Technology and Context of Robotics and Autonomous Systems (TCRAS)

Note- in some cases I have written for both lectures on both days, for later reference.

**Week 1**

UoB 29/09/17

*Introduction – Dr Nathan Lepora.*

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This introductory lecture began by discussing the various definitions of a robot, as well as the interpretation of the term by the general public. An interesting point was made on the role that robots play in the modern human world, where the ‘four d’s’ (dirty, dangerous, dull, delicate) describe scenarios in which robotic/autonomous systems have the most potential.

Discussion then moved to the progress of robotics over the history of the discipline; Particularly important was the addition of sensors to robots, allowing the input – computation – output loop to be closed, allowing autonomous systems to adapt to changing external conditions through feedback loops. This was followed by a summary of likely future applications, such as agriculture, bionics and care work.

Finally, the challenges facing roboticists were highlighted (software and hardware), such as cost, power, sensor fidelity and AI complexity.

**Week 2**

UWE 04/10/17

*Human-robot interactions – Manuel Giuliani*

This research was based around interactions between humans and robots in various different contexts. The importance of such research was heavily stressed, due to the likelihood of a massive increase in the numbers of robotic systems in civilian life, be it in the home or workplace. Many robots currently used in industry are in no way suited to direct human interaction, due to the potential for injury that they pose.

The research highlighted the difficulties in creating fluid, natural interactions between people and robots; the many nuances of human language and physical expression make interactions extremely difficult. Also of note was the natural human reactions to such systems, in particular to broken social conventions and robot error scenarios.

**Week 3**

UoB 09/10/17

*Soft Robotics – Dr Jonathan Rossiter (soft robotics group, BRL)*

An general introduction to the work done by the BRL in soft Robotics, spanning many different areas of research. Particularly emphasised were the limitations of rigid robots; though incredibly useful in manufacturing applications, replication of biological systems becomes very difficult, since rigid systems are not very forgiving. An important consideration was also emphasised; as robots become more ubiquitous in day to day life, soft robots will likely play an increasing role due to the need for safe robot-human interaction.

This is a rather new area of research, and many challenges need to be overcome before such systems enter regular use. In particular, biological systems have extremely complex sensory capabilities, allowing for fine motor control of limbs etc. ‘Octobot’ was highlighted as an interesting example of an entirely soft robot, though the gulf between the capabilities of Octobot and the biological system that inspired it show that there is a long way to go (though this in no way detracts from the obvious potential of soft robotics). Also, as of yet soft actuators do not even come close to the power of conventional rigid systems, limiting their use in industry.

UWE 11/10/17

*Morphological Computation; The hidden superpower of soft bodies – Dr Helmut Hauser (Note – also read a short paper by Dr Hauser to clear up some confusion that the talk presented).*

A video of a slinky on a treadmill formed an effective introduction to the concept of adaptive morphology; though obviously not possessing any intelligence of its own, the slinky nevertheless displays the seemingly intelligent behaviour of changing direction towards the centre of the treadmill upon reaching the edge. This is considered a rudimentary form of ‘emergent’ intelligence, in which seemingly complex behaviour results from a simple set of rules

Most modern robotic systems are formed from rigid bodies, and though incredibly useful in highly controlled situations (manufacturing etc), issues do arise in dynamic situations where adaptability is key. Clips from the DARPA robotics challenge demonstrated these issues particularly well, in which attempts to reproduce humanoid structures using rigid bodies obviously lacked the sensory and mechanical fidelity that largely ‘soft’ humans possess, making completion of various simple tasks very difficult (simple for a human to complete at least).

It was then highlighted that nature takes a completely different approach; biological systems utilise soft bodies, with very high DOF, many underactuated (passive) DOF, and physical parameters such as friction and springiness that are intrinsic to their morphology.

Discussion then moved to computational methods for such complex systems – rigid systems with lower DOF are inherently simpler to control, since each joint etc can be directly actuated, while replicating something as complex as a tentacle is a whole new problem, especially when requiring constant computation with feedback The approach in the research displayed here involved the use of reservoir computing, in which physical parameters of the soft body in essence carry out the computation, taking some of the burden away from any control system. Examples included were the tentacle embedded with ‘stretch’ sensors, and the artificial spine embedded with pressure sensors.

This approach, when combined with some degree of machine learning, allows for the system to adapt to changing conditions far more effectively, hence going some way to replicating the adaptability of biological systems. Some further research mentioned suggested that spiders may use their webs as a computational device, listening to and interpreting the complex stream of data coming back – ie. the many different vibrations on the web (characteristic of different disturbances) are combined into one stream of data, that the spider ‘reads’ and interprets accordingly.

**Week 4**

UoB - 16/10/17

*Dr Nathan Lepora – Tactile Robotics*

Discussion began with a consideration of the necessity for increased sensory capabilities of robots, in particular touch; humans (and animals in general) are particularly adept at manipulating world around them, largely due to the combination of vision and touch, and replication of these capabilities would be a huge boon to robotics as a discipline. However, this is in no way a trivial task.

The BRL approached this problem by 3D printing their own modular sensors (to massively reduce cost). These sensors utilise soft skins, with optically tracked internal ‘pins’ to measure force and shape change, inspired by human skin, which utilises a similar structure. The data flow from the sensor is then computationally interpreted. The challenge lies with interpreting this data stream, and various methods were demonstrated that increased the positional accuracy of surface readings,

With the rapid advancements in sensory technology like this, the next step would be the application of this technology to robotic hands/prosthetics, to provide such systems with a sensory input that is so important for interaction with such a dynamic world.

*Tim Adam – Designability (charity name) – Function Adaptive Support Systems for Neuromotor Disability.*

An interesting insight into the development process of a support system for disabled children, in an attempt to improve quality of life for those afflicted with neuromotor diseases. The emphasis he placed on simplicity as a desirable trait, and the elegance and functionality this provided, was particularly resonant.

The main research discussed was that of a dynamic, adaptive seat that allowed for the spasms typical of many NM diseases, constraining them enough to reduce harm, whilst also allowing the spasm to happen naturally. This somewhat mimics the way a parent might hold the child. Research suggested that full suppression of these spasms by static seats actually increased the severity of the spasm, in turn increasing pain and risk of injury for the patient (child in this case). After various prototypes (this is not a trivial problem, and the design process hit a few dead ends), the finished design was found to be particularly effective in reducing the severity of spasms, while the freedom of movement it provided to the legs individually allowed the child greater control over movements elsewhere in the body, and (arguably more importantly) greatly reducing discomfort for the child.

The fresh challenges facing the project lie with the designing of an *active,* adaptive support system, in which the level of suppression of spasms is proportional to the severity of the input, and thus mimicking the parent’s ability to adapt to a varying severity of symptoms. This is where the relevance of this project to us is particularly obvious, through the need for a combination of mechanical, electrical and intelligent control systems that would be of great benefit.

UWE – 18/10/17

*Mark Hansen, PhD – Applied Machine Vision for Agritech and Biometric Security.*

Research within the Centre for Machine Vision, aimed at utilising photometric stereo methods for 3D imaging across a range of applications in the above fields. The method employs the use of lighting at various angles to illuminate the subject, with each lighting position forming an image. The combination of images of the subject under these different lighting conditions is then interpreted by the system to form an accurate 3D model of the surface. This technique has the potential to greatly reduce costs 3D imaging, and therefore perhaps increase the ubiquity of such technology across a wide swathe of applications.

For security applications, 3D imaging of faces for rapid identification was explored, and has the potential to allow for very rapid facial scanning. Another application is 3D video for detection of objects under clothing; shapes of solid objects beneath clothing can be easy to miss visually due to lighting conditions, colour etc., while 3D images give objective data on the underlying shape.

For agritech applications a range of research areas were explored: overhead imaging of cows to determine the cause of lameness, as well as displaying potential for improved recognition of specific animals; Weed detection applications, in which weeds must be rooted out if they are outgrowing surrounding pasture, that utilised spatial and frequency variations of images to highlight weeds; 3D plant phenotyping, to alleviate the time spent manually measuring changes in position, length, colour etc of various plants during growth; Pig face recognition to improve livestock management.

Various challenges arose across these applications. Neural networks used in some of the examples are fraught with issues relating to the ‘black box’ problem, in which the exact method used by a network to identify between individuals/animals is unknown even to the programmer of the network. The plant phenotyping example brought problems with leaf labelling, and the subsequent tracking, an issue that was alleviated through the introduction of deep learning methods.

***Week 5***

UoB – 23/10/17

*Soft Robotics – Smart materials – Andrew Conn*

Discussion on research into smart materials and their potential applications in soft robotics, beginning with a summary of the limitations of traditional rigid body robots; their lack of adaptability and the difficulty of HRI presents a difficult problem in modern robotics.

Soft robotics presents a solution to some of these issues, whilst also opening up new areas of research previously deemed unfeasible. Implantable devices could be made to merge seamlessly with the body, whether under the skin or embedded inside organs, while HRI technology is likely to boom with further research into soft body robots (and sensors). The field of biomimetics will also benefit greatly, where the mimicking of biological systems was previously difficult using only rigid components.

Emphasis was put on the role that smart materials with have on the field of robotics on the whole; soft robots are unlikely to completely replace their rigid counterparts, but instead provide a set of tools with very different characteristics, that can be combined with rigid components. Rigid robots still have many advantages (strength and power in particular, at least at the moment), but could greatly benefit from the inclusion of soft components.

Much of the research into soft actuators has centred around fluid elastomer networks, in which fluid is pumped around a structure to expand and contract cavities, and in turn generate the desired movement/force. Smart materials offer another solution, with lower complexity and less support systems. The research at the BRL focused on replicating biological actuators, using smart materials that bend, expand or contract upon electrical stimulation.

These actuators have a range of forms and uses, of which two examples were given. Actuators inspired by musculoskeletal systems allow high degrees of freedom, whilst simultaneously remaining extremely simple and utilising the elastic properties of the material to store potential energy. Another application would be in the field of medicine, where smart materials could replace or supplement various aspects of the human body where needed, such as mucus membranes or sections of the intestinal tract.

UWE 25/10/17

*Dr Lili Tao – Computer Vision in Healthcare Applications.*

Began with an introduction to the SPHERE project, in which various sensor systems were embedded within the homes of the elderly and disabled. Data from these sensors was then sent to a hub for use in machine learning, with the eventual goal of understanding how the less able interact with their homes.

Many aspects of these interactions were studied, but only two were mentioned here in detail. The first example given was the used of 3D depth images to form skeletal structures representing the movement of the patient. These sensors were placed at various points throughout the test home, with the example shown analysing the movement of the patient climbing a set of stairs. Through analysis of the gait of the test subjects using these skeletal frames, and combined with machine learning, changes in gait could easily be identified, particularly over long periods of time. This allowed for the identification of various traits, such as a leading leg, or general slowing of gait, that could suggest to a clinician that an ailment is present, even in its early stages. This could provide a powerful tool to supplement the natural intuitions of doctors and nurses, and allow closer monitoring without the presence of a care worker.

Depth sensors were also utilised, combined with wearable accelerometers, to estimate the calorific expenditure of patients. To test the efficacy of the system, the estimations were tested against a ground truth, consisting of a gas mask, for definitive caloric burn measurements. Comparison of the results suggested that the system was very effective for estimation, potentially providing useful calorie expenditure data with minimal invasiveness. Information provided could be used by clinicians to watch for trends in activity levels that may be indicative of a new ailment, providing an early warning system of sorts.

**Week 6**

UoB 25/10/17

*Ultrahaptics (Company name*

This talk focused on the technology developed at the BRL/UoB to aid in haptic feedback. Emphasis was placed on the importance of haptics in robotics, in particular replicating the sense of touch. Ultrahaptics focuses on creating an interface device through which the feeling of touch can be imparted to the user through ultrasound.

A square array of ultrasound emitters is used to form areas of constructive interference in the 3D space above device, effectively creating a localised sense of pressure on the skin that can be formed into any desired 3D pattern. An infrared depth sensor provides an accurate virtual representation of the hand above the array, providing the data required to allow the software to control the emission levels of the individual emitters.

The obvious application of this technology would be to virtual and augmented reality, where the sense of touch is largely absent with current technology. The combination of this technology with VR/AR (an already highly immersive experience) could provide an incredible new avenue of interaction with the virtual world.

The technology has other wide-reaching applications, even if not as exciting. Many interfaces for new products, particularly those with touch screens, lack the tactile feedback that old products used to provide. As an example, the many sliders and dials on car dashboards are slowly being replaced by touch screens, decluttering the car but taking the drivers attention away from the road when trying to change a car setting. This sensor could allow the driver to feel for a virtual dial, without needing to divert attention.

UWE – 01/11/17

*Sanja Dogramadzi – Healthcare Robotics at BRL*

Began by outlining the benefits of the surgical robotics to the medical profession; more difficult procedures can be carried out by less skilled individuals. The rate at which patients can be treated depends heavily on the surgical challenge – very difficult procedures require highly skilled, highly specialised surgeons, for which demand is always high, and the low availability of such skilled professionals greatly reduces treatment rates.

The various methods of robotic surgery were mentioned, ranging from the fully autonomous (cyberknife used in radiotherapy), to shared control devices (SteadyHand, DaVinci), which can also allow for tele-operation.

One area research at the BRL focused on the development of a hand exoskeleton, combined with haptics, to provide the surgeon a control interface that provides haptic feedback from a small three fingered robotic hand. Soft robotics has now also been proposed as a way to improve the ergonomics of the device, reducing the bulkiness and providing a more natural feeling interface.

Another interesting advance was in the use of CT scans to produce 3D models of fractured bones, to allow surgeons to manipulate the virtual bone fragments and determine how best to reset the bone, and where to insert pins if required.

The TacTip devoloped at the BRL was also mentioned as a method of providing a more objective detection of lumps under the skin, and perhaps providing some insight into the shape of the offending mass.

**Week 7**

UoB – 06/11/17

*Let there be sight – Majid Mirmehdi*

Essentially an overview of current computer vision research at UoB. He began with a brief introduction to the concept of computer vision, and the obvious ties to the study of biological vision, stressing that computers are still very limited, with narrow capabilities.

The main important aspects of vision were then highlighted – detection, identification, object categorization, scene and context categorization, and 3D depth. These provide a myriad of challenges, for which he briefly summarised; an important point to take away was that the human brain is astoundingly good at interpreting visual data, taking into account an incredible number of variables that would often cause a computer to stumble.

Various research projects were then presented, such as penguin identification, and text extraction from 3D objects.

UWE – **Absent due to illness.**

**Week 8**

UoB 20/11/17

*Energetically Autonomous Robots – John Greenman*

A summary of research at the BRL into self-sustainability for robotic systems. Focus was on developing robots capable of replicating nature, and actively finding a food source to allow it to meet its energy needs. Fully autonomous systems require both computational and energetic autonomy, so developments in this field could be of huge impact on the robotics discipline.

Much of this talk was focused on the technology providing the capability of energetic automation; the microbial fuel cell. By utilising the chemical reactions created by microbes feeding on biological material, the fuel cell can produce a small, but viable source of electricity, and as long as the fuel cell is continuously fed, the energy will continue to flow.

Various iterations of this technology were presented, from an early robot that could travel towards light (very slowly) when fed, to later robots that utilise an entire circulatory system, sustained by captured flies.

**Week 10**

UoB 27/11/17

*Nathan Lepora*

Another general talk about robotics, looking into some interesting topics, such as proprioception in robotics. Interesting insights into various pioneers in robotics.

UWE 29/11/17

*Jonathon Winfield – FARSCOPE projects for Bioenergy.*

A general discussion of the projects available to students, based around the technologies developed in the wet lab at the BRL. The focus was mainly on the microbial fuel cell technologies, both on their operation and current capabilities.

The ‘functioning biodegradable robot’ was of particular interest; discussion of the potential applications of such technologies gave the impression that this would one day allow full autonomy in the natural environment, particularly as the energy cost of actuators and sensors reduces sufficiently to allow powering of more complex devices.

Also of note was the ‘paper based power source for a GPS tracker’, in which urine could be used to power a flat pack bio reactor. Even with low power levels, the device could be capable of powering a GPS beacon. Such a device would make for a fantastic life saving device in extreme situations, since urine is a readily available resource even when all else has run out.

**Week 11**

UWE 06/12/17

*Dr Khemraj Emrith – Multimodal Automated Feeding System*

Presentation of research into a robotic feeding system for the disabled, combining a range of research areas to create a safe, capable and intelligent feeding assistant.

Currently, robot arms used in feeding are open loop, in that they do not include the human in the system to provide constant feedback, and are instead preprogramed to carry out tasks. This research aimed at combining 3D facial modelling, emotional reading, and understanding of environmental context, to create a system that is actively looking for cues that it is needed (or not needed), and safe for HRI.

**Week 12 – Absent Due to Illness.**