**The Problem**
Human assembly is error-prone, and slower than robotic assembly. However, robots are not yet able to independently complete complex assemblies.

**The Gemini Solution**
Have a robot guide you through an assembly, projecting instructions down on a workspace for you to follow. The instructions are clear and understandable, and you will make the assembly faster, with fewer errors, and with less training than conventional systems (e.g. written instructions).

**Approach & Design**

Over the past 8 months, a working prototype of an assembly instructing robot was developed. The base used for this system was the ABB IRB-140 manipulator. The end-effector was custom made, as well as all of the software required to run and test the system.

**Kinematics**
The system initially had 8 DoF and was modified to 7 DoF when it was discovered that 8 DoF were not required. The end-effector changed from 2 DoF to 1 DoF over four prototype iterations. OpenRAVE and MoveIt! were used to do inverse kinematics and planning.

**Visual Feedback**
An XTion Pro Live was used to collect RGB-D data from the workspace. Using a combination of point cloud processing techniques (PCL library), we could determine when objects were placed incorrectly.

**Future Work**

More user tests (both control and robot), moving to a compliant robot (such as the Baxter or a Universal Arm), and working with UI experts to create a robust UI.

**User Interface**
The UI displayed to the user shows the current state of the assembly. A simulation of the intended robot pose was displayed, as was the current robot pose values and useful textual information / instructions to the user.

**Instruction Planner**
The Instruction Planner told the User Interface which instructions should go next, sent the current and intended state of the projecting end-effector, and received the current end-effector pose and current object pose from the Visual Feedback subsystem.

**Use Case**
Worker Sue prepares to assemble a new object. The robot guides her through the process by projecting down instructions - which part to work with, what to do, and where and how to do it for each step.

Upon completion of the assembly, Sue is given feedback on her performance during the assembly, in terms of accuracy and speed.

**Results**
User studies were run comparing a quick visual slide-deck instruction and our system. Low-fidelity tests were performed while the end-effector was being constructed, using three iterations of transparencies to improve the UI.

Analytics were recorded based on the time it took a user to assemble the part, the number of errors the user made, and the number of questions they asked.

**Conclusions**
After discarding outliers (90% confidence level), our system doesn’t significantly change the user’s experience. The system does appear to reduce the errors made while slightly increasing the required assembly time. Significant improvements may be seen with a more intuitive UI.

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