EMATM0058

Robotics Research Technology and Methods

ASSIGNMENT 1

Critical Evaluation of Robotics Research

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Contents

1 Week 3

1.1 Seminar——Mon 10th October 2022. Robotics and AI for Extreme Environment Applications (Tom Scott)

1.1.1 Research area

Professor Scott's research area is the application of robots to replace humans in extreme environments (e.g. nuclear environments) to examine the deterioration of materials and structures within the environment. Examples include the use of hexapod robots to pick up contaminants or 3D scanning through SLAM.

1.1.2 Research challenges

Working in extreme heat exchange, extreme pressure, and under extreme radiation exposure poses obstacles for the robot's hardware as well as its telecommunication. Besides, how to drive robots precisely return to the origin whether mission completion or failure is another challenge.

1.2 Seminar——Mon 10th October 2022. Aerial Robotics: sensing, control and planning for conservation (Tom Richardson)

1.2.1 Research area

UAV control systems are studied to maintain the vehicle's flight posture or to hover in order to accomplish specific tasks in turbulence, e.g. collecting volcanic ash samples. As well as locating and mapping scenarios where there is no reference point. Not only that, but a complete control system also requires to land the vechicle at a designated location.

1.2.2 Research challenges

The airflow indoors differs from the airflow outdoors, so the results of indoor experiments can hardly be used to inspire parameters in outdoor experiments. In addition, the major difficulty in controlling the vehicle underground is the loss of the GPS signal, which can only be located from the starting point.

1.3 The paper I read

"Real-Time Multi-Contact Model Predictive Control via ADMM" .

1.3.1 Research discovery

In this paper [1], the authors propose a new algorithm: consensus complementarity control, based on the alternating direction method of multipliers. The algorithm enables the solution of hybrid model predictive control problems for multi-concact systems in real time due to the distributed nature of ADMM. In addition, the feasibility of parallelisation makes the C3 algorithm faster and robust to noises.

1.3.2 Personal review

Firstly, the performance of the C3 algorithm is convincing because the authors validated their concept in three experiments: cart-pole with soft walls, finger gaiting, and pivoting. Nonetheless, the ADMM projection in the C3 algorithm is not the fastest nor the most widely explored. There is also subjectivity in the choice of parameters in this algorithm, which impacts performance.

1.4 The paper presented in reading group

"Interactive Robotic Grasping with Attribute-Guided Disambiguation".

1.4.1 Research discovery

The authors developed an interactive robotic grasp system in this paper [2]. The system applies attributed-guided equation of the partially observable Markov decision process (Attr-POMDP) and pointing-based questions to eliminate ambiguities in the language. The system achieves an astonishing 91.43% accuracy on a real robot, surpassing some previous approaches such as RandAsk, REG, FETCH-POMDP, etc.

1.4.2 Personal review

Although the disambiguation system has a 91.43% accuracy on a real robot, a problem with this approach is that it fails to take the situation when an item is out of or only partially within the camera range into account. The placement of items is another potential concern since the items in the experiment were placed in order on the table, whereas in reality the situation is more untidy, e.g. overlap.

2 Week 4

2.1 Seminar——Mon 17th October 2022. Computer Vision in the Carbon Fibre Composites Industry (Gary Atkinson)

2.1.1 Research area

Professor Atkinson's research aims to apply novel image processing (e.g. polarisation imaging and photometric stereo) and deep learning to automated detection of defects in carbon fibres. These technologies support the reduction of manufacturing costs for carbon fibre materials as well as the elimination of imperfections that are not visible to the human eyes.

2.1.2 Research challenges

One of the research challenges arises from black and shiny reflections, which lead to defects in fibre orientations being difficult for human eye to observe. Another challenge is the repair of carbon fibres, as the location and extent of the damage are unknown, while a small gap can weaken the yielding force that the carbon fibre material can withstand.

2.2 Seminar——Thur 20th October 2022. Soft Robots - from exosuits to robot organisms (Jonathan Rossiter)

2.2.1 Research area

The research in soft robots tries to harvest chemical energy from nature and convert it into mechanical energy that is beneficial to humans, such as helping the elderly or disabled to regain mobility. Traditional robots have separate motors, control systems, actuators, etc., while soft robots integrate these three, like organs in human body.

2.2.2 Research challenges

First, the control systems of soft robots are highly material-dependent. Secondly, the control systems, actuators and other mechanisms are closely linked in soft robots and work as a whole. Third, the soft robot interacts with the environment and is part of the environment at the same time, meaning that soft robots are like animals in nature.

2.3 The paper I read

"Control framework for collaborative robot using imitation learning-based teleoperation from human digital twin to robot digital twin" .

2.3.1 Research discovery

Lee et al. [3] developed a vision-based remote control operating system to address the reliance on deep learning frameworks for human recognition algorithms in collaborative robots. The system applied a convolutional encoder-decoder to recognise the pose of the human body, which was mirrored to the synergistic robot with the assistance of a digital twin model and a Bessel curve.

2.3.2 Personal review

Despite verifying the effectiveness and accuracy of the system, Lee et al. offered no explanation on how to eliminate communication errors between control transitions. In addition, the system is limited by the fact that only 2D human postures were used as input and the implementation of real-time posture transfer had yet to be extended.

2.4 The paper presented in reading group

"How to include User eXperience in the design of Human-Robot Interaction" .

2.4.1 Research discovery

Prati et al. proposed a user experience (UX)-oriented measurement matrix to study HRI when executing shared tasks to obtain valuable HRI design requirements [4]. They applied it to a robotic and AGV-assisted oil pump assembly operation and the results showed that the approach was capable of improving the identification of interaction requirements and the design of a driver interface.

2.4.2 Personal review

Firstly, Parti et al. failed to validate the generalisability of their approach, so it is unknown whether the methodology can be adapted in other manufacturing scenarios like milling, stamping and welding. Secondly, one concern is whether the assembly of a specialist team would hinder the roll-out of the solution in enterprises because of the cost.

3 Week 5

3.1 Seminar——Mon 24th October 2022. Safety Engineering of Robotics and Autonomous Systems (Chris Harper)

3.1.1 Research area

Safety engineering of robotics attempts to design systems with appropriate safety attributes to prevent accidents or reduce harm to humans from robots to an acceptable level, thus, keep the risk within acceptable limits. Safety engineering of robotics covers areas such as surgery robots, socially assistive robots, manufacturing, and autonomous vehicles.

3.1.2 Research challenges

Firstly, the curse of dimensionality. If an autonomous system takes into account all the factors in the environment, the dimensionality of the data will explode. Secondly, rare events: how to lower the probability of an accident to a negligible threshold. Last, the black box effect of neural networks: the inexplicability of the human reasoning process for AI.

3.2 Seminar——Thur 27th October 2022. Neuromorphic Prosthetics (Benjamin Ward-Cherrier)

3.2.1 Research area

The research area of integrating prosthetics into the human body lies in the creation of prosthetics with biomimetic tactile sensors, neuromorphic perception and haptic feedback, thus enabling the user to operate a robotic hand. Meanwhile, the research involves computational neuroscience, being drawn on to mimic the brain's transmission and processing of signals.

3.2.2 Research challenges

One of the challenges of the study is the capture of dynamic information and reconstruction. Another difficulty lies in spiking neural network, which, despite its advantages in mimicking the brain's signalling, low energy consumption and fast processing speed, lacks back propagation, so it is needed to contemplate other ways to update parameters.

3.3 The paper I read

"Carbon emission reduction effects of industrial robot applications: Heterogeneity characteristics and influencing mechanisms" .

3.3.1 Research discovery

Li et al. [5] have gone some way to remedying the lack of research into the environmental effects of industrial robot applications. They found that: firstly, the adoption of industrial robots improved productivity and energy efficiency; secondly, industrial robots reduced carbon intensity more in manufacturing and agriculture than in construction and R&D.

3.3.2 Personal review

On the one hand, the authors have not treated the carbon reduction effects and heterogeneous characteristics of the various types of industrial robots in detail. On the other hand, the authors have focused only on the regulating role of absorptive capacity, leading to the neglect of other variables.

3.4 The paper presented in reading group

"Attitudes of hotel customers towards the use of service robots in hospitality service encounters" .

3.4.1 Research discovery

Ahu et al. [6] collected questionnaires online from 1078 hotel guests towards the robots serving them at the hotel. They found that there is no measurable differs in guests' attitudes towards service robots depending on which continent they were from, while guests of Generation X were not as interested in exploring the service of a robot as guests of Generation Y and Z were.

3.4.2 Personal review

Due to the COVID-19, the single research method - an online questionnaire - could not ensure the reliability of the findings of the experiment, thus focus groups and observations should be introduced. Furthermore, geographically, the study was limited to Asia, Europe, North America and Australia.

4 Week 7

4.1 Seminar——Mon 7th November 2022. Responsible Robot Dexterity (Nathan Lepora)

4.1.1 Research area

Dexterous robotics research aims to augment the dexterity of robotic hands in order to replace human hands in their interaction with the outside world and thus perform activities that are beneficial to humans. For instance, with the help of tactile sensors, robotic hands mimic the human hand to gently grasp objects and ensure that they are not dropped.

4.1.2 Research challenges

One of the research difficulties is high-resolution tactile sensors, for which there is no protocol for manufacturing yet, so their cost has remained high and home-made tactile sensors cannot meet the accuracy requirements. Secondly, research on AI, modelling and control of robotic arms equipped with tactile sensors has been progressing slowly.

4.2 Seminar——Thur 10th November 2022. Robot Learning for Dexterous Manipulation (Dandan Zhang)

4.2.1 Research area

Research into robotic learning for dexterous robots intends to enable robotic systems to complete tasks in situations of uncertainty and to automatically compensate for failures without external help. The robot's learning capability is reinforced by robot perception techniques such as stereo vision and tactile sensors plus deep learning.

4.2.2 Research challenges

Robotic systems first have to deal with a great degree of uncertainty in the environment, leading to a dramatic increase in the cost in reinforcement learning. Besides reinforcement learning, robots can also learn by imitating human behaviour, i.e. imitation learning. However, the black-box effect, the need for volume of data, and the lack of universality are the current bottlenecks.

4.3 The paper I read

"Semi-Autonomous Mobility Assistance for Power Wheelchair Users Navigating Crowded Environments".

4.3.1 Research discovery

Ashley et al. designed a semi-self-assisted navigation system adapted to a number of wheelchairs [7]. The navigation system collects data from a ring of ultrasonic sensors and combines the data with user's joystick input to generate a potential field description consisting of vectors, thus avoiding wheelchair collisions with dynamic and static obstacles in busy environments.

4.3.2 Personal review

The hardware costs just $400, which sets the stage for its broad market prospects. However, the authors' experimental results show that the time taken to complete the same task using the assistive system is 19.5% more than using the joystick control directly due to processing the data. Also, the assisted control reduces the speed in a straight line of the wheelchair.

4.4 The paper presented in reading group

"Design and Characterization of the OpenWrist: A Robotic Wrist Exoskeleton for Coordinated Hand-Wrist Rehabilitation".

4.4.1 Research discovery

Pezent et al. developed a rehabilitation robot arm called OpenWrist to assist in the treatment of motor nerve injuries at the wrist [8]. The results of the experiments, i.e. compatible with the subject's hand to complete the assisted grasping task, showed that the device has pleasing performance in range of motion, torque and output, and is more wearable than previous products.

4.4.2 Personal review

The authors mentioned four periodic peaks in static friction caused by possible misalignment of the rails, however, they made no attempt to solve the problem and just hoped for a break-in of the equipment. Another weakness is that the authors did not propose a specific control implementation to compensate for the excessive torque in the PS joints.

5 Week 8

5.1 Seminar——Mon 14th November 2022. Morphological Computation ——Building better bodies for better robots (Helmut Hauser)

5.1.1 Research area

One area of research in morphological computing is the construction of a body that collects information from environment and learns itself, and the other is the building of a perceptual system to derive knowledge from low dimensional information. For example, researchers collects information generated by the vibrations of spider webs.

5.1.2 Research challenges

Firstly, morphological computing develops robots by mimicking the behaviour of creatures in nature, and if the intended function differs from the animal's instincts, then we need to reprogram it. Furthermore, it is challenging to develop intelligent materials such as soft passive tissues that change their morphology (elasticity, softness, colour, chemical properties, etc.) depending on different environments.

5.2 Seminar——Thur 17th November 2022. Neuro-SLAM (Martin Pearson)

5.2.1 Research area

The research of Neuro-SLAM focuses on adopting whisker sensors for navigation, i.e. the robot makes inferences about its surroundings by avoiding obstacles and statistically recording its orientation. With the help of SLAM, the researchers are able to create discriminative features, as the robot simultaneously integrates paths and identifies locations.

5.2.2 Research challenges

Firstly, errors accumulate as the robot moves; secondly, the sensors are exposed to noise and uncertainties from various sources. Both of these impact on the evaluation of the performance of localisation & mapping. Third, the compromise on purely mathematical solutions as it is intractable and fourth, the head orientation of the grid cells.

5.3 The paper I read

"Software Development Framework for Cooperating Robots with High-level Mission Specification".

5.3.1 Research discovery

Hong et al. proposed a software development framework by extending the SeMo framework [9]. Their platform added functions like team hierarchies, group services and global information sharing. They achieved dynamic allocation of tasks in heterogeneous robotic reconnaissance tasks and swarm robots, demonstrating that their framework can support cooperation of both distributed and swarm robots.

5.3.2 Personal review

The authors only adopted the number of keywords as a quantitative metric for comparing software frameworks, which is singular to represent the framework's superiority compared to other frameworks such as ROS and Karma. Additionally, while the success of the two experiments validated the feasibility, other metrics, such as time consumed and quality of completion, were not present.

5.4 The paper presented in reading group

"ArduCode: Predictive Framework for Automation Engineering".

5.4.1 Research discovery

To assist engineers in classifying code, querying similar code segments and sizing hardware, Canedo et al. developed a solution called ArduCode incorporating [10]. They validated the solution on two real datasets and showed that the solution was able to match code segments (F_1 score of 72%) and recommended hardware models with high accuracy.

5.4.2 Personal review

Firstly, the approach does not have access to all C++ libraries when obtaining the code structure and, moreover, cannot trace the complete path in the Arduino program. Secondly, ArduCode only recommends hardware and cannot advise engineers on the selection of third-party libraries. Finally, the parameters learned by ArduCode cannot be updated in real time due to the performance of the hardware.

6 Week 9

6.1 Seminar——Mon 21st November 2022. Critical Issues in Connected Autonomous Vehicle Research (Tony Pipe)

6.1.1 Research area

Prof Pipe's studies are dedicated to ensuring the safety of HRI in connected autonomous vehicles. A test bench was proposed in which researchers describe road conditions, implement various autonomous control systems on simulation platforms and introduce agents to confuse it in the test, thereby exposing defects or potential collisions in the systems.

6.1.2 Research challenges

The challenges in autonomous vehicle research are, firstly, ethics, who is responsible for the behaviour of a robot when it is competing with a human for dominance in a hazardous environment. Secondly, the limited number of states automated vehicle detects, such as how to be aware of other vehicles on the road or pedestrians on the pavement.

6.2 Seminar——Thur 24th November 2022. Toward Field Swarm Robotics (Edmund Hunt)

6.2.1 Research area

Field Swarm Robotics' research is inspired by the self-organised nature of animals. The control of field swarm robotics relies on a bottom-up approach based on the communication between individuals. As a result, each individual only needs to perceive minimal information to create large-scale movements of the entire swarm. Meanwhile, mistakes by a few individuals do not affect the performance of the group.

6.2.2 Research challenges

The main challenge is heterogeneity, i.e. drawing on the functionality of heterogeneity to trade off efficiency and energy consumption and behaviour-response thresholds. Secondary challenges arise from the dynamics in real environments, such as the drain on the robot's energy management due to disturbances.

6.3 The paper I read

"The ethical issues of social assistive robotics: A critical literature review".

6.3.1 Research discovery

This paper [11] focuses on the ethical issues of Social Assistive Robotics (SAR) through a critical review of the literature. Boada et al. divide the current discussion of the ethics of SAR into three themes: personal, practice-related, and sociopolitical. They categorise 60% of the topical issues, such as privacy of data, deception, and autonomy, into the personal domain because of their relevance to well-being.

6.3.2 Personal review

The authors not only identify and analyse existing ethical issues in SAR, but also outline future research priorities. Nonetheless, the scope of this paper is limited to ethics. To expand the framework for addressing ethical issues in SAR, more diverse knowledge, such as freedom and responsibility in philosophy and cultural influences in the field of culture, needs to be integrated.

6.4 The paper presented in reading group

"Preparing for a robot future? Social professions, social robotics and the challenges ahead".

6.4.1 Research discovery

Share et al. discover a growing trend in the use of information technology such as assistive technology in the field of social robots [12]. They then present challenges regarding the application of social robots, covering ethics, human-robot interaction, user acceptance and social impact. In response to these challenges, they propose a syllabus for practitioners who employ social robots as an assistive.

6.4.2 Personal review

The main weakness of this paper is that although an educational syllabus is presented, the lack of practical tools and materials to help practitioners learn about social robots renders the syllabus unconvincing. Secondly, automated systems (e.g. decision support systems), specific applications of artificial intelligence technologies in social robots and trends are not included in the scope of this paper.

7 Week 10

7.1 Seminar——Thur 1st December 2022. Robot Teleoperation for Nuclear Decommissioning (Paul Bremner and Alex Smith)

7.1.1 Research area

Dr Bremner's research area is the teleoperation of robots to decommission nuclear plants and the sonification of risks to robots. The former includes: 3-D modeling of nuclear plants based on point clouds, surveillance of waste storage facilities, and remote control of robots for tasks. The latter involves transmitting information in the form of sound when the robot arm encounters an obstacle or is overloaded.

7.1.2 Research challenges

The research challenge for teleoperation comes from a flaw in point clouds - sparsity - the less the distance to the object, the lower the resolution of the object. The challenge of sonification, on the other hand, comes from ethics, as sounds that are too sharp and persistent may be perceived as stressful noise. The next step then is to identify the amount of information from sound that a person can tolerate.

7.2 Seminar——Thur 1st November 2022. Embodied Cognition for Human-Robot Interactions (Manuel Giuliani)

7.2.1 Research area

Research in embodied cognition for HRI aims to develop robots that engage with humans in a multimodal and socially based manner. Specifically, whether or not a robot follows social etiquette when interacting with humans greatly influences the human experience, and Dr Giuliani has created a database of 201 videos in which 578 erroneous situations were found.

7.2.2 Research challenges

One of the difficulties of the study is the annotation of the data, for instance, labelling 201 videos takes five people six months. Secondly, the gender and personality of the subjects influenced the rating of the experiments, so it is not possible to assess the robot's performance by a uniform standard and personally-tailored error handling strategies had to be developed.

7.3 The paper I read

"Intelligent control of assembling robot using vision sensor".

7.3.1 Research discovery

Ishikawa et al. present a control method for an assembly robot arm [13]. In this method, force and vision sensors not only help to correct small errors in the assembly, but also make the robot arm conform to the corrected planned trajectory. They then validate their method by applying a SCARA three-joint robot to tighten inaccurately placed bolts.

7.3.2 Personal review

One of the drawbacks of the method is the error due to the vision sensor, where one pixel of the vision sensor introduces an error of $\pm 5\ mm$ in the approach direction and $\pm 3\ mm$ in the translation direction, and the authors were unable to identify this error in the image. In addition, although the errors converged steadily, the sampling time of the images reached 500 ms, which is rather slow.

7.4 The paper presented in reading group

"3-D world modeling based on combinatorial geometry for autonomous robot navigation".

7.4.1 Research discovery

Goldstein et al. proposed a method for constructing 3-D scenes based on combinatorial geometry [14]. The method collected coordinates by constructing solid spheres, subsequently merging the spheres to visualise the 3-D shape of the scene. The method was successfully validated by navigating automatically through a room with static obstacles, with the robot completing 70% of the mapping of given locations.

7.4.2 Personal review

The proposal of 3-D modelling was groundbreaking at a time when robots were generally limited to 2-D mapping. Nevertheless, the time consumed by plotting the results and calculating the distances from the surface of the robot to given points was hampered by the computer hardware available at the time, delaying the progress of 3-D modelling.

8 Week 11

8.1 Seminar——Mon 5th December 2022. Enabling Aerial Physical Interaction Tasks with Drones for Infrastructure and Environment (Bahadir Kocer)

8.1.1 Research area

Dr Kocer's research focuses on environmental awareness by aerial robots, e.g. leaf assessment and monitoring of extreme events. In addition, Dr Kocer develops a micro UAV control system based on optical flow sensors and force sensors to collect data at close range in trees, which allows the UAV to hover in its current position after contacting an obstacle in front of it.

8.1.2 Research challenges

Firstly, the database created for predicting crown shedding combines real photographs with images generated by the virtual engine. Afterwards, they are trained by supervised learning, however the labelling in this process is subjective. Secondly, if there is shading and occlusion between trees, then separate recognition becomes problematic.

8.2 Seminar——Mon 5th December 2022. Swarms at Scale (Sabine Hauert)

8.2.1 Research area

Research on large scale swarming concentrates on two techniques: bio-inspiration and machine learning. A typical example of bio-inspiration is the translation of the path planning of an ant swarm towards food into rules that a robot can understand. And where inspiration from bionics is not available, the robots need to learn by machine learning to complete the task.

8.2.2 Research challenges

One of the research bottlenecks lies in applications, i.e. how to create swarm robots that serve humans. Although most people are receptive to swarm robots, researchers have not found an industry as a breakthrough. Another challenge is how to eliminate the time requirements when increasing or decreasing the size of a swarm.

8.3 The paper I read

"TouchRoller: A Rolling Optical Tactile Sensor for Rapid Assessment of Large Surfaces ".

8.3.1 Research discovery

Cao et al. created a visual-tactile sensor roller called TouchRoller to address the inefficiencies in flat tactile sensors [15]. It rolled around its central axis, thus maintaining contact with the surface being evaluated throughout the movement. Their experiments showed that the TouchRoller covered a textured surface, more efficiently than a flat tactile sensor and with a higher similarity of the reconstructed textures.

8.3.2 Personal review

Firstly, the size of the subject is 8 $cm \times 11$ cm, which is far from a large surface area. Secondly, the quality of the reconstructed image is influenced by the focus of the camera. As a result, the reconstructed image is blurred when the roller was too fast for the camera to focus in time. Finally, the positional accuracy decreases as the distance between the inspection area and the radial axis of the roller increases.

8.4 The paper presented in reading group

"Autonomous robotic laparoscopic surgery for intestinal anastomosis".

8.4.1 Research discovery

Saeidi et al. present an autonomous strategy for intestinal joining laparoscopy in surgical robots to help the robot perform tasks independently under the supervision of an operator [16]. The authors experimented with laparoscopic surgery to join the intestines in a porcine model on the basis of it and found that it is superior to expert surgeon and robot-assisted surgical techniques in suture spacing and lumen patency.

8.4.2 Personal review

A drawback of this paper is that although the autonomous strategy reduces the involvement of the surgeon, operator supervision is still indispensable in complex procedures. Another limitation arises from the mechanics of the robot arm's kinematics, which prevents it from being able to partition the target tissue at will.

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