Automatic Generation of an Assembly Instruction for a Mixed Reality Environment

Motivation

One of the most exciting applications of mixed-reality head-mounted devices like the Microsoft HoloLens is to assist a user to learn / perform tasks.
The HoloLens captures the world through a depth and an RGB camera to map the position of the user in the real world. It can also provide compelling experiences where virtual 3D objects (holograms) are mixed with real ones in the real world. Hence, this device can be used to assist users in an assembly task.

Approach

A program is given a machine-readable file of assembly instructions. The automatic generation of these instructions based on a CAD file will not be in the scope of this project and the student will have to define a suitable format. The program is supposed to represent the constructions steps as a directed graph, where the vertices represent valid construction states and the oriented edges between them represent a single step. In each step, two building blocks are put together. A building block can either be a single piece or consist of multiple, previously put together pieces. As a result, the users may grab any building block and the HoloLens is supposed to either let them know one or various possible ways to proceed, or to inform them, that they cannot continue with this building block at the current state. It must, however, whenever possible, not make any assumptions on the order in which the users decide to start the assembly task. This leads to many possible valid orders. All central elements of the project, namely the HoloLens device and directed graphs, are well-known. Using those to create a new user-experience through maximal flexibility in an assembly task is new. Hence, this is different from previous projects, where the assembly instructions had to be followed in a linear, fixed order. Using this graph, it is also possible to generate human readable assembly instructions by following a single path between two special vertices, namely the one representing the empty state and the one representing the final state.

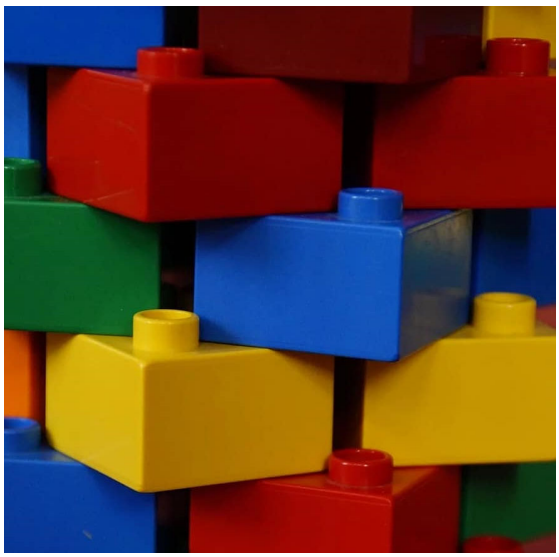

Figure 1: Duplo Bricks in various colors. Source: https://www.pikist.com/free-photo-vcogq

Project Goal

The goal of this project is to develop a corresponding HoloLens 2 app which guides the users through an assembly task. It is possible, that parts of the computations must be executed on a server to avoid performance issues. As a first approximation to a real-world task, this project focuses on assembling a wall with Duplo (large Lego for toddlers). A possible real-world application is in a factory, where assembly instructions must be manually created before other employees can start working on mass production. Using this program, the employees can either work with a HoloLens 2 device or use a set of automatically generated instructions. The app will heavily rely on detecting if the right brick sizes of the right color have been put in the right place. The student will get access to a HoloLens 2 device and will therefore be able to leverage recent capabilities like fully articulated hand tracking, eye gaze tracking, and visible light cameras to view the environment.

Task Description

For a proof-of-concept, the task will be to assemble a wall with color-coded "Duplo" bricks. Using the HoloLens 2 with potential support from a server or cloud app, the goal is to automatically find all possible orders of construction for previously defined Duplo walls. Afterwards, the goal is to support a worker in an assembly task by automatically highlighting all possible bricks that may be used for any possible steps at the current state, and by automatically inspecting whether an assembly step was performed correctly or not. The walls will be built in front of a monochrome background. In a first version, we use only two sizes of Duplo, namely small and large. Later, medium sized pieces will be added, which potentially makes the recognition more difficult. As a further challenge, assembly may take place in a more realistic environment, for example on a desk with other objects on it instead of just a monochrome background.

Afterwards, a user study should first verify the reliability of the developed app, and second it should compare a written work instruction against the mixed reality instructions using the HoloLens. To compare the effectiveness, one could measure the time needed to construct these walls.

Tasks

1. Initial literature research on existing approaches for using HoloLens in assembly instructions
2. Automatic creation of assembly instructions for a wall of Duplo on a HoloLens 2 device, using two different sizes (e.g., 2x2 and 2x8) of Duplo and multiple shades of colors.
3. Comparing the test wall obtained by following the instructions on the HoloLens 2 and alerting the user when pieces are being misplaced. This should be done before having completed the wall. Obviously, correctly placed pieces should not be misclassified.
4. Medium sized pieces of Duplo will be added, and again, the device is supposed to create assembly instructions and detect misplacements afterwards.
5. Repeating the previous tasks, but in a realistic work environment instead of a monochrome background.
6. Evaluation of the developed app in a user study and comparison of written work instructions against mixed reality instructions using the HoloLens.
7. Final and intermediate presentation, written report