these two holograms.
   The user can either manipulate the holographic robot's arms directly or s/he can provide a higher-level assembly task. Concerning this task, the user can construct a structure out of holographic rectangular prisms (representing the wooden sticks). Once the holographic structure is completed, the robot starts to construct the same

structure out of the real wooden sticks. While the robot is moving, its movements are visualized by the holographic model in real-time. Sub-tasks of this work package are:

a. Visualizing a hologram of the YuMi
b. Animating the hologram such that it shows the current movement of the robot in real-time
c. Implementing a user-interface that enables the user to drag the holographic arms and thereby control the robot's arms
d. Implementing a user-interface that enables the user to click anywhere on the workspace to command the robot to move its end-effectors to that position
e. Implementing a user-interface for placing virtual sticks on the workspace, and combining all placed sticks into an assembly task

3. ***External Holographic Operation with Shared Workspace:***
   This is an extension of the previous manipulation method. We detect if the user is facing the real robot. If so, the robot's hologram is aligned with the actual robot and the robot's workspace is aligned with the holographic workspace. As a result, given an assembly task like before, the robot should place its wooden sticks exactly aligned with the holograms placed by the user. Also, while the robot is moving, its movements are animated ahead of time so that the user knows what the robot is going to do next. Sub-tasks of this work package are:
   a. Detecting the robot using markers or by its shape
   b. Aligning the robot's hologram with the actual robot
   c. Visualizing the robot's future movements by showing a 3D trajectory or by animating the holographic robot model.
4. ***Internal Immersive Operation (mimicking the VR Immersive Telemanipulation):***
   In this mode the user controls the robot's actuators directly. A holographic window (optionally full-screen VR mode) shows the RGB-stream of the robot's stereo camera. The user's hands are tracked by the HoloLens and the filtered information of such poses are sent to the robot, enabling the user to directly control the robot's arms with his/her arms. Simultaneously, the HoloLens tracks the user's head movements, which are used to control the stereo camera of the robot. Sub-tasks of this work package are:
   a. Displaying the robot's RGB stream in the HoloLens as a window (when in external holographic mode) or in full-screen (when in internal immersive mode). Developing a user interface for switching between external and internal modes.
   b. Tracking the user's hand movements and mapping them directly onto the robot's end-effectors.
   c. Tracking the user's head pose and mapping it to the controller of the robot's camera.
   d. Integrating a gesture to control the clamping mechanism of the robot's end-effectors.

Project Timeline:



3. Outcomes and Demonstration

- Low Target:
    - Communication Interface
    - Animated Robot Hologram
    - Manipulate Holographic Arms

  Planned to be done by Interim Demo. Demonstration will be able to show external holographic operation partly.

- Desirable Target:
    - Visualizing RGB Stream
    - Immersive Teleoperation

  Planned to be done by Beta Release. Demonstration will be able to show internal immersive operation in addition to the low target.

- High Target:
    - Assembly Tasks
    - Align Hologram with Robot
    - Show Future Movement

  Depending on the progress on the vital features for proof of concept, these work packages might be implemented by the Final Demo. Demonstration will be able to show full functionality as described above.