Pilot Study of a Haptic Soldering Environment

R.C.W. Sung, J.M.Ritchie, T.Lim
Heriot-Watt University
School of Engineering & Physical Sciences
Riccarton, Edinburgh, EH14 4AS
+ 44 (0) 131 451 4569
{r.c.w.sung, j.m.ritchie, t.lim}@hw.ac.uk

R. Dewar, N. Weston
Renishaw PLC, Research Park North
Riccarton, Edinburgh, EH14 4AP
+ 44 (0) 131 451 1616
{Rick.Dewar, Nick.Weston }@Renishaw.com

ABSTRACT
Soldering plays an important role in the electronics manufacturing industry, whether it is carried out manually, semi-automatically or fully-automatically. Even though it is straightforward to learn the fundamental techniques involved in manual soldering, it still requires a vast amount of time and effort to reach an expert level. The research presented here aims to simulate the manual soldering process in a haptics environment, and by logging the users' actions automatically and unobtrusively in the background, the aim is to investigate human hand dexterity and learn how novices and experts operate differently through knowledge capture. A pilot study was carried out in which the obtained log files were parsed and the capture of knowledge was demonstrated.

Keywords
haptics, automatic knowledge capture, knowledge representation.

1. INTRODUCTION
Haptic technology is the science of applying tactile sensation to human interaction with computers. Force-reflecting haptic devices generate computer-controlled forces to convey to the user a sense of the feel of the virtual environment and objects within it. This is referred to as a haptic interface.

Even though there is an abundance of research related to haptics, none have been found which focuses on the application of it to soldering. However, research has been carried out on a soldering simulation environment using a graphics tablet [1], and by varying the pressure applied using the stylus pen, the amount of solder applied can also be varied. Drawbacks of the current system include the tactile feedback being limited to that on the plane of the tablet surface, and the user is limited to using only one hand, rather than using both hands as in the real world.

The haptic soldering environment in this research consists of two Sensable Phantom Omni™ devices [2] that run the software environment developed using the OpenHaptics API [3].

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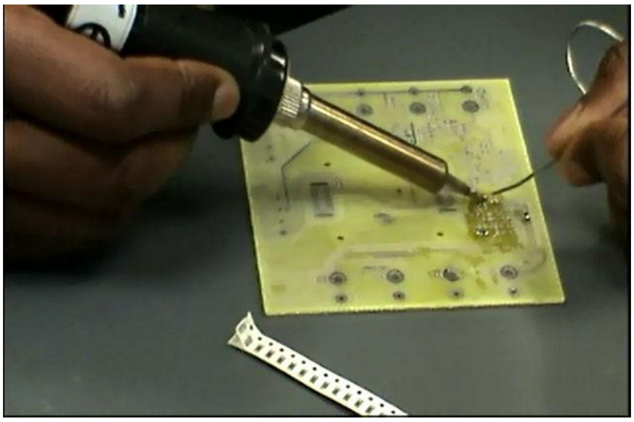
The standard configuration has the right-hand side Phantom Omni controlling the soldering iron and the left-hand side controlling the tweezers that is used to position a resistor which is to be soldered, as illustrated in Figure 1. Depressing a button on the left-hand side controller also displays the soldering wire so solder can be applied onto the soldering iron. After a specific amount of solder has been applied by the iron, a message will be flagged to the user to indicate more solder needs to be added to the iron. The current simulator does not model the solder flow or heat processes involved but this will be added in a future revision. Finally, even though the visual display of the soldering simulator is not superimposed onto the position of haptic devices, the tactile feedback provided by the haptic devices should still provide a realistic experience for the user; furthermore, the hand motions that will be captured by the system will not be affected by the positioning of the visual display.

Figure 1 - Dual Haptic Devices

2. PILOT STUDY
The pilot study carried out involved two participants with prior soldering experience carrying out a soldering task in the real world and in the haptic environment, as shown in Figure 2.
User activity in the haptic environment is automatically and unobtrusively logged in the background so properties such as the force, velocity, position and angle of the haptic pen is recorded, as well as the haptic pen buttons that are pressed. By logging expert users performing a soldering operation, their technique can be recorded used to aid in the training of novice users.
By automated parsing of the log files, important user actions were extracted and formalised using several knowledge representations

utilised in previous research [4] - some of which are also used in engineering companies – and these include: XML (Extensible Markup Language)[5]; PSL (Process Specification Language) [6]; IDEF0 (Integrated Definition Methods) diagrams [7]; DRed (Design Rationale Editor) [8]; English-syntax instructions. The knowledge representations that have been automatically generated for a simple soldering task are illustrated in Figures 3-7, and the information contained in the representations include the sequence in which the tasks were performed, the position of the haptic device that corresponds to the soldering iron, and the time each task took to complete.



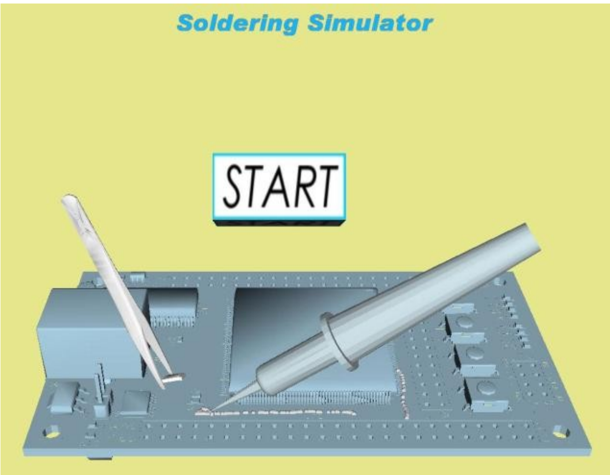


Figure 2 - Real world Soldering (top) and Haptic Soldering (bottom)

This formalised representation could, potentially, allow the data to be stored in a knowledge base for future re-use; for example, a Product Lifecycle Management (PLM) system that many companies now utilise.

In the questionnaires that were completed after the experiment, positive user feedback was obtained for the intuitiveness, tactile feedback and graphics quality of the virtual environment. However, the users commented that there were slight issues with depth perception and the control over the viewpoint positioning.

Regarding the realism of virtual soldering environment, the users suggested a way to monitor the PCB temperature and more accurate modelling of solder flow as possible improvements to be made to the haptic environment; however, the users felt this was not essential for the training application concerned as long as the haptic feel of the process was useful and quite similar to the real world.

3. FUTURE WORK & CONCLUSIONS

A haptic environment has been developed to simulate the soldering of electronic components to a printed circuit board, and a pilot study has been conducted to compare the soldering process in the real world and haptic environment. The users' actions in the virtual environment were logged, and by performing automated post processing of the log files, knowledge relating to the soldering processes performed by the users was extracted and formalised using various representations.

Future work will involve improving the realism of the haptic environment by adding a stereoscopic view to aid depth perception. In addition, the modelling of the solder flow process can be made more accurate. Further user trials will be carried out that involve more participants, and by involving novice and expert users their performance can be compared by analysing their respective log files.

4. ACKNOWLEDGMENTS

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5. REFERENCES

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Figure 3 - IDEF0 Knowledge Representation

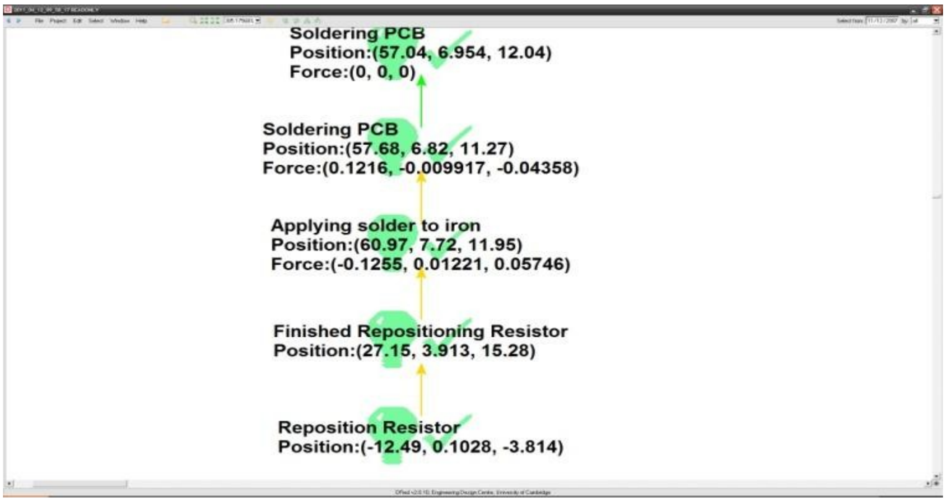
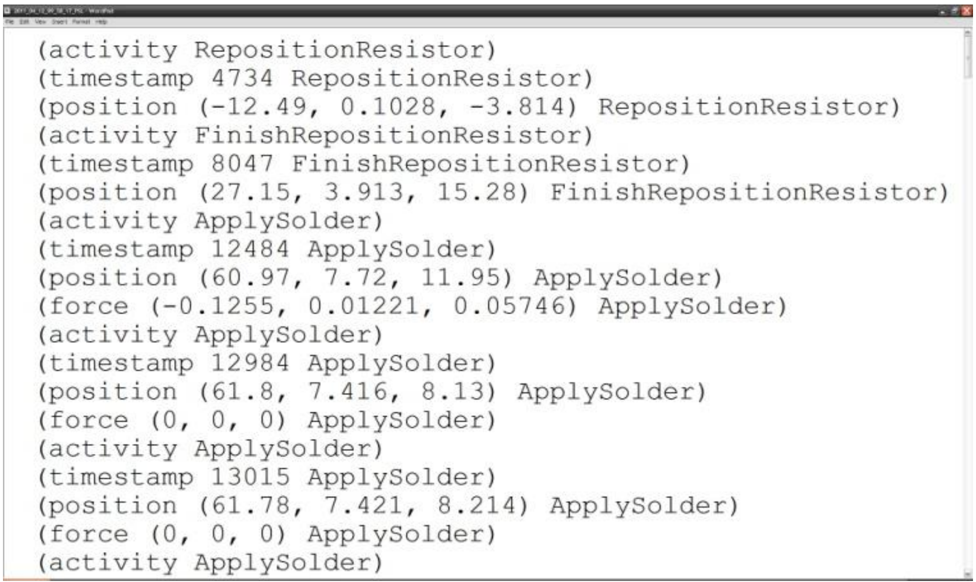


Figure 4 - DRed Knowledge Representation

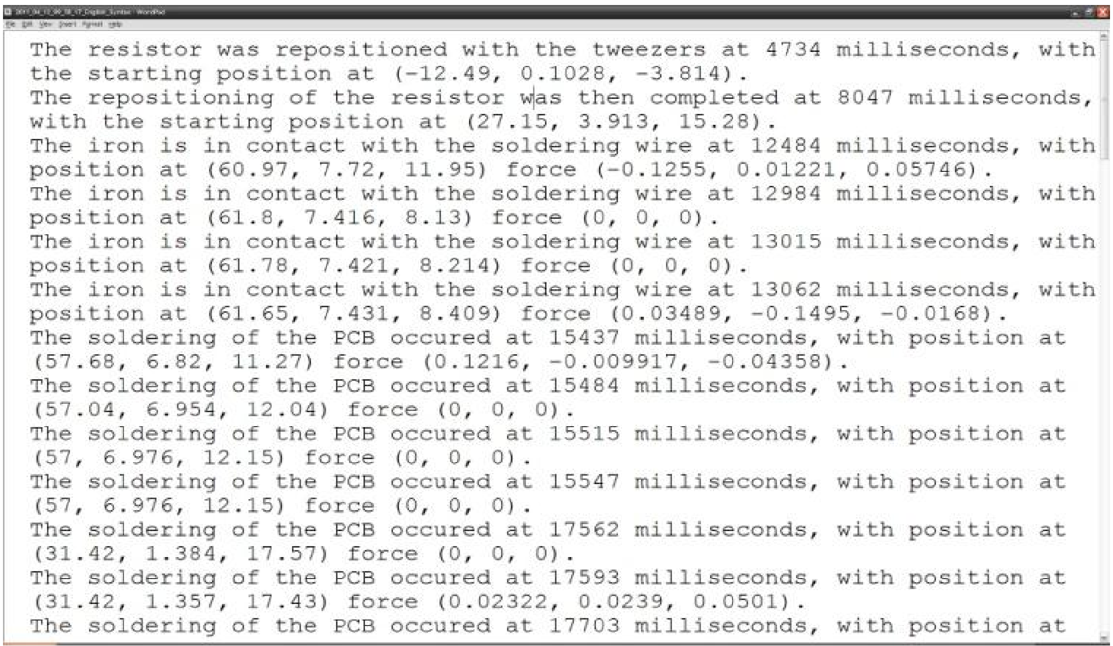


```
(activity RepositionResistor)
(timestamp 4734 RepositionResistor)
(position (-12.49, 0.1028, -3.814) RepositionResistor)
(activity FinishRepositionResistor)
(timestamp 8047 FinishRepositionResistor)
(position (27.15, 3.913, 15.28) FinishRepositionResistor)
(activity ApplySolder)
(timestamp 12484 ApplySolder)
(position (60.97, 7.72, 11.95) ApplySolder)
(force (-0.1255, 0.01221, 0.05746) ApplySolder)
(activity ApplySolder)
(timestamp 12984 ApplySolder)
(position (61.8, 7.416, 8.13) ApplySolder)
(force (0, 0, 0) ApplySolder)
(activity ApplySolder)
(timestamp 13015 ApplySolder)
(position (61.78, 7.421, 8.214) ApplySolder)
(force (0, 0, 0) ApplySolder)
(activity ApplySolder)
```

Figure 5 - PSL Knowledge Representation

```
<?xml version="1.0" encoding="UTF-8" ?>
- <soldering_events>
  - <reposition_resistor>
      <reposition_resistor_timestamp>4734</reposition_resistor_timestamp>
      <reposition_resistor_position>(-12.49, 0.1028, -3.814)</reposition_resistor_position>
    </reposition_resistor>
  - <finish_reposition_resistor>
      <finish_reposition_resistor_timestamp>8047</finish_reposition_resistor_timestamp>
      <finish_reposition_resistor_position>(27.15, 3.913, 15.28)</finish_reposition_resistor_position>
    </finish_reposition_resistor>
  - <applying_solder>
      <applying_solder_timestamp>12484</applying_solder_timestamp>
      <applying_solder_position>(60.97, 7.72, 11.95)</applying_solder_position>
      <applying_solder_force>(-0.1255, 0.01221, 0.05746)</applying_solder_force>
    </applying_solder>
  - <applying_solder>
      <applying_solder_timestamp>12984</applying_solder_timestamp>
      <applying_solder_position>(61.8, 7.416, 8.13)</applying_solder_position>
      <applying_solder_force>(0, 0, 0)</applying_solder_force>
    </applying_solder>
  - <applying_solder>
      <applying_solder_timestamp>13015</applying_solder_timestamp>
      <applying_solder_position>(61.78, 7.421, 8.214)</applying_solder_position>
      <applying_solder_force>(0, 0, 0)</applying_solder_force>
    </applying_solder>
  - <applying_solder>
      <applying_solder_timestamp>13062</applying_solder_timestamp>
```

Figure 6 - XML Knowledge Representation



The resistor was repositioned with the tweezers at 4734 milliseconds, with the starting position at (-12.49, 0.1028, -3.814).
The repositioning of the resistor was then completed at 8047 milliseconds, with the starting position at (27.15, 3.913, 15.28).
The iron is in contact with the soldering wire at 12484 milliseconds, with position at (60.97, 7.72, 11.95) force (-0.1255, 0.01221, 0.05746).
The iron is in contact with the soldering wire at 12984 milliseconds, with position at (61.8, 7.416, 8.13) force (0, 0, 0).
The iron is in contact with the soldering wire at 13015 milliseconds, with position at (61.78, 7.421, 8.214) force (0, 0, 0).
The iron is in contact with the soldering wire at 13062 milliseconds, with position at (61.65, 7.431, 8.409) force (0.03489, -0.1495, -0.0168).
The soldering of the PCB occured at 15437 milliseconds, with position at (57.68, 6.82, 11.27) force (0.1216, -0.009917, -0.04358).
The soldering of the PCB occured at 15484 milliseconds, with position at (57.04, 6.954, 12.04) force (0, 0, 0).
The soldering of the PCB occured at 15515 milliseconds, with position at (57, 6.976, 12.15) force (0, 0, 0).
The soldering of the PCB occured at 15547 milliseconds, with position at (57, 6.976, 12.15) force (0, 0, 0).
The soldering of the PCB occured at 17562 milliseconds, with position at (31.42, 1.384, 17.57) force (0, 0, 0).
The soldering of the PCB occured at 17593 milliseconds, with position at (31.42, 1.357, 17.43) force (0.02322, 0.0239, 0.0501).
The soldering of the PCB occured at 17703 milliseconds, with position at

Figure 7 – English-Syntax Knowledge Representation