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**The Application of Robotics – Examining Automation of Hazardous Tasks Within the Manufacturing Industry**

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**Introduction – Overview of the Problem Solved and Rationale for Topic Choice**

With the occurrence of the Industrial Revolution manufacturing machinery advanced considerably. However, there was still dependence upon human operators, seen with inventions such as Jacquard’s Loom that required punch card instructions (Science and Industry Museum, 2019). Within an industrial setting there are often repetitive procedures with inherent safety risks for human employees, involving exposure to heat, hazardous fumes, and heavy lifting. As stated by Cunningham et al. (2022) fatigue is an extreme hazard for workers in roles with disproportionate risks, this is more apparent in repetitive roles where fatigue and long working shifts foster human errors. Removing the reliance on human operators or limiting their involvement was a potential solution to mitigating these risks. The integration of articulated robotics within manufacturing and their application for automation of hazardous tasks began in the 1960s. Exemplified by the introduction of the UNIMATE 1900 series. Throughout this analytical report there will be opportunity to highlight the differences between the UNIMATE 1900 and its contemporary counterparts, with references to a current industry leader ABB Robotics. Using their IRB 2600 series (ABB Robotics, 2023a) which provides an exemplary articulated robot used within manufacturing today. This will allow demonstration of how the approach to solving the issue of workplace safety using robotic replacement has evolved.

The exploration will encompass a detailed examination of how robotic intervention enhances workplace safety, the technological advancements driving these applications, the associated algorithmic thinking, and the resultant shift in the design process. Moreover, the report will discuss the broader implications for the workforce and society whilst also highlighting some of the potential pitfalls of an autonomous production process. Ensuring to discuss any legal, ethical, social, and professional issues that are presented by proposed solutions. Through this analysis this report aims to provide insights into the potential of technology in safeguarding workers.

**The Application of Computer Science in Solving the Problem**

The UNIMATE 1900 series developed by George Devol and Joseph Engelberger is considered widely as the first industrial robot. Its successful implementation set precedent for the developments in industrial robotics that followed. When compared with modern robotics the UNIMATE’s lack of adaptability and capabilities is pertinent. Due to the control systems, cumbersome components and programming languages or lack thereof being rudimentary compared to modern-day equivalents (See Figure 1 Appendix)

The UNIMATE 1900 was implemented to conduct spot welding operations within the General Motors (GM) Lordstown, Ohio factory in 1969. Their great efficiency and utility stemmed from the intelligent design employed by their creators. Regarding programmability, the UNIMATE 1900 used non-volatile sequential memory storage (Computer History Museum, 2009). Magnetic drum memory consisted of a large cylinder coated in magnetic fluid. The read and write heads were electromagnetic. This allowed them to detect magnetic spots on the drum, with magnetised spots representing a binary 1 and demagnetised spots representing a binary 0.

The binary language illustrated the flow of electricity, 1 representing the flow of electricity to components and 0 representing no flow of electricity. Through a series of electrical relays this would activate the UNIMATE’s hydraulic actuators and cylinders allowing the robotic arm its movement capabilities. Reprogramming the machine would be physical due to this, meaning that cables would have to be unplugged and rerouted. This caused significant downtime and would lower overall cost efficiency of the systems themselves. The accuracy of hydraulic components was far more limited than electro servo motors seen in modern systems, this meant higher error rates and less accurate movement paths comparably.

This is in direct contrast to ABB robotics IRB 2600 series, which uses a combination of both volatile and non-volatile memory, classified as the hardware memory. The primary memory store is in the Omnicore controller system (ABB Robotics, 2022). The critical information such as safety parameters, calibration settings, and configuration settings will be stored within the non-volatile memory. This allows the data to stay intact when the system is not receiving power ensuring system integrity (Trick, 2022). The operating system of the Omnicore controller is responsible for the execution of RAPID code, this code first developed in 1994 by ABB is used to programme the robots’ movements. Using ABB’s RobotStudio software (ABB Robotics, 2023b) a simulation of these movements can be seen prior to execution. This allows for offline programming and storage of several pre-configured executable actions, also providing insight into functionality and space requirements. Alternatively, if an engineer does not wish to write code manually using RAPID, they can use ABB’s FlexPendant. Using simple controls on the FlexPendant device, they can move the robot along the desired pathways. The corresponding code and movements are then saved without the need for manual programming.

Both methodologies remove the danger created by physically reprogramming such as electrical hazards or those presented by proximity with the system. Although the use of such programming languages, software and systems requires sufficient training the end user experience and accessibility has improved greatly. Devices like the FlexPendant also seek to lower barriers to entry presented by insufficient knowledge of programming languages. With more users able to utilise and access this technology this only contributes to further adoption rates and mitigation of risks posed by a lack of familiarity.

Programming and memory storage capabilities are fundamental, however, developments in both movement components and sensor technology have allowed for further precision and reduced error rates. In addition, further awareness provided by improved sensor technology and improved attitudes towards accident prevention have only increased the safety of current systems comparative to their ancestral predecessors. Sensory technology was in its infancy when the UNIMATE was developed. Limit switches were used to signal the end of movement paths and capabilities, proximity sensors were used to detect nearby objects and potentiometers gave feedback on the robot’s position. Their sensory capabilities were relatively limited.

On the other hand, current systems are highly proficient in this aspect. Encoders are used to establish the robot’s relative position; these are more accurate than potentiometers and provide further reliability. Conjunctively with vision systems such as cameras this allows the robot to effectively navigate its environment and be aware of obstacles to reduce collision risk (IBM, 2023a). There is scope to further enhance this ability, presented by the continued integration of artificial intelligence technology with robotic systems. An example being the current research and application of computer vision technology. This allows contemporary systems to fully understand the data provided by the cameras or vision sensors it is equipped with and make decisions based upon their environment. It achieves this using a type of machine learning known as deep learning and what is known as a convolutional neural network. The neural network is traditionally made up of three distinct layers and attempts to mimic the capabilities of a human brain. Deep learning algorithms are for suited to processing unstructured data, like that found in processing an image or frames of a video (IBM, 2023b). With enough data provided the system becomes capable of making its own inferences, effectively learning. As stated by Soori, Arezoo and Dastres (2023) deep learning capabilities will aid particularly in object recognition within and industrial environment. This will only increase the assurance of safe human robot interaction. The advancements seen in movement components are allowing robots to not only replace humans but surpass their abilities in the accuracy they provide.

The improvements seen in safety features since the UNIMATE 1900 have further contributed to worker safety. To further reduce the likelihood of collision with factory workers current systems employ light curtains. A light curtain consists of both a transmitter and a receiver. The transmitter contains LEDs that send pulses of infrared light to the receiver. If any opaque object passes through these light rays the robot is signalled and that causes its immediate shut off. This allows factories to establish safety zones surrounding articulated robots to further mitigate collision or accident risk (OEM Automatic, 2021). Earlier machines did not have such technology and were often limited to an emergency stop button.

Another important aspect of safety is the ability to monitor the system. With the UNIMATE system monitoring tools were not comparable to those available today. Meaning, it would have been significantly more difficult to establish whether the system was operating safely and within its capabilities. With monitoring tools and software employed in contemporary systems workers can access real time data regarding system health using interfaces such as the Omnicore controller. Examples of metrics measured are those such as temperature, torque applied, and component health. This ensures the robot is operating within the necessary confines and ensures both the safety of the robot itself and those around it. These metrics also allow for levels of predictive maintenance especially when integrated with AI capabilities. This, in turn, limits the risks posed by mechanical failure such as overextension, unnecessary or uneven force application, and deviation from movement paths.

Robotics was offered as a solution to reduce human exposure to high-risk procedures. In turn we have recognised that it is key not to simply replace one risk for another, the dangers presented by robotic systems can be significant if due procedure and training principles are not applied. This is an important safety consideration. There is opportunity for employers to provide adequate training, whilst governing bodies can also develop legislation to establish best practices to mitigate this risk. Although there are various health and safety legislation governing workplace safety requirements within the UK such as the Health and Safety Act 1974 there are currently no specified laws surrounding autonomous robotics (Jarota, 2021). Governing bodies such as The Health and Safety Executive (HSE) should develop laws to ensure safe interaction with robotic systems present in the workplace. This necessity reaches beyond the UK, relevant governing bodies in each country would benefit from developing such legislation.

Developments in the technological and the approach to safety have allowed computer science to continually improve the safety benefits achieved by such systems. It will be necessary to employ an agile framework such as the Deming Cycle of Plan, Do, Study, Act (PDSA) (Deming Institute, 2021). This supports the need for continued refinement, as opposed to the problem being solved or not solved by computer science. As technology and innovation goes further, so too can proposed solutions and their effectiveness in mitigating safety concerns.

**Measuring Success and the Societal Impact of Industrial Robotics**

Success of the initial UNIMATE system can be measured by the effects it had on the efficiency. With the installation of the 26 UNIMATE 1900 systems, car production rates at Lordstown GM rose from 60 to 101 cars per hour. The systems could complete 520 welds per vehicle and there was a vehicle completed every 36 seconds (Weller, 1974). From 1969 we have witnessed the gradual widespread adoption of industrial robotics worldwide, with steady year on year growth seen in the market. Being worth an estimated 55 billion U.S. dollars in 2020, with market value predicted to rise to 165.35 billion dollars by the year 2028 (Thormundsson, 2023).

As the problem addressed is primarily concerned with worker safety, we can consider this to be another metric that indicates success. Firstly, the developments in technology allowing safety features such as light curtains and computer vision systems. These contribute to reduction of emergency response time, especially when compared directly with the emergency stop button systems which primarily relied on human reaction times.

It is pertinent to also consider the number of fatal injuries occurring year on year in the manufacturing industry. Data provided by the HSE concerning fatal accidents within the UK indicates that fatal injuries within manufacturing totalled 15 in the year 2022/2023. This was a decrease of seven from the previous year. Furthermore, there was approximately 0.57 fatal injuries per 100,000 workers employed (The Health and Safety Executive, 2023). The manufacturing industry is becoming an increasingly safer environment to work in. Supported by the growing industrial robotics market statistics and adoption rates, robotic technology should be credited as one of the factors responsible for this decline in workplace injuries as supported by Liu, Luo, and Seamans (2023).

Regarding the impacts seen upon society there are many benefits of autonomous production processes. Examples of positive implications include humans no longer having to perform dangerous tasks such as spot welding, improved precision, increased efficiency, and higher product quality. Overall employee health should increase due to the lower levels of exposure to hazardous conditions in the workplace. Increased production rates mean higher economic stimulus provided demand is sufficient to track with supply levels. There is further job creation due to adoption of robotics technology, for instance robotic engineers, being solely responsible for designing, building, and maintaining machines for automating tasks (National Careers Service, 2019).

However, there are potential negative societal impacts. Although workers are less likely to suffer physical injury due to robotics, their mental health may be adversely affected. This is supported by a study conducted by Gihleb at al. that suggests further likelihood of mental health issues and substance abuse problems in workers frequently exposed to industrial robotics. Overall harming the welfare of certain employees with effects being seen by general society, their friends, and families.

With the rapid development seen in the field of industrial robotics since 1969 there are skills gaps being created. This is due to the inability to provide adequate training for the existing workforce fast enough. A report conducted by Global Knowledge (2019) established that only 9% of IT professionals considered themselves competent in machine learning. With 67% of companies using machine learning in the year 2020 the need for competent professionals in this discipline is apparent (Brown, 2021). It is vital that the workforce has the necessary skills to understand the technology to mitigate the risks they may pose to society if errors are made due to a lack of knowledge when designing or using the systems. Mitigating the risks to society whilst also ensuring further success in the future will certainly be a process involving consideration of a multitude of factors.

**Legal, Ethical and Professional Issues Associated with Industrial Robotics**

With the both the initial launch of industrial robotics and the subsequent developments seen in the field there are a multitude of legal, ethical, and professional issues associated with the discipline. Legally there are regulatory considerations such as conformation with a particular country’s safety regulations. Moreover, in event of accidents there is the question of liability, it can often be difficult to determine who is at fault for workplace accidents involving robotic systems. Whether it is fault caused by poor design, inadequate training provided by the employers, or simply the negligent actions of the employees.

Regarding ethical concerns, this begins at a design and programming level and spans to the implementation phase. Bias and influence can arise in both the algorithms that underpin the systems, selection of system components how the system is designed concerning safety features and adaptability. The process is human led and this can encourage subjective thinking if not correctly monitored and reviewed. Another important ethical consideration at the design phase and thereafter is the impact that these systems can have on the environment. Attaining the raw materials for construction of the systems is costly from a carbon emissions standpoint. When system components reach the end of their lifecycle it is also important to ensure that they are disposed of correctly. There are various environmental issues such as leaching, that occur when electric waste is not properly disposed of. Even if properly disposed of, these systems to contribute to greater levels of electrical waste. Aside from environmental, bias and influence issues there is the issue of lack of availability of robotic technologies. The initial investment to acquire and install autonomous production facilities is great, this unfortunately means this technology is not accessible to all, its benefits to safety in the workplace may not be seen by those in less economically developed countries due to this.

Furthermore, there are extensive professional implications. As previously mentioned with the continued development of robotic systems and their further integration with AI skill gaps are becoming more prevalent. Especially when concerned with machine learning aspects of the design process, it is important that from a professional standpoint the workforce have the necessary certifications and training. With adoption rates and the market value for industrial robotics increasing at its current rate a skill shift will be imperative. Addressing such issues will be a collaborative effort between legislators, key stakeholders, and professionals within the field of robotics. Only through adhering to legal frameworks, ethical guidelines and ensuring responsible practices can societal welfare be increased.

**Conclusion and Future Considerations**

Advancements in robotics for an industrial application have continued at an exponential rate since the deployment of the UNIMATE 1900 in 1969. The contemporary landscape of industrial robotics is far removed from the early systems and infrastructure seen in that formative period. Addressing the problem of removing humans to hazardous task in the manufacturing process has raised a multitude of ethical, social, professional, and legal implications. All of which need to be carefully considered moving forward to ensure success in the application of robotics in both and industrial manufacturing setting and other respective industries.

The continued integration of AI technologies allowing robots to become fully autonomous in their decision making and path planning abilities is both an enticing and potentially dangerous concept. The desire for advancement should not supersede the understanding of the need for caution, closing the skill gap should be at the forefront and understanding the way in which society can utilise such technology in a safe and ethical way will be key.

In the case of industrial robotics, it is not whether the problem of automating hazardous tasks has been solved, it is the how it is solved as we progress further. Continuous refinement of applied algorithms, components responsible for operation and adaptability, and instilling ethical guidelines and frameworks will be of upmost importance. This will be a collaborative effort, involving various professions including engineers, programmers, legislators, and governing bodies. Only through ensuring continued development can the use cases for autonomous robots expand and the positive impacts be realised.

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**Appendix**

A close-up of a white sheet

Description automatically generatedA close-up of a document

Description automatically generated***(Figure 1) System components and capabilities comparison table – UNIMATE 1900 series and ABB Robotics IRB 2600 Series***

***(Figure 2) Portfolio work conducted in study of the topic and the problem solved***

A screenshot of a test

Description automatically generatedBoolean Algebra quiz:

Notes: This quiz solidified my further understanding of the use of Boolean algebra within computer systems and how they can be applied in programming devices. It will prove useful to remember 0 = false and 1 = true

A computer screen with white text

Description automatically generatedAlgorithm for making a cup of coffee – coded in Python:

Notes: It was useful to attempt to code this exercise in Python. The activity stimulated research of the process within Python itself. Looking back at the algorithmic steps I believe certain steps lack the desired specificity required from an algorithm. ‘Cool slightly’ for instance is largely subjective. I should ensure that in the future when working with algorithms I reflect upon and analyse the steps to maintain acceptable standards of practise.

Types of computer systems – Analysis of tablet systems:

|  |  |
| --- | --- |
| Which system have I chosen and why? | Tablet PC devices. I have chosen these devices because they appropriately filled a gap within the market in relation to user needs. |
| What problem have they been designed to solve? | Tablet devices were designed to overcome some of the drawbacks of mobile devices. Especially in relation to a mobile not being as well equipped as a laptop for work applications. |
| How does the system solve this problem? | Through the interface. The employment of bigger screen sizes allows further compatibility and a better user experience with traditional desktop applications such as word and excel. Reliable remote connection hardware. Along with capable Central Processing Units. They also remain slim in design making them easier to carry than traditional laptops (Lenovo, 2023) |
| Who benefits from this system? | A variety of users due to the functionality of a tablet. Office workers or business applications. However, they also can be used primarily as an entertainment system. 19.2 million units of Android tablets were shipped in the second quarter of 2022 (Statista, 2022) |
| Is the system good or bad? | The systems themselves are widely popular with consumers, students, market enterprises and working professionals |

Revisiting the Tablet system analysis – further considerations and developments in thinking:

|  |  |
| --- | --- |
| Which system have I chosen and why? | Tablet PC devices. I have chosen these devices because they appropriately filled a gap within the market in relation to user needs. |
| What problem have they been designed to solve? | Tablet devices were designed to overcome some of the drawbacks of mobile devices. Especially in relation to a mobile not being as well equipped as a laptop for work applications. |
| How does the system solve this problem? | Tablets contain a variety of hardware components that allow it to serve its functionalities:   * Display screen – resistive or capacitive screens allow user input (touch) to be conveyed to the CPU (often microprocessors) * CPU – Microprocessors used for the energy efficiency and compact size * Memory (RAM) – volatile temporary data storage that allows the tablet to quickly access data and run applications * Storage – Flash memory used as internal storage, housing OS (operating system), applications and the user data. Some tablets allow for expanded storage options in the form of SSD cards * Battery – This allows for the portability; the device is not always reliant on mains power as the battery can be recharged from a mains outlet by the user * OS – This will likely be Windows, Android or IOS. The OS is responsible for running the applications, managing system resources, and providing the UI (user interface) * Connectivity options – WIFI, Bluetooth and Cellular. This gives users the option to connect to the internet and other devices whilst on the move. Removing the need for a wired connection. * Sensors – Accelerometers and gyroscopes. These allow the tablet device to detect orientation. Other sensors such as ambient light sensors allow for auto adjusting screen brightness features. These further enhance the user experience. * Cameras – These can be front or rear cameras. Often tablet devices have both a front and rear camera. This allows for further compatibility with common workplace apps such as Microsoft Teams. * Ports – ports both for charging and data transfer allow for portability and connectivity. Audio jacks allow for sound transfer and ensure an immersive experience. * GPU (Graphics Processing Unit) – This supports the visual element of the display on the tablet device and is responsible for rendering graphics * Built in microphone and speakers – again allows for use of office apps such as MS Teams. Among other use applications. |
| Who benefits from this system? | * Students – portability for note taking and research * Professionals – workplace tool and application * Countries where IT infrastructure is not in place * General consumers – entertainment |
| Is the system good or bad? | The systems themselves are widely popular with consumers. However, there are various limitations the systems themselves have due to size. For instance, a lack of computing power due to the size and capabilities of smaller CPUs found within tablet devices when compared to a laptop or more traditional desktop systems. |

Notes: revisiting the system allowed for further investigation into some of the computer science principles supporting how the device achieves its functionality using carefully selected hardware components.

Re-examining tablet PC devices – focusing on any social, legal, or ethical issues**:**

|  |  |  |
| --- | --- | --- |
| **SOCIAL ISSUES** | **LEGAL ISSUES** | **ETHICAL ISSUES** |
| * The affordability of tablets themselves present some social issues. In areas where the technology is not easily afforded this can create a digital divide. The barriers to entry may be considered too high for some. * Screen time concerns. Especially prevalent with younger users. The effects of excess screen time such as disturbed sleep, eye strain and mental health concerns. * Increase in social isolation. The functionality of many mobile devices can allow the users the ability to reduce their face-to-face interactions often with a detrimental effect on their interpersonal relationships. * Privacy Concerns. Users are not only storing their personal data on their tablet devices they are also using such devices to communicate with one another. This can lead to concerns regarding data breaches. | * Point of sale systems – tablet devices are commonly used for transaction systems within retail organisations. This lends itself to the need for enforcement of GDPR legislations. * Cybersecurity concerns – Not only for the companies that design the systems themselves but also those who develop applications for such devices. They will have to comply with legislation surrounding reporting of data breaches. * Piracy concerns – due to tablets being used for both creation and consumption this presents issues regarding intellectual property rights, copyright infringement and illegal distribution of protected content. | * Ethical design – The system should firstly be designed ethically. Implementing technologies to enhance the user experience. Second to this are the applications that are designed for the system itself. This raises concerns regarding the way design influences user decision making (e.g. advertisement placement, preferences etc.) * Environmental impact – tablet PC devices use Lithium-Ion batteries. There are major concerns over chemical leaching with improper disposal of these batteries. The CO2 emission rates during production of the batteries themselves and the mining practises for the metals used to make up such batteries (Cobalt, Nickel, Manganese and Lithium) |

Personal reflection on the system analysis:

Conducting analysis on tablet PC devices up to this point has further solidified certain beliefs I held regarding computer systems and has also updated the way in which I perceive certain devices. For example, I have always considered computer devices to be a useful tool at the disposal of society for furthering their own welfare. This impact alone and how my future career could be impactful using this discipline was the reasoning behind undertaking the MSc qualification. However, always being a strong advocate for technology I had not considered the negative implications. Perhaps not wanting to truly acknowledge them even being aware of their existence. This investigation highlighted some of the negative effects reliance upon technology can have such as health concerns, cyberbullying issues, cybersecurity issues etc. Realising that to an extent there will always be some negative implications of technological advancement is an important consideration. It has allowed me to develop my critical thinking skills, acknowledge my existing biases and aiming to perceive points of thought more objectively within the future. My understanding that the efficacy of analysis is only as effective as the ability to research alternative viewpoints has been solidified. Developing as a computer science professional it will be a necessity to reflect upon my work, considering my thought process and how I conducted the decision-making process. This will ensure the outcome that provides the highest benefit to the majority, whilst aiming to mitigate the negative repercussions where possible.

A shift in subject matter – changing the computer system considered:

Notes: Having looked at the assignment for assessment task 1 I have realised that the computer system I have chosen lacks specificity regarding a problem solved. Due to the extensive functionality of tablet devices, it will prove difficult to narrow the scope to a particular problem solved. To combat this issue, I have decided to conduct further research on the UNIMATE robotic arm employed in the Lordstown, General Motors factory going forward. I believe that this will allow for further specificity regarding success metrics and the application of computer science to solve a singular problem.

A screenshot of a social media account

Description automatically generatedDiscussion of the proposed topic:

Re-examining and updating the earlier proposed system to the current selection (UNIMATE 1900 series):

|  |  |
| --- | --- |
| Which system have I chosen and why? | I have chosen the UNIMATE 1900 series robotic arm. Specifically, its implementation at the Lordstown General Motors factory. The implementation of technology to steer humans from repetitive or dangerous tasks is one that is poignant. Especially regarding industrial productive methodology. |
| What problem have they been designed to solve? | The robots were designed considering Asimov’s three laws of robotics with particular focus on the first law ‘A robot may not injure a human being, or through inaction, allow a human being to come to harm’ (Salge, 2017). They were designed to undertake the more hazardous and or repetitive tasks required by general assembly lines. In the case of the Lordstown factory they were to be used for spot welding procedures. |
| How does the system solve this problem? | * Magnetic drum memory – used to store the programmable actions. Allowing the robot to be programmed for a variety of tasks * Did not possess a traditional CPU (central processing unit) * Used a combination of relays, circuits to conduct its programmed tasks stored as binary in the magnetic drum memory |
| Who benefits from this system? | * Enterprises – manufacturers could implement such systems to increase workplace safety and increase efficiency * Consumers – higher precision meant that higher quality products were produced * Employees – employees could focus on more stimulating and less dangerous tasks, this led to their increased safety within the workplace |
| Is the system good or bad? | The systems themselves have various positive and negative connotations. The positive implications are previously touched upon within the table. The removal of humans from potentially harmful tasks. The various use cases due to the programmability of the robots. The potential negative impacts fall under the LESP (legal, ethical, social, and professional) issues displayed in the table below. |

Legal, ethical, social, and professional issues associated with the UNIMATE 1900 series:

|  |  |  |  |
| --- | --- | --- | --- |
| **Legal** | **Ethical** | **Social** | **Professional** |
| * System must comply with health and safety legislations in place * Adequate training must be given to staff to ensure safety in the workplace, often a legal requirement | * Ethical programming considerations and ensuring systems provides best outcome for end users * At this point humans themselves had very little experience of interacting with robots. How we should interact with robots came into question | * Issues surrounding job displacement * Management staff potentially expecting robotic productivity levels from the human staff * The workplaces themselves will be overhauled to an extent | * Adaption of skills. With robotics at this stage being in its infancy there is an inherent need for the learning of entirely new skills * Engineers tasked with the designing of robots needed to be thorough in their considerations of the work. Ensuring they considered the safety of the technology they were creating. |

A diagram of a problem

Description automatically generatedPolya’s four stages – Useful tool to stimulate algorithmic thinking:

A computer screen with white text

Description automatically generatedRe-examining the created algorithm for making a cup of coffee considering Polya’s four stages:

Notes: It is important to remove some of the ambiguities from the algorithm (plan) to establish further executability. I would achieve this by removing some of the abbreviations and altering selected language within the index. Specificity is important within an algorithm, and I want to remove any potential ambiguities. I would also change the order of the steps slightly.

A screen shot of a computer

Description automatically generatedNotes: as seen in the re-written algorithm further specificity has been achieved. This should allow for further executability of the algorithm. Whilst establishing a set temperature for allowing the coffee to cool to is safety measure ensuring end user protection. I have conducted the algorithm myself the result solved the problem set. There amount of water used was adequate as was the coffee strength. There are assumptions made i.e. access to a kettle and instant coffee. Other than these constraints I would deem the algorithm, plan, and solution as acceptable. There is scope for further development in algorithmic thinking as my career progresses.

***(Figure 3) Portfolio reference list***

Lenovo (2023) *What is a tablet PC?.* Available at: [What is Tablet PC? | Meaning, Types and Uses | Lenovo US](https://www.lenovo.com/us/en/faqs/laptop-faqs/what-is-a-tablet-pc/) [Accessed: 06/11/2023]

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Salge, C. (2017). *Asimov’s Laws Won’t Stop Robots from Harming Humans, So We’ve Developed a Better Solution*. Available at: <https://www.scientificamerican.com/article/asimovs-laws-wont-stop-robots-from-harming-humans-so-weve-developed-a-better-solution/> [Accessed 10/12/2023].

Statista (2022) *Tablet shipments worldwide by operating system from 2010 to 2022.* Available at: [Global tablet shipments by OS 2022 | Statista](https://www.statista.com/statistics/273268/worldwide-tablet-sales-by-operating-system-since-2nd-quarter-2010/) [Accessed: 06/11/2023]

***A poster with text and images

Description automatically generated(Figure 4) Assessment task one – creating a poster based on the UNIMATE 1900 series***

***A screenshot of a computer

Description automatically generated(Figure 5) Assessment task one reference list***