Haptic Soldering & Knowledge Capture

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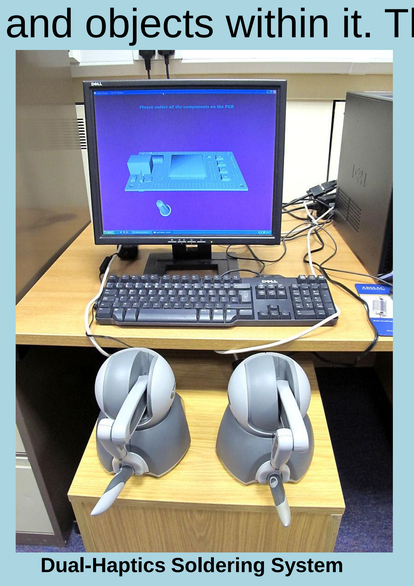
Introduction

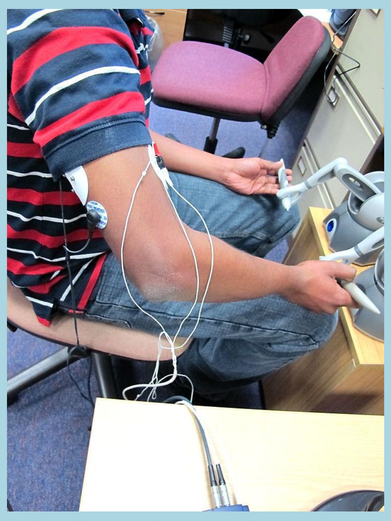
In the electronics manufacturing industry, soldering plays a key role in the process, whether it is carried out manually, semi-automatically or fully-automatically. Even though the basic techniques in manual soldering are comparatively straightforward, to master it at a high level still requires a lot of time and effort. The research presented here aims to identify the motor skills involved in soldering and the ability to recognise when a soldering process is likely to go wrong. If this soldering knowledge was able to be captured, this would allow the development of automated soldering processes that work more efficiently. By simulating the manual soldering process in a haptics environment, the aim is to employ automated user logging to investigate human hand dexterity and learn how novices and experts operate differently through knowledge capture.

Haptic Soldering

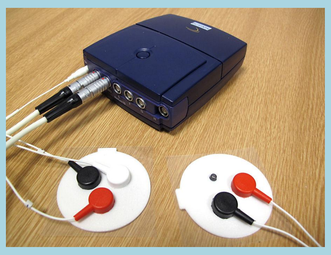
The word Haptic comes from the Greek, haptesthai, meaning to touch. Haptic technology is the **science of applying tactile sensation to human interaction with computers**. Force-reflecting haptic devices generate computer-controlled forces to convey to the user a sense of the feel of the virtual environment and objects within it. This is referred to as a haptic interface.



Dual-Haptics Soldering System

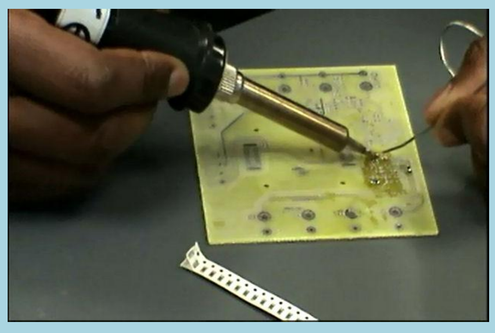


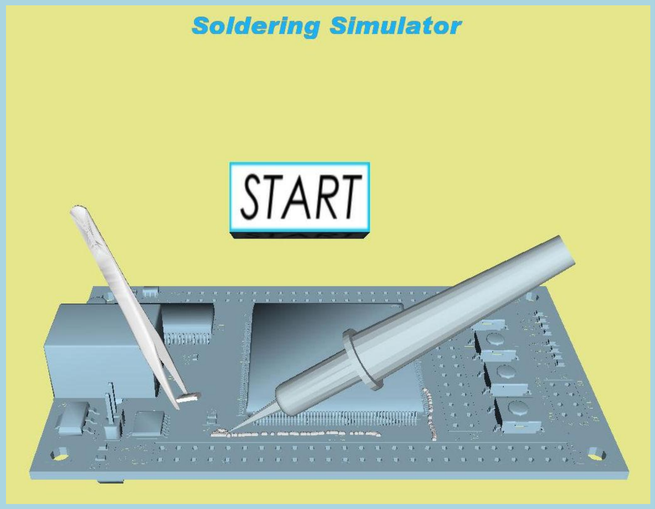
Arm Muscle Response Measurement



NeXus-10 Muscle Response Measurement Device

The haptic soldering environment in this research consists of two Sensable Phantom Omni™ devices that run the software environment developed using the OpenHaptics API.
The standard configuration has the right-hand side Phantom Omni controlling the soldering iron and the left-hand side controlling the tweezer that is used to position the resistor that is to be soldered. Depressing a button on the left-hand side controller also displays the soldering wire so solder can be applied onto the soldering iron.





Soldering inside the Real World and the Haptic Environment

Pilot Study

The pilot study carried out involved participants with prior soldering experience carrying out a soldering task in the real world and in the haptic environment whilst having their arm muscle response measured. 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 automated parsing of the log files, important user actions were extracted and formalised using several knowledge representations utilised in previous research, which are: XML (Extensible Markup Language); PSL (Process Specification Language); IDEF0 (Integrated Definition Methods) diagrams ; DRed (Design Rationale Editor);English-syntax instructions.

```
(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)
```

PSL Knowledge Representation

IDEF0 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>
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    <applying_solder_timestamp>13062</applying_solder_timestamp>
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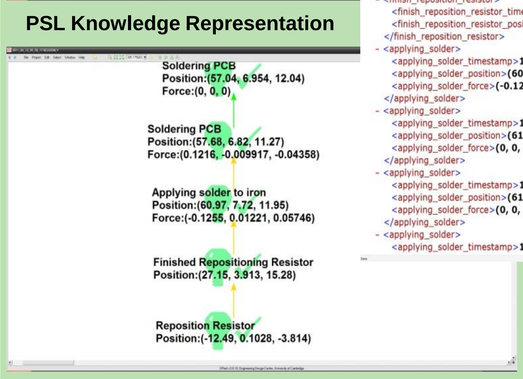
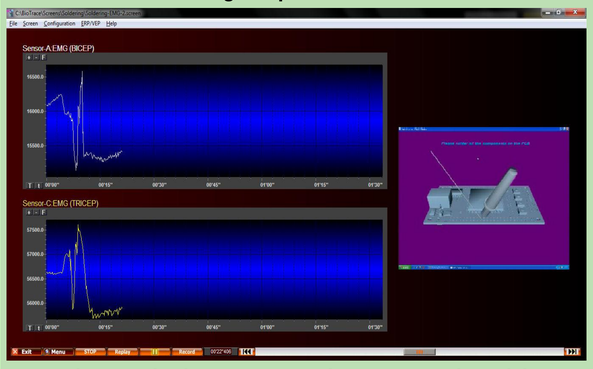
XML Knowledge Representation



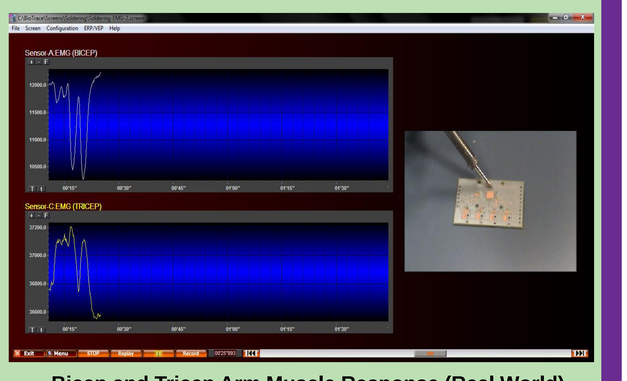
DRed Knowledge Representation

```
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
```

English-Syntax Knowledge Representation



Bicep and Tricep Arm Muscle Response (Haptic)



Bicep and Tricep Arm Muscle Response (Real World)

Conclusions & Future Work

- Development of haptic environment to simulate the soldering process
- Conducted user trials involving soldering in the real world and haptic environment with users' actions being logged
- Automated post processing of log files enabled knowledge to be extracted and formalised using various representations
- Arm muscle responses in the haptic and real world environments showed similarities
- Need to investigate the affects of adding stereoscopic view to soldering environment
- Further analysis of soldering log files is required to identify and extract more detailed embedded tacit knowledge

IMRC Innovative Manufacturing Research Centres
James Watt Institute *for* High Value Manufacturing - Edinburgh
EPSRC Engineering and Physical Sciences Research Council