Intent Recognition and Temporal Relaxation in Human Robot Assembly

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Abstract

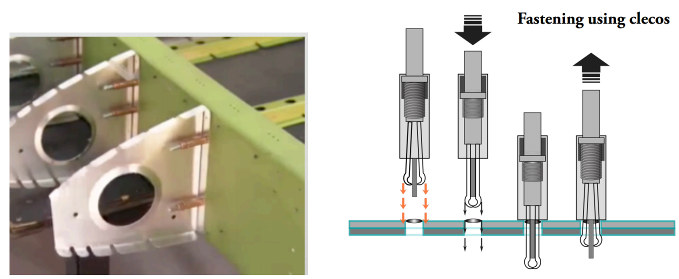
In this demo, we demonstrate how intent recognition and temporal relaxation are used in the context of a joint assembly line, with humans and robots working side by side. Intent recognition is demonstrated by the robots on the assembly line responding to the humans' actions, according to a given plan with choices. This plan with choices compactly represents several possible plans achieving the goal. However, if achieving the goal under the given time constraints is not feasible, our system negotiates feasible time bounds with the human. The specific task we demonstrate these capabilities on is one subtask of assembling a wing for a large fixed-wing aircraft: temporarily fastening the ribs (the skeleton for the leading edge of the wing) onto the already built wing frame, using a cleco gun.

Introduction

In any realistic environment in which robots and humans must act together to achieve a common goal, there are multiple sources of uncertainty. In this demo, we demonstrate two capabilities which deal with some of that uncertainty: intent recognition and temporal relaxation.

Unfortunately (at least, from our the point of view of our system), humans are not directly controllable by it. Therefore, the robots that are controlled by the system must adapt to the humans' choices, as well as to certain other uncontrollable events, such as action failure. We achieve this by following a plan with choices, which compactly represents a set of possible plans. Some of these choices are directly controllable by our system (for example, which action a robot takes), while others are uncontrollable by it (for example, which action a human takes, or whether an action succeeds or fails). Our executive, Pike, reasons about the uncontrollable choices, and makes the controllable choices such that the goal will still be achieved. This capability is described in detail in Levine and Williams (2014).

Another problem with humans, is that sometimes they set unachievable goals for the system. While a typical planning system will simply fail, our system contains a negotiating agent, Uhura. In case the goal is not achievable under the given time constraints, Uhura will ask the human to relax some of these, so that a plan can be found. This capability is described in detail in Yu and Williams; Yu, Fang, and Williams. (2013; 2014).



(a) Ribs Fastened to Frame (b) Clecos in Action

Figure 1: Ribs and Clecos

The task we demonstrate these capabilites on is one subtask of assembling the wing of a fixed wing aircraft, that of temporarily fastening the ribs of the leading edge of the wing on to the wing frame. The following section describes the task in detail, and our proposed demo.

Demo Task

The task in our demo scenario is to temporarily fasten ribs to a wing frame. Figure 1a depicts our goal: two ribs that are temporarily fastened to a frame using clecos. Clecos are fasteners, which are used to join two sheets of metal temporarily, before being permanently riveted together. Clecos are usually inserted using a high pressure cleco gun, which pushes the cleco into the hole. Figure 1b shows how clecos are inserted.

In order to accomplish this goal, each rib must be placed in the appropriate slot, clecos must be fired into every hole. Only then can we let go of the rib and move on to the next one. We will use three robots that will act together with a human, in order to accomplish this task.

The robots we will use are a Rethink Robotics Baxter robot, and two Barrett WAM arms, which are shown in Figure 2. Figure 3 illustrates how we intend to accomplish our goal using these robots. The two WAM arms will manipulate the frame, while the Baxter will place each rib in the appropriate slot, and handle the cleco gun. The Baxter will be aided by a human in several ways, which are described by the plan with choices depicted in Figure 4. Each action in the plan corresponds to an action in our domain model, formulated in PDDL 2.1 (Fox and Long 2003).

In our proposed demo, we intend to physically bring these

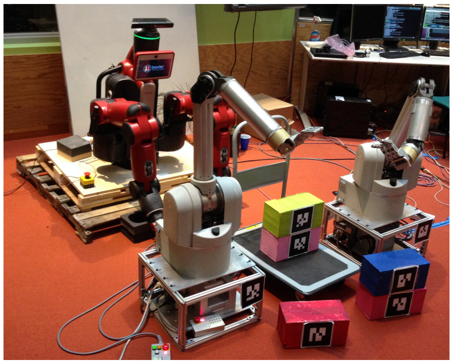


Figure 2: The robots: Baxter (the red robot) and two WAM arms, playing with blocks when they were children

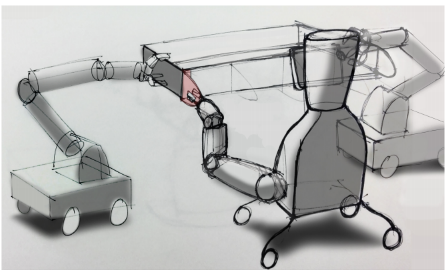
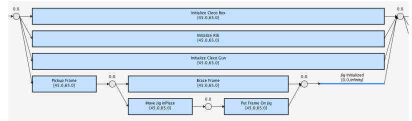
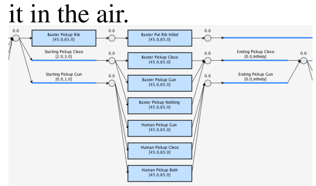


Figure 3: Illustration of our assembly concept: The two WAM arms hold the frame, and Baxter places the ribs on the frame and operates the cleco gun, aided by a human.

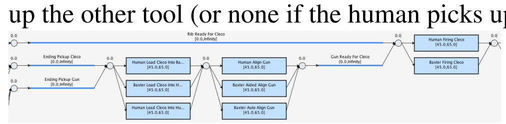
robots to Portsmouth, and demonstrate the execution of several possible plans, which are all encoded by this plan with choices, and demonstrate Uhura's negotation capability, as described in the next section.



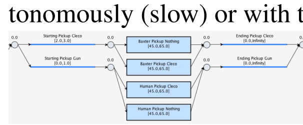
(a) Human chooses whether to move jig into place. WAM arms will respond by either placing frame on jig, or bracing it in the air.



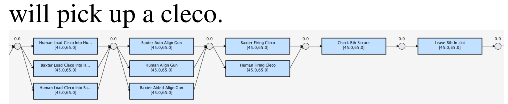
(b) Human chooses what tools to pick up. Baxter will pick up the other tool (or none if the human picks up both).



(c) The cleco gun is loaded, aligned with the hole, and fired. If Baxter is holding the cleco gun, it can align it autonomously (slow) or with the aid of a human (fast).



(d) The second cleco can be picked up by the human. If the human picks up a cleco, Baxter will not; otherwise Baxter will pick up a cleco.



(e) The second cleco is loaded and fired, and Baxter lets go of the rib.

Figure 4: The plan (with choices) that will be executed.

Execution Scenarios

First, the plan will have an unrealistic time bound. Uhura will negotiate with the operator in order to get a realistic time bound. Execution will then start, where the first choice is whether the WAM arms will brace the wing frame in the air or place it on a jig. We will execute the plan once with each choice.

The next choice is whether the human will pick up the cleco gun, a cleco from the box, or both. Baxter will respond by picking the complement. Then whoever holds the cleco will load it into the cleco gun. We will execute the plan several times, showing these different choices.

Next, if the human is holding the cleco gun, he[1] will align the cleco gun with the appropriate hole, and fire the cleco gun. If Baxter is holding the cleco gun, it has two possible actions which allow it to aim: autonomously, which is slow, or aided by a human, which is faster. Our system can reason about the remaining time, and determine that only by asking the human to help Baxter align the cleco gun, will the deadline be met, and we will demonstrate this.

After firing one cleco into the hole, a similar execution is repeated, with the difference that someone is already holding the cleco gun. Therefore, either the human will pick up a cleco, or the Baxter will, and, as before, load the cleco gun, align it with the next hole, and fire.

After two clecos have been fired, the rib is securely in place, and so Baxter can let go of the rib, and move on to the next one.

[1] currently, there are no women in the MERS group

References

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