James Dyson Undergraduate Bursary 2017/18

Tactile-Based Robotic Control for the Examination of a Soft Object

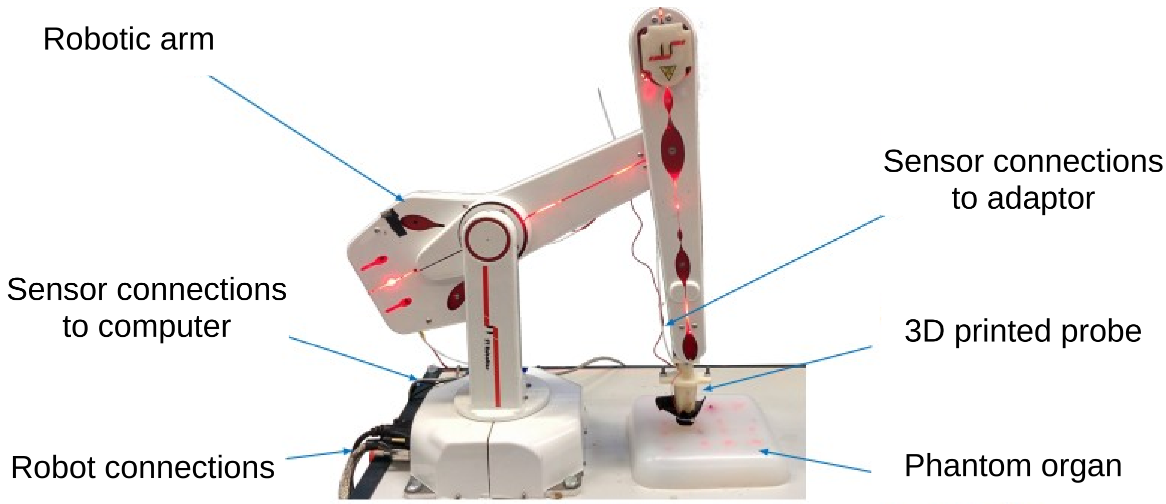
Edward Bray, Fitzwilliam College

In recent years, robots have been getting increasingly more advanced. They have been used in certain areas, such as factories, for decades as these environments are very organised, so robots can be programmed to simply perform the same movements repeatedly as all the tools and components can be placed in the same location over and over again. However, the real-world is not like this at all, so research needs to be done into how to make robots more advanced before they can become a more common part of everyday life.

One factor that needs to be considered is called *feedback*. This is where information from sensors is passed onto the computer controlling the robot and used to help it decide what to do next. Animals generally use five senses to interpret the world around them (sight, touch, hearing, smell, and taste) so it would seem logical that robots could use similar senses. Sight is the most useful, and because of this there’s been a lot of research into how robots can use cameras to let them see. Touch is almost as important though: consider how hard it is to do something easy like tying your shoelaces when your hands are numb with cold! There’s been surprisingly little research into how to give robots a sense of touch though.

My project was related to how robots could use touch to help them with a task. The specific task chosen was that of *palpation* during a breast cancer diagnosis. This is where doctors will use their fingers to examine a patient to determine if they have breast cancer or not. They are trying to find tumours, which are hard lumps within the soft tissue of the breast. Robots are already used in medicine, for example in surgery or x-rays, so it’s likely that in future they’ll continue to be devloped for similar applications. With proper programming, they can be made more reliable than humans and so help to save lives.

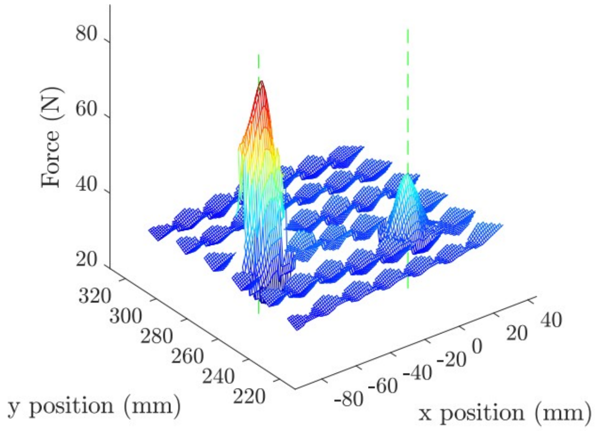
Obviously a real patient couldn’t be used for this project, so a *phantom organ* was used instead. This is a lump of soft silicone with 3D printed plastic spheres buried inside it. This was examined with a robotic arm with a probe attached to the end of it. The tip of this probe was covered with a sensor that could detect the forces across the probehead when it was pressed down into the phantom. This is called a *tactile image*, as it’s similar to a photograph. A photo of the whole setup is shown below.



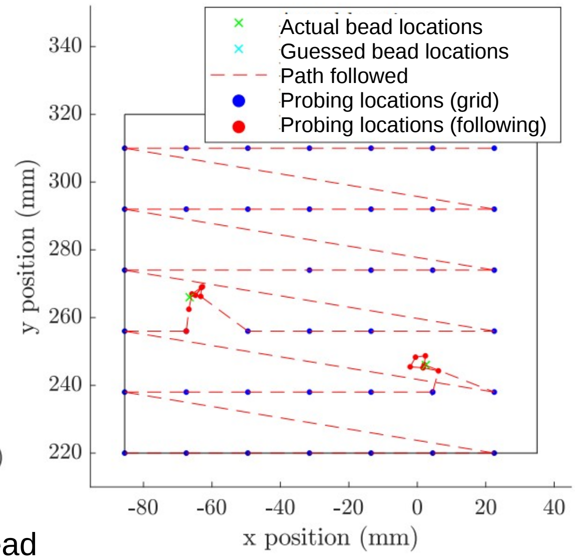
The robot was programmed to perform two seperate tasks. The first was to try and find the beads within the phantom organ. The probe was pressed vertically downwards to a fixed depth and a tactile image recorded at this point. The task was to decide where to press down next, given the previous information, to reduce the total number of locations the robot had to probe.

The most obvious way to do this is with just to do it in a grid with a small spacing so that no areas are missed. However, this takes a lot of steps. The way I developed was to start off probing in a grid, but with a large spacing. Whenever the robot had probed near to a bead, the gradient of the tactile image would become large as the bead would produce a larger force on one side of the probe than the other. The robot would then stop probing in the grid and instead follow this gradient to close-in on the bead.

All of the tactile images were collected into a *force map* that shows the variation in force across the phantom organ. If you look at the example below, you can see three peaks that correspond to the location of beads in the phanom organ. Large and shallow beads produce a bigger force than small and deep ones, which is what you'd expect. Using this method, the robot could detect beads to an accuracy of a few milimeters in only 70 steps, whereas using a grid required over 200 so is much less efficient.



A force map, showing the peaks at the bead locations



Locations where the robot had to probe during this test

The other task was to look into how the robot could determine other things about the beads, such as their size and depth, once they'd been found. This is similar to how a doctor could tell how dangerous a tumour is by feeling how large it is. We looked at how far you need to press straight down on a bead to accurately decide this, and also whether it's better to rotate the probe as well.

This data was analysed, and it was found that both pressing straight down and rotating are as good as each other for this task. As expected, the deeper you pressed the better the data got and the more certain the robot became about the classification of the beads.

However, it's important to remember that this could be used in humans as well. The vertical motion needed to press really far into the phantom organ to be certain, which could be uncomfortable for a real person. The rotary motion, on the other hand, didn't need to press anywhere near as much into the phantom to get enough data, so would be more suitable for a final palpation diagnosis robot. This shows the importance of remembering the final purpose of a product in all stages of the development.