What is the best design for an AI Chef?

Dev Thakkar

Contents

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Abstract

This project aims to explore techniques used by different variations of robot chefs in order to find each of their advantages and drawbacks. One way to test this is by modelling them in a 3D Modelling software and testing them in different environments, such as them trying to crack an egg. Using a table of successes in each environment, I can take inspiration from each model to help create a final model which surpasses its predecessors in the manner it cooks, cleans and serves food.

1 Introduction

"Some people call this artificial intelligence, but the reality is this technology will enhance us. So instead of artificial intelligence, I think we'll augment our intelligence."

—Ginni Rometty [1]

Artificial Intelligence (AI) is a field of study where machines are taught to learn and improve in a certain environment to reach an end goal. They are algorithms and combinations of pieces of code which are used to optimise elements of our lives.

Many people fear for what AI has in store for the future of our world, without fully understanding that it is already currently integrated into current society, from the searches we make on our smartphone, to the transport we take to commute to work or school. It improves the efficiency of everyday life, and its bounds are limitless. As Ginni Rometty says, it works to improve our intelligence. However, one of the sectors which AI has not really been able to break into would be the cooking industry. It remains heavily unexplored, and attempts have been made such as AI being used to develop recipes [2]. The idea behind this was that despite what ingredients are in the house, the AI would be able to generate recipes to complement human taste. This would aim to tackle prominent issues like food waste, which currently consists of wasting 1.3 billion tonnes of food each year, around one-third of all food produced for human consumption [3].

Therefore, in this project I hope to uncover a more efficacious way to revolutionise the cooking industry. Having an AI robot cook a meal would remove any unnecessary waste which occurs alongside cooking and would work to improve the productivity of people. Studies found that in 2019 the median time spent on cooking was around an hour, with weekends usually having a higher time spent [4]. However, the percentage of people eating breakfast is only around 44%, despite numerous studies showing it as the most important meal of the day [5]. This results in a tired working force and reduces the optimisation of mankind as a whole.

In order to improve upon this, we must return back to the basics. Many people who cook do so without understanding the underlying concepts and ideas which result in such extravagant dishes. Most dishes are created to be simplistic and easily understood, concealing their complexity. I want to focus on building a machine which utilises the diverse range of techniques which can be found at the culinary chef level, all of which deserve to be recognised and appreciated and hopefully open the mind of the user to a new side of cooking they have never seen before. Cooking is comprised of timing, consistency and mathematical proportion. By varying each of these aspects and using different raw ingredients, different variations of dishes can be created to complement different tastes and even fulfil nutritional requirements.

Understanding how humans cook and how it can be implemented and understood by a machine is crucial for the new product I hope to create but will also be the most challenging aspect given all the knowledge of coding and 3D modelling required is that of university standard. This project will focus on visually observing how other AI robots have approached this problem and trying to find the solutions to areas where they are lacking, finding a gap in the market and improving upon it. Throughout this, I shall guide those interested on a journey from start to finish, outlining the techniques used during cooking and how they can be replicated by a machine from initial ideas, methodology, development and testing, enlightening them to the complexities that arise during cooking and the ideologies behind different actions which are seen as the norm in the current cooking world, such as cracking an egg.

The outcome of this project will be a 3D Model of a robot capable of carrying out a series of instructions that enable it to cook sufficiently. It will be created using similar ideas of rivalling companies however, comprised of using a completely unique approach to overcome some of the major setbacks the other models suffer from. The new model will be an artefact developed using new learning concepts and tested under excruciating detail, whilst ensuring each step is documented in order to find future improvements more easily. The main objective is bringing awareness to healthier eating habits and to encourage more people to save time in mornings for breakfast and other crucial meals throughout the day, which would be an essential part of the project's success. I wish to inspire others to find other such areas where implementation of machines and AI would help boost workforce productively and help the world as a whole tackle prominent issues such as food waste.

2 Literature Review

This chapter consists of five sections which lay the foundations for the project as each propose a different solution to the same problem – how to implement AI into a robot designed to cook. In each section I will evaluate the effectiveness of each source by comparing them with each other and extracting elements that may aid to help create the new model. I have looked at multiple approaches done by many different companies at an attempt to reduce bias due to selection.

2.1 Recipes by AI

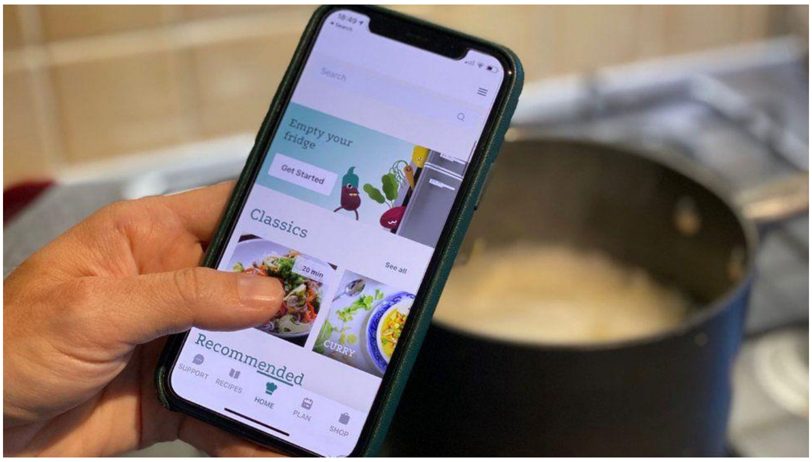

Figure 1 An Image showing a user-friendly, AI recipe generating app

Initially, I explored a magnitude of different articles and video with ranging levels of complexity, with Mackenzie's "Can artificial intelligence create a decent dinner?" [6] being the simplest. It provides an introductory approach into the industry of cooking through the creation of generated recipes based on ingredients and dietary requirements. It works by analysing a large database of recipes and tries to learn the underlying logic to understand the effects of combining ingredients. With this knowledge base established, it reviews chemical affinities of ingredients to create unique recipes. In this specific article Mackenzie expresses the boundless potential the algorithm possesses as it provides people the chance to master "less wasteful" cooking. She explains the various different ways it can be used: the user could directly copy the recipe given or it could be used to inspire them to create new recipes. Nevertheless, she elaborated on the finer details of both, stating how in her attempt to create a vegetable burger, the recipe resulted in an overcooked dish. However, hours later, the platform had adjusted due to her feedback. Mackenzie having graduated from the University of London with a diploma in financial journalism and having more than five years in the industry makes her a credible source. In addition to this, the unbiased reports suggest the reliability of the said reports and the reputation of the BBC helps to back this up. This article is relevant to my project in the way it teaches methodologies in which AI can be implemented in the cooking industry and could be implemented in the final project in order for the model to have another unique aspect – being able to create completely unique dishes never seen before. However, as Mackenzie mentions, the AI is not perfect and has room for improvement which should come with higher levels of usage and a larger database. Because of this, it will be used as the starting point of my research, after which its use will become limited. Overall, this is a useful basic source for self-sustaining adults and children to help grasp an initial understanding of AI's implementation into cooking.

2.2 NVIDIA's Approach

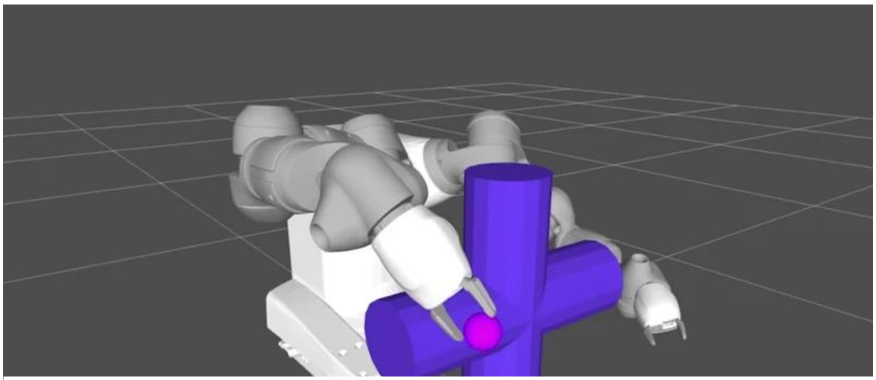

Figure 2 Model of NVIDIA's 'kitchen manipulator'

Whilst the article above covers the broad introduction of AI, Xi's article "NVIDIA's 'kitchen manipulator' is the ultimate robot chef" [7] takes a combinatorial approach where aspects of robotics and AI are combined to achieve a machine that can be used more practically. Xi mentions that the robot is capable of tracking dishes, opening and closing draws, identifying ingredients and even making meals. Accompanied with the article is a video which displays the machine placing items into shelves, and therefore gives the presumption that the prerequisites mentioned are true. Nvidia have said their hope for this robot is to "naturally perform tasks alongside people" which allows it to take up the role of an assistant. The key features of this robot are the two pincer-like claws and rotary spin created due to the use of a segmented arm system. These claws allow for objects to be opened and picked up meanwhile the spin allows for improved accessibility for the claws, so they can reach even the toughest of spots. However, one thing that could be concluded from the video was the speed of the machinery – it was incredibly slow. Seeing as the author of the article was Kieron Marchese who had been in the industry for around five years and that the company she was working for had been sustained for around twenty years at the time of publishing, due to their reliability, led me deduce that the video could not have been tampered with. This left a very key issue in hand as one of the major points of the final robot was it had to work efficiently to get food to the user as quickly as possible. Nevertheless, it was a start and the rotary spin did not seem to have an apparent downslide and so could be crucial to improve mobility for my project. Alongside the movement issue, one other thing had become apparent, this machine was not intended to replace a chef and therefore it lacked the interaction with the food aspect that I was hoping for in my final project.

2.3 Dexai Robotics' Approach

While the article above only covers the broad introduction, "Harvard and MIT-born robotics start-up Dexai Robotics scores $5.5M seed round to launch Alfred, a Robotic Sous-chef" [8] focuses more on applying the theory into a practical model with more involvement with food itself. In this article, Louise states the company's goals are focused on automating activities in the commercial kitchen and the food industry. They were able to create an innovative breakthrough which enabled robots to control deformable materials, such as ice-cream. This software improvement is extremely useful for my project as the final model should not only be able to handle tough materials, like tin cans, but also deformable materials. Although the article does not specifically mention how the company has been able to do so, it shines a light on the future potential machinery has the field as they found a "150,000-person labour shortage in the restaurant industry". This left a gap in the market which could be addressed by robots tackling repetitive tasks, as they are easier to program. Despite this article being well written, it lacks specific details necessary for my project which would be useful in the latter part of my model building. Further, Louise makes the article heavily one sided by only proceeding to interview employees and therefore it is not a fully credible source. In addition to this, while the robot does work with food, it does not exactly make the food from raw ingredients, and therefore is not fully applicable for my project.

Figure 3 Image of Dexai Robotics'' Sous-chef

2.4 Samsung's Approach

Due to the practical elements related to food only being partially explored by the previous article, this next source centres more deeply in the use of machinery to make dishes. The video "Samsung Bot Chef first look at CES 2020" [9] conducted by Velazco takes a longer dwell into the world of AI Chef Robots. He shows the intricacy of the robot and its elegance. The video displayed the robot working alongside a human to cook a dish and even had features which enabled it to work with a coffee machine. The amount of information a visual video can give is extremely helpful as it not only shows the external design of the model, but also how it reacts with certain environments. Velazco has had 10 years in the journaling industry and the YouTube channel it was published on has amassed a million-plus subscriber count

Figure 4 Samsung Bot Chef

making the information stated in the video highly credible. This would mean this source would be exceedingly useful in helping model my version. However, as shown in the video, the bot lacked capabilities that allowed for intricate movements which does not allow it freely to use high level cooking techniques. Some of the key features of the robot are the three claws and the separated machinery combining to make up the arm. Some of the advantages that can clearly be seen throughout are how easily it is able to pick up and utilise many household and food equipment. As seen in Figure 4, the machine has no troubles in being able to squeeze olive oil from the bottle. However, similar to the Nvidia's kitchen manipulator, the Samsung bot chef was designed to be "worked alongside with" as expressed by Velazco. This, however, is capable of handling the prep work and so could help reduce cooking times substantially. It identifies where and which objects are needed through the use of machine learning and one of the most admirable goals Samsung seems to have with this project, keeping it affordable. Affordability would be key in my final project in order to ensure that the highest number of people could have access to conveniently cooked food as this would ensure that it had left the most impact. Therefore, this aspect I would try to replicate in order to reach the largest audience possible. Overall, it becomes clear that this video is a useful demonstration as to how machine learning can be implemented with robotic arms and helped give me a strong understanding of the importance of object detection in order to allow the robot to work seamlessly.

2.5 Moley Robotics' Approach

Figure 5 Moley Robotics' Robot Chef

The final source, a video which represents machinery compatible with my end goals was the ultimate encyclopaedia as it, unlike all the previous sources, such as Samsung's bot chef, was designed primarily to work fully automated. The title "These robotic arms put a five-star chef in your kitchen" [10] allows the machine to do just as described. It can essentially work by recording the movements of already high-class chefs and replicating them with the robotic arms it has, along with its arsenal of unique features, to recreate a Michelin level dish. Some of these unique features are comprised of the hand-like structure, which is done to make it so that replicating movements of humans is much more simplified; the separated machinery, which similar to Samsung's bot chef, leads to increased mobility; and finally, the kitchen itself, which is predesigned to allow the machinery to work in a recognised environment. This does lead me to the drawbacks, firstly beginning with its inability to work in unique environments which would drastically scale up its pricing. In addition to this, the robot seems to struggle with cutting food and locating utensils or food that may have been moved or knocked out of place. The video was created by Stephan Beacham, an individual who has worked in the video making industry for upwards of 20 years and has received awards such as two-time award-winning video producer. Furthermore, it was published CNET, notorious for their reviews on products for their massive following of three-plus million. This leads me to believe the validity of the review and take it further into account when amassing my final project. A few major drawbacks that I would have to consider are, as previously mentioned, the price, as it costs an exorbitant £248,000 according to a source from the Guardian [11], and awareness of surroundings, as the price inflation is caused partially due to kitchen being needed to be built alongside it. Despite these drawbacks, Moley Robotics have created a machine that can work completely autonomously to create dishes and so does portray elements of what I hope to be able to create.

2.6 Conclusion

As discussed in the introduction, the literature surrounding AI in cooking can be separated into varying levels on autonomous. The projects with more reliance on humans helped provide an introductory view as to how artificial intelligence has a part to play in the culinary world. These literary pieces also helped construed different machine learning strategies which could be implemented whilst cooking to help enhance the nutritional benefits of a dish. As the literary pieces represent high levels of autonomy robots, a contrast can be made between each to exemplify positives and advantages of each model. Ultimately, by assessing each piece and thoroughly evaluating their drawbacks, it equips me with far more tools to help tackle certain problems I may run into during the designing process, especially when focused on more abstract applications such as cracking an egg. They each allow the reader to use elements that would be best for their uses which becomes more apparent in the extreme case, where automation is maximised and visual representation of such a model suggests the project is accomplishable. All these key tools collectively would finally be able to create an efficient, powerful and completely automated design of an AI chef that would be more accessible than all its predecessors.

3 Methodology and Development

3.1 Time Frame and Organisation

Following further research on the culinary world, I had arrived at a deeper understanding of concepts that allows my practical methods to be conducted more effectively. Throughout this project a timetable was implemented [see Figure 6] with the intent of successfully being able to reach established deadlines. This helped constructively figure how I planned to approach the problem and reduces the chance of missing personal goals I had related to the project. As shown in Figure 6, the timetable provides a time to each task allowing me to plan ahead and allowed me to be ahead of the curve. The tasks themselves were split up into three fields: research, modelling, and writing. Firstly, I started with research which can be subdivided into primary and secondary. My primary research involved modelling the existing models of AI chefs and seeing their applicability and drawback they had in realistic environments. These success rates would then be modelled as graphs, as visual representation allows us to gain a more comprehensive understanding of what the data represents. Meanwhile the secondary research comprised of browsing through already existing articles, videos and other pieces of literature online to gain a stronger understanding of the field. Secondary research was mainly used to produce the introduction and literature review. Then as I began specialising my research to a more mechanical approach, this data would be more apparent in my methodology. Then the primary research which I had personally conducted would be used to make up the initial results, along with conclusions to these said results. Finally, by compiling all I had learnt and uncovered from my primary

(STARTING DATE 1ST OCTOBER) Note: Rest Days/Weeks not included	How long this will take:
At the beginning, research into how to code AI programs applicable to 3D models to find out restrictions and find a few appropriate methods that can be used.	2 Weeks
Then research would develop into looking into all types of things found in kitchens, and the shapes they come into. Then doing research into other AI chef-like options which are already in the market and checking what the advantages and disadvantages of the physical components are. The analysis into each methodology would allow me to create the best combination for the physical component of my AI-Chef.	1 Week
Write up introduction and Literature Review of article for EPQ (DUE 1ST NOV 2021)	1 Week
The second part would require me to create a 3D model of the AI-Chef. Here I would experiment with different software to find the easiest to use/ the most relevant to my project.	4 Weeks
Using the 3D model to pick up and move around equipment and items such as food. Then creating a table of success to failure rates and then converting the data into a graph.	2 Weeks
Writing first section involving my personal experiments with my 3D model, including table and graph	3 Weeks
Writing up AI algorithm which compliments 3D model. This algorithm should be able to use different methods in order to test which method is the most appropriate.	4 weeks
Writing code which creating tables and graphs and recording these from testing different methods.	2 Weeks
Writing up all data found so far with complementary research.	1 Week
Writing up glossary type section going through topics which many may not be familiar with	1 Week
Concluding which shapes for physical part of AI-chef are most effective and which AI algorithm method is the most efficient (Due 7th Feb 2022)	2 Weeks
Draw up presentation with all data so far	3 Weeks
Rehearse Presentation	1 Week

Figure 6 Timetable for EPQ

research, I obtain a final model. This would be placed in the later part of my article and the presentation, including all other key pieces of data that I had uncovered leading to this moment.

3.2 Software

As part of my research in methodologies I also thought it would be a good idea to research different 3D Modelling software as each presents its own positives and negatives. Among all possible options, I found blender to be the most user-friendly due to vast amounts of videos online explaining different applications of the software and therefore, as someone without a vast knowledge in 3D modelling, I found it to be the most appealing. In addition to this, blender's API is based on python, which is a programming language I have used before and therefore comfortable with. Furthermore, python is a free and open source which is easy to read and understand, despite it being a high-level programming language. Such readability and versatility allow it to be a good programming language for the task.

Similar to blender, Wings 3D is another free and open-source modeller. It allows users to model, and texture meshes to create a final model. Whilst it being open source is a huge advantage as it enables lots of tutorial videos to be made as lots more people have access. Wings is held back by the inability to do much else expect modelling. Animation is not supported, and it only has basic rendering abilities. Thus, it makes this not appropriate for me to use to tackle my issue as I would need to see how the robot chef interacted with the environment.

Some other options I had explored include RoboDK which is well known in the 3D modelling world for being useful to program an industrial robot and test it within a simulated environment. One of the major drawbacks to this piece of software was the pricing; it was more for professionals and companies who had lots of experience previously and so had costs up to €145 for a 2-year subscription [12]. These high prices also meant that it did not come with as many tutorial videos. Despite it having a trial period of up to 30 days, I concluded that this would not be long enough for me to create a design that I was happy with.

Overall, this resulted in me sticking to blender as my software. Not only was it free unlike RoboDK, but it also had smooth rendering abilities with EEVEE, blender's real-time engine focused on interactivity and is known for its promising speed, which leaves Wings 3D as the less appealing option.

3.3 Conclusion

Creating the timeframe allowed me to ensure I was always on target and gave me a comprehensive understanding of the amount of work I had left. Having decided what software to use, it also gave me plenty of time in order to potentially sift through plenty of tutorial videos in order to increase my complementarity with the blender.

4 Key Concepts

4.1 Introduction

Understanding the ideology of this project is primarily about understanding the fundamental terminology exercised when modelling robotics and working with automation. On the simplest level of automation, robotics would be simply designed to repeat an autonomous task which would not require any level of intelligence. However, as the environment the robot is placed in gets more complicated and random, a higher level of intelligence is required to handle the situation in a manner that the creator would expect. In a more complex scenario, machine learning is used to help the robot know and learn what to during each decision scenario. For a robot to be able to handle the tasks it has been given effectively, the model itself should provide enough tools that can be used within the robot's discretion.

4.2 3D Modelling

The process of creating a mathematical representation of inanimate or living objects within a 3D plane. Generally, this is done for two reasons: recreation in the virtual world or recreation in the real world.

Virtually, the objects created could be implemented in a game for example, or the creator may choose to animate these objects to help with the creation of a movie.

Meanwhile, objects could be modelled on a 3D plane to find out the dimensions they may take in the real world. This may be vital for engineers for instance who would need to know the physical dimensions of a project and its distance to other objects in relation.

4.3 Machine Learning

The utilisation of computer systems in a manner which allows them to learn and adapt by finding patterns in data. Commonly seen as a subset of Artificial Intelligence, it is applied to every aspect of everyday life from medical diagnosis to image processing and often involves a system understanding and manipulating new data.

In terms of the project, the ideology of machine learning is important to keep in mind when developing the machinery as smooth movements and different tools should be implemented into the model to allow it to tackle a variety of tasks.

4.4 Selection Bias

In terms of for an AI, selection bias refers to the selection of data used for training a machine learning model. This may be done to allow it to specialise and be able to carry out an individual or a set of tasks optimally.

As the aim of this project is not to create the software tasked with handling the artificial intelligence itself, it is not necessary to have the model attempt to create a whole dish. Instead, it is vital to see if the physical functionalities of the model allow it to do complicated individual tasks such as cutting an apple or cracking an egg.

4.5 API

Application programming interface are a set of protocols which are involved with building and integrating application software. They are tools and allow a programmer to deliver communication between two applications and make it easier to create a program as the initial infrastructure is already there. An example of API application is the Apple API which is responsible to detect touchscreen interactions.

An API would be necessary in this project to allow multiple different fragments of the project to work together. The main robot itself would likely need to interact with cameras or other such technologies that would allow it to know its surroundings and move around applicably.

4.6 Rendering

Rendering is the process of creating a final 2D image or animation as a result of stitching together a sequence of information. This helps produces the final frames of the upmost highest quality and allows the application of photorealistic or other effects.

4.7 Anodising

An electrochemical process which entails covering a metal surface with a corrosion resistant anodic oxide finish [13]. This is done so that the metal inside is protected from corrosion as it is not exposed to the oxygen or water vapour in the surroundings.

5 Initial Results

5.1 Introduction

Using all the knowledge acquired in the research thus far, this section will begin to tackle solving the problem – creation of the best model for an AI chef. Each proposed model will be analysed and compared not only to prior models by different companies but also its respected predecessor. The proposed models and by no means perfect and therefore the selected idea will go through rigorous testing process explained within the next subsection.

Models presented in this section have taken inspiration from variants of previous attempts along with items we find in our everyday life. A completely original model design is particularly challenging due to sheer number of successful previous models designed to be able to efficaciously pick up and work with items. Nevertheless, I have attempted to come up with three potential ideas for the designs I will create.

5.2 Measuring Success

Testing is integral to develop a successful model and hence a strict success criterion should be followed. For this project, it entails as follows:

SPECIFICATION	**EXPLANATION**
PHYSICALLY CAPABLE MODEL	A model which is physically capable of being built
SMOOTH MOVEMENTS	Model can move in such a manner such that there are no blind spots
CAN HANDLE DIFFICULT COOKING TECHNIQUES	Ability to cut and move appliances and perform other cooking related actions
CAPABLE OF WORKING IN ANY GIVEN ENVIRONMENT	Compatibility with visual tracking technology
MATERIAL USED IS THE MOST OPTIMAL	E.g. Overall material used should be inexpensive and material for the claws should enable model to pick up appliances and food alike

5.3 Model I

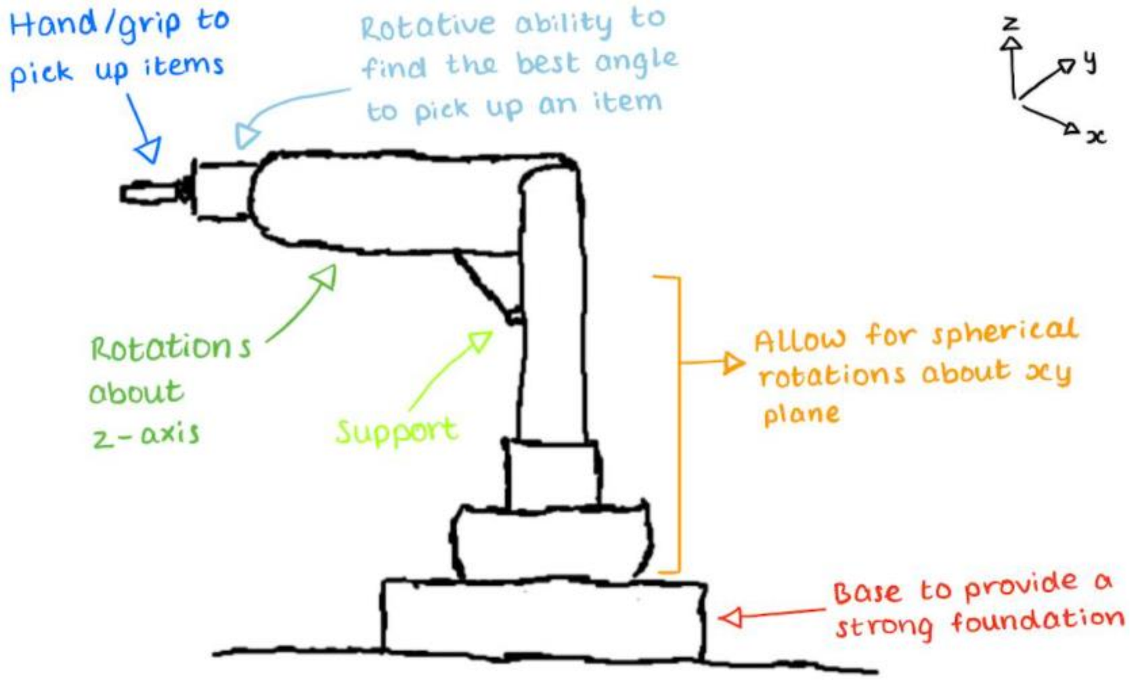

Diagram 1 Concept Design for Model I - SIDE VIEW

The first model [see Figure 7] is inspired by both Nvidia and Dexai Robotics' design, considering the two pincer-like claws which are used to interact with food and utensils. I originally created this model to see where the benefits and drawbacks of a two-finger machine lie and due to its simplicity. As starting with a brand-new software, the world of blender seemed overwhelming, resulting me closely following a YouTube video which provided an informative introductory start [14]. However, I decided to further develop the project with having it interactive with a prerequisite environment [see Figure 8]. This methodology was a replica of Moley Robotics techniques, however as this was the first model, I had many future changes that could be made, with it being able to work in any environment being key. However, Model I did consist of smooth movement and rotation which enabled it to successfully pick up items. The main issues followed picking up the item – as doing other tasks became notoriously difficult. With the model only comprised of one arm, issues such as stabilisation became apparent. Putting aside these original problems, another

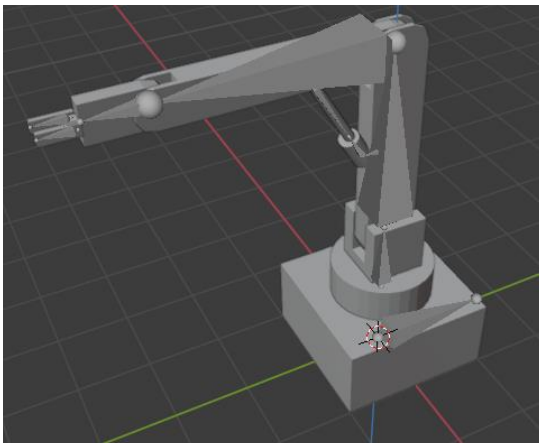

Figure 7 Model I for AI chef

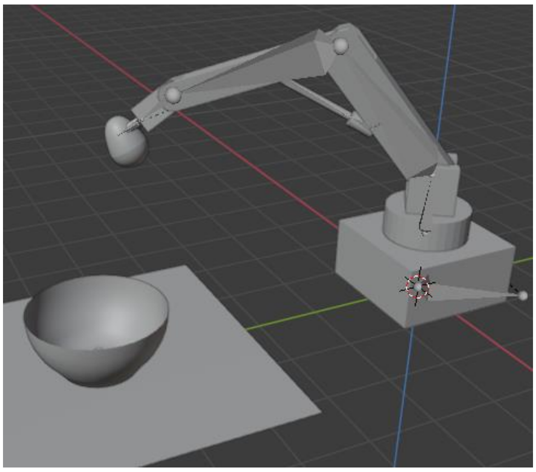

Figure 8 Model I interacting with egg

issue became visible – the difficulties of conducting tasks with only two pincers. The robot struggled cracking an egg and ensuring that no parts of the egg fell outside the bowl. Hence one thing had become apparent, having a two-claw system would not be viable as basic actions such as cracking an egg were not plausible.

In order to ensure this was the case, further testing must be done, however this time instead of doing it in a simulated environment, it was to be done in the real word. As creating the Model I from scratch could be extremely time consuming and cost an excessive amount, a more realistic approach was taken - recreating the two-claw system using my index finger and thumb.

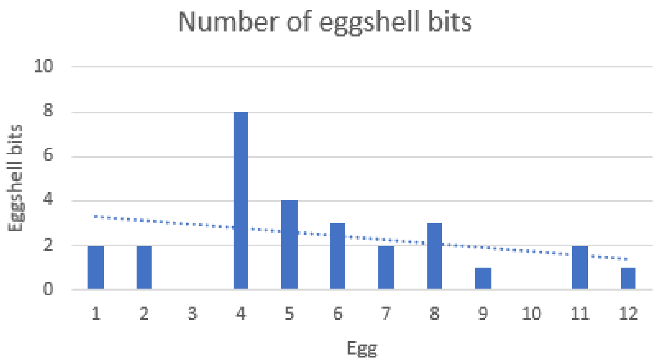

Figure 9 Column Chart of Two Straight Fingers Experiment

I conducted a test in which I would pick up eggs and crack them using only my index finger and thumb. In order to ensure this test was fair, it was conducted by one individual, me, who repeated the experiment multiple times to reduce bias. The information found suggested that using a two-finger set up was slightly ineffective as eggshell bits could be found despite careful handling [found in Figure 9]. However, over time the number of eggshell bits did reduce due to improved strategies such as twisting my two fingers. Overall, the mean number of eggshell bits are 2.33, suggesting this was not a desirable trait for the final robot. The graph also represents a high level inconsistently as one of the eggs cracked ended up with 8 eggshell bits – an extremely high value when compared to other results.

5.4 Model II

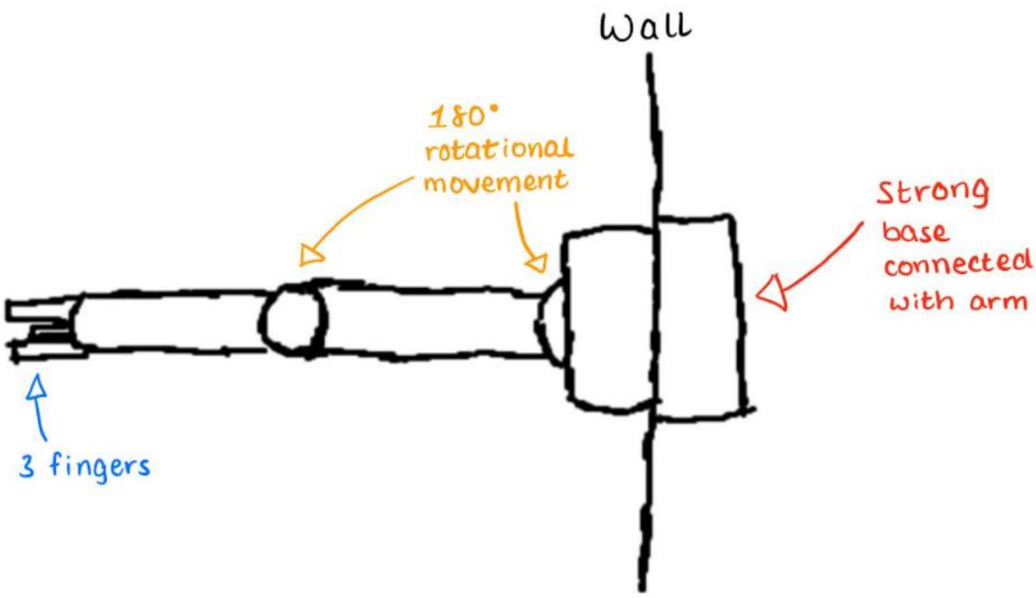

Diagram 2 Concept Design for Model II - SIDE VIEW

Taking on board the feedback of the first model, I began by changing the number of fingers which make up the grip - from two to three. This change made a drastic change instantaneously as equipment could be much easily picked up and handled. One other apparent change would be changing the rigid objects of Model I into more smoother replicas [see Figure 10]. The inspiration for this was the joysticks found in controllers on modern consoles [shown in figure 11]. They allow an almost 180 degree of movement and by having two such joysticks attached together, it enhances the mobility of the robot claw drastically.

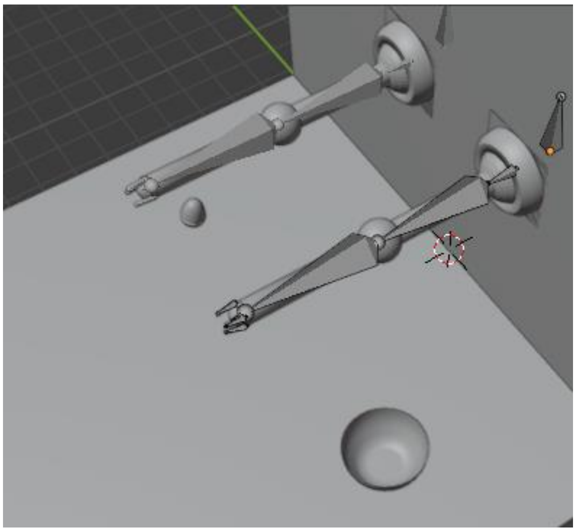

Figure 10 Model II in a pre-set environment

In addition to all the previous additions, I decided it would be extremely beneficial to have two robot arms which would work simultaneously to cook. This would not only drastically improve preparation times but enable specialising for either hand in future models. As visibly apparent in Figure 10, it would allow the robot to move both the egg and bowl concomitantly.

Although this model does attempt to tackle quite a few of the problems of the previous model, it still does not allow for a robot to work in any environment, as the given environment is pre-set. Another shortcoming may revolve around stability of the model – if the arms weigh a large amount it may be difficult for them to remain attached to wall as over time, heavier movements will slowly misplace the arms and may eventually result in them breaking away from the wall. This could be overlooked by the material used which would be discussed later in this section.

Figure 11 Controller Joystick

Furthermore, to test the practicality of the three-finger claw, a further test needed to be done in the real world. This would allow for a numerical comparison to be made between the two models.

A substantial difference can be seen when comparing Figure 12 and Figure 9 – with the second experiment have a drastically smaller mean of 1.17 eggshells. Additionally, the experiment with 3-fingers having a mode of 1, whereas 2-finger experiment has a mode of 2. Overall, however, similar trends can be seen. There are similar inconsistencies with egg 3 in Figure 12 having an eggshell bit count of 5. Then there is also the line of best fit suggesting that overtime as technique improves, there are fewer eggshell bits. One thing to note is the gradient of Figure 12 is drastically steeper implying a quicker rate of learning.

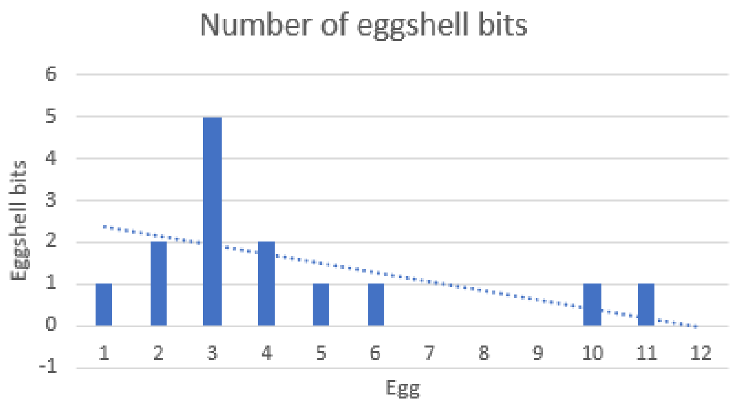

Figure 12 Column Chart of Three Straight Fingers Experiment

5.5 Model III

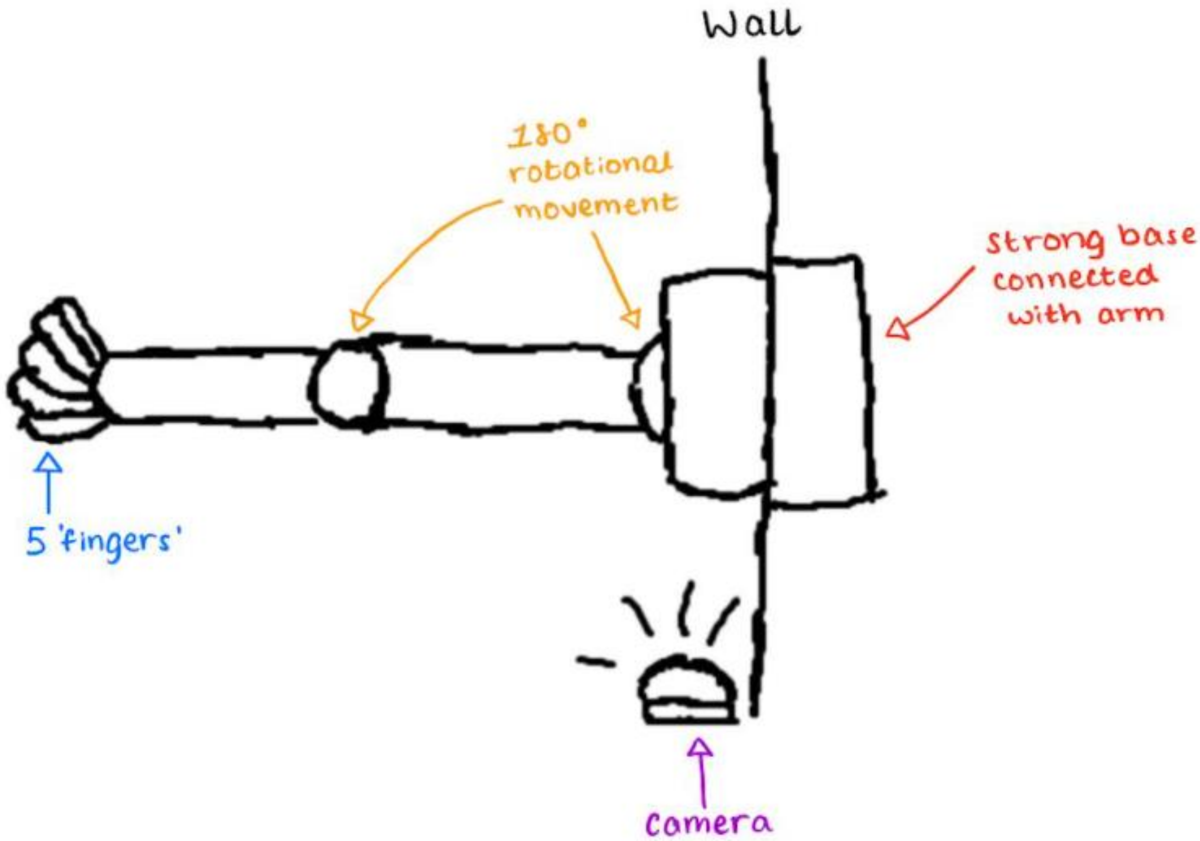

Diagram 3 Concept Design for Model III - SIDE VIEW

The inspiration for this model [see Figure 13] is hugely based upon Moley Robotics' approach [10]. As their design matched the success criteria the most, I replicated their 5-finger design for the claw however kept the unique concepts used in Modell II – such as the joystick design for the base. This was so I could find out the advantages a 5-finger system had.

One of the huge advantages that Moley Robotics' exploited with said model is it is much alike our own hands; thus, with the help of motion capture gloves, the robot could be taught how to create a dish instead of having to learn it. This would enable the robot chef to use world-class techniques from the world's greatest chefs. Therefore, by replicating the 5-finger design it enables my model to be able to do the same. This would be game-changing as instead of the robot having to learn how to cook dishes, it would simply be able to copy another individual.

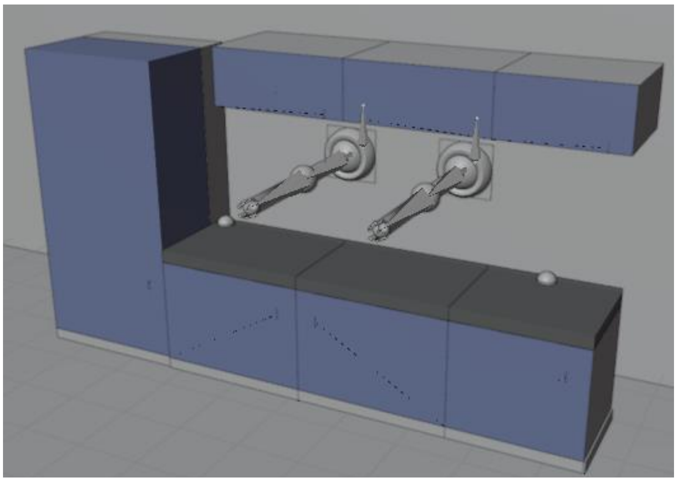

Figure 13a Model III in 'kitchen' environment with camera implementation

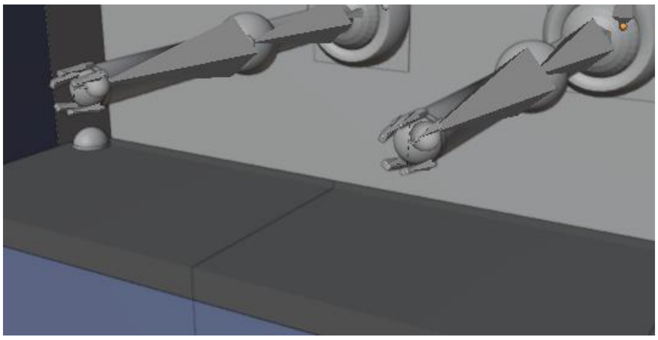

Figure 13b Zoom in of Model III

On the contrary, this defeats the purpose of an AI chef and eradicates the possibility of reinvention. While it may decrease the time taken for the bot to learn how to cook a dish substantially, it would be very unproductive to show the robot how to cook each iteration of a dish and very much time consuming as new recipes are made on the spontaneously. This also would not allow the robot to account for personal tastes and would just normalise all dishes for the public. One key advantage of having an AI chef is the specialisation per user factor and this would be lost with the implementation of motion capturing.

In addition to this, by adding into more fingers, it increases the amount of material used and hence the overall price of the product. As one of the criteria is affordability it is important to balance out the number of fingers needed vs cost of the final product.

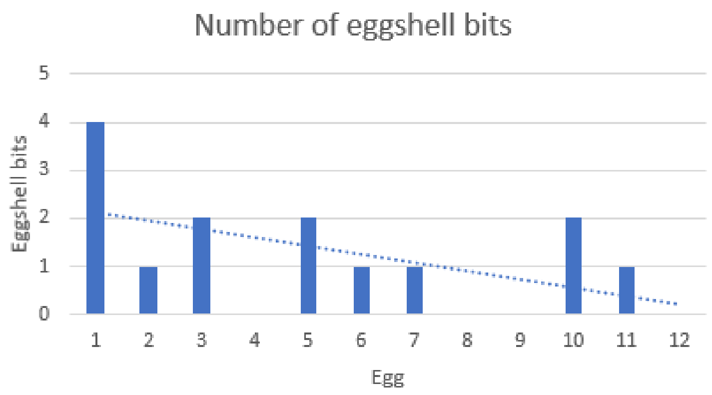

Figure 14 Column Chart of Five Straight Fingers Experiment

In order to understand whether the benefits of a 5-finger system outweigh the extra costs, an experiment must be done in the real world to find a numerical contrast. Comparing Figure 14 with Figure 12, not many differences can be found, with the mean being the same 1.17 eggshells. There are fewer extremes hinting at lower inconsistencies, however not much else can be found.

5.6 Camera Technologies

One other unique feature Model III possesses is its connectivity with camera system. In the corners of Figure 13, two spherical objects can be found which could emit varying different types of light used as sensors.

Infrared light would allow the bot to gain awareness of its surroundings. By doing so, it enables the robot to be able to work in any given environment at any given time, as even in pitch darkness, infrared cameras work spotlessly. However, the downside of using infrared is its inability to penetrate through cupboards and other kitchen furnishings, hence preventing it for knowing what the user has outside its normal range.

Another such type of emission could be radio waves. Previously used by government services and can be found on communicative devices worldwide in this current day and age, radio is known for its capabilities to travel through walls and other such obstacles. Like the technology of RANGE-R [15], it would light up a field of view with radio waves and enable the sensors to comprehensively suggest where and what items can be found in a strict radius. However, its inability to travel through metal and a pricing of $6000 makes it less appealing.

Comparatively, radio waves seem very much like an overkill, with the price and as knowing the location of anyone and anything in a set location. It would simply leave the user exposed as a data breach or hacking of the systems could be disastrous as it would give away valuable information. On the other hand, infrared seems incapable of gathering such important information and therefore not enabling the robot to know what ingredients a user has available and their locations in cupboards. Contradictorily, in the modern world, privacy is becoming more of an issue and in a survey it was found that 86% of respondents have a growing concern regarding data privacy and a further 40% do not trust companies to use their data ethically [16]. In order to appeal more to the consumers, the downside of infrared could be flipped to be seen as more of a positive and the shortcomings of this type of light could be overcome through the use of an app where the user states the ingredients they have available or by other software additions.

5.7 Material

Observing materials used by other robust robots [17], I found that beginning with steel for the base would be the most effective. It is a sturdy metal capable of withstanding harsh conditions. An alloy of steel (for instance aluminium) could be used due to its lightweight and heat resistant properties. Such a base is vital when working with flames during cooking.

Moving up from the base, just aluminium could be used due to it being easier to shape and significantly lighter. It's ability to corrode in wet environments may be a hassle, however, can be easily overcome by a coating – through anodisation.

Closer to the stem of the arms, Kevlar should be used to due to its tolerance to extreme temperatures which the lower end of the arm could be exposed to. This easy-to-use protection would help maintain the robot's functionality despite the dish that needs making. It would also make handling extreme polar opposite ingredients much easier such as peas (often left in fridges) and melted cheese.

Figure 15A Glasses

Figure 15B Zoom in of Glasses

Finally, the fingers of the robot should have an extremely good grip, hence I got the idea to use rubber which initially sprouted from my glasses [found in Figure 15]. They have an orange design and small triangle cut-outs which is used to help improve its hold. Similarly, if applied to the fingers of the robot, it would help clutch on items. As the grip would get worse overtime, separate grips could be sold to replace those after a set amount of time. This additionally would provide an alternative source of income allowing the overall prices of the robots to be cheaper.

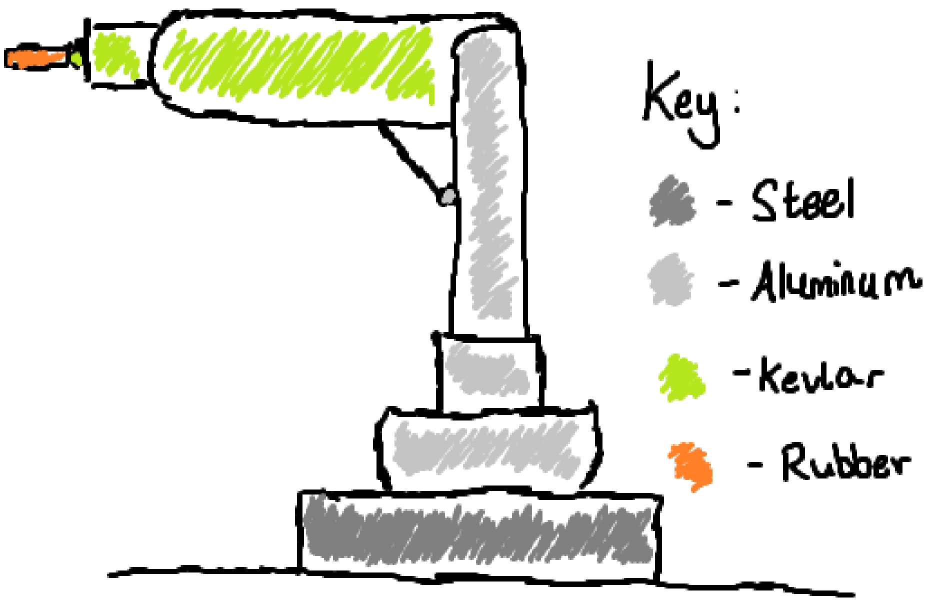

Diagram 4 Summary of materials and their respected locations

Ultimately, these materials collectively would make up the bulk of the exterior design. As aluminium is more expensive than steel, it was not used to make up the base as the only main additional property aluminium adds is malleability, which is not required for the base. Kevlar is then used closer to the fingers as this section would be exposed to more extreme temperatures. Kevlar is not used for any other parts due to its excessive pricing and not matching the properties required for other sections. Rubber is used for a similar reason – when recycled from tyres it has a melting point of 600°C [18] and has a resemblance of the same grip required for the robot. This makes it a perfect material for the fingers of the robot as it can handle extreme temperatures and has a strong grip. The fact that rubber's grip worsens overtime can be resolved by selling rubber grips separately as they are inexpensive and should be easy to replace. Collectively, these materials should help make up the bulk of the robot's exterior.

5.8 Conclusion

On the whole, Model I was used to help me become more familiar with the software and have a stronger general understanding of robotics. It consisted of a 2-finger system which was generally inferior to the 3-finger and 5-finger system comprised in the other two models, as shown by the higher mean and mode. It allowed me to figure out which components are needed to make up a robotic arm and through testing, I figured out the disadvantages each part held.

One of the main disadvantages which I hoped to improve on with Model II was mobility - I felt the previous model had stiff movements and couldn't encapsulate a higher degree of movement. Hence with the addition of joystick technology, the design was better equipped to handle any random given environment. Despite the addition of all the new features, the model was missing randomness – the ability to work in any given environment. Furthermore, further testing should be done in order to verify the superiority of a 3-finger system.

Hence Model III was found. It was created to bridge the gap between a robot hand and an actual human hand and understand the benefits that could lie with motion capture technology. The model threatened and would attempt to redefine the need for AI implementation in such a robot. However, the caveats with the model, related to time and resources, seemed too unrealistic. Furthermore, in spite of excessive testing, the 5-finger model did not provide a revolutionary improvement as I had seen before and therefore seemed like unrequited addition. The camera technology on the other hand, helped provide a foundation for sensor technology to be implemented alongside the robot; thus, providing a peripheral vision that the bot can use to work in any given environment.

The formatting from Model I, the 3-finger system from Model II and the camera technology of Model III are collectively the best attributes from each of the models and therefore would be collectively implemented into the final model.

6 Final Model

6.1 Introduction

Having created 3 previous models which each had their unique selling points, it was time to combine them to finally create the final model. I was able to build off from Model II as it most encapsulated what the individual bot would look like. As discussed in the previous section, it was important for this model to be efficient in terms of handling items and being able to work in any environment, more so then all its predecessors.

6.2 Model IV

This was what all the prior research and testing had led up to; to re-envision and reimagine the cooking industry…

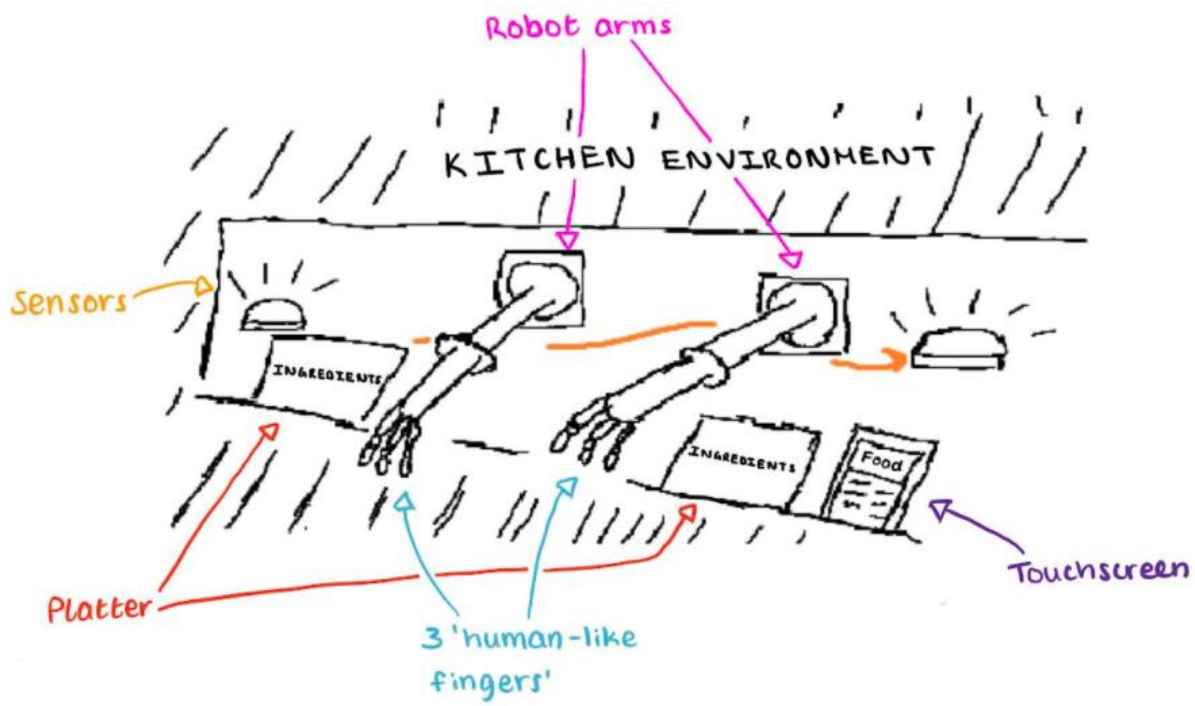

Diagram 5 Concept Design for Model IV – SIDE VIEW

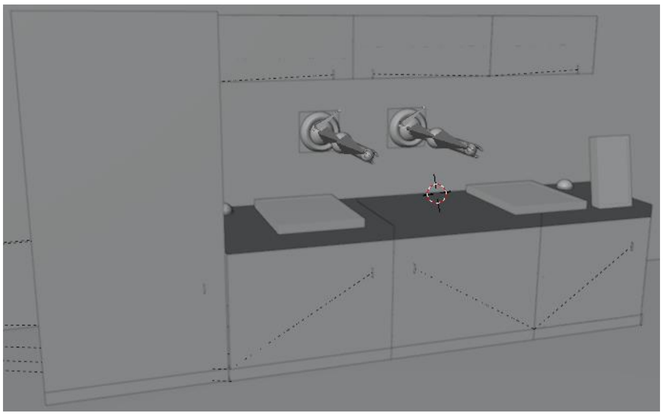

Figure 16a Model IV in 'kitchen environment'

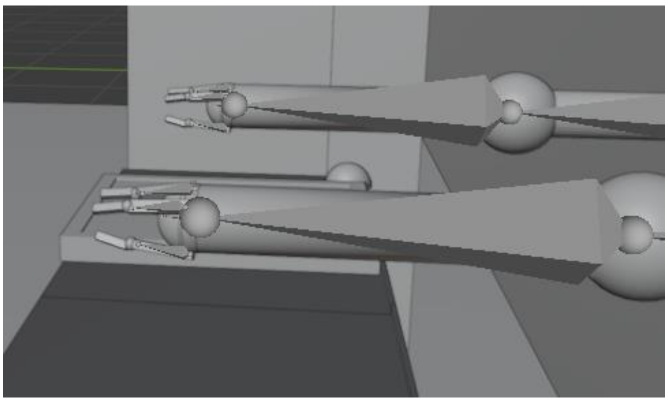

Figure 16b Zoom in of Model IV

The key features this model displays [as seen in Figure 16] involves things such as sectioning for ingredients, a touchscreen display which would allow for interaction between the user and machine, without the need for an app. It takes a more realistic approach on the project as it allows all the separate segments, such as the infrared cameras, to work amicably alongside other parts. It continues with a 3-finger setup with double rotary joystick technology implemented alongside it. Additionally, a small noticeable addon with the model would be the extension of the fingers and segmenting them to work more similarly to human fingers. This addition was made in order to ensure higher stability when gripping utensils and other itinerary. As most items found in the kitchen have been optimised to work with human hands, having features that appropriate them the most to this may help the robot work with more appliances.

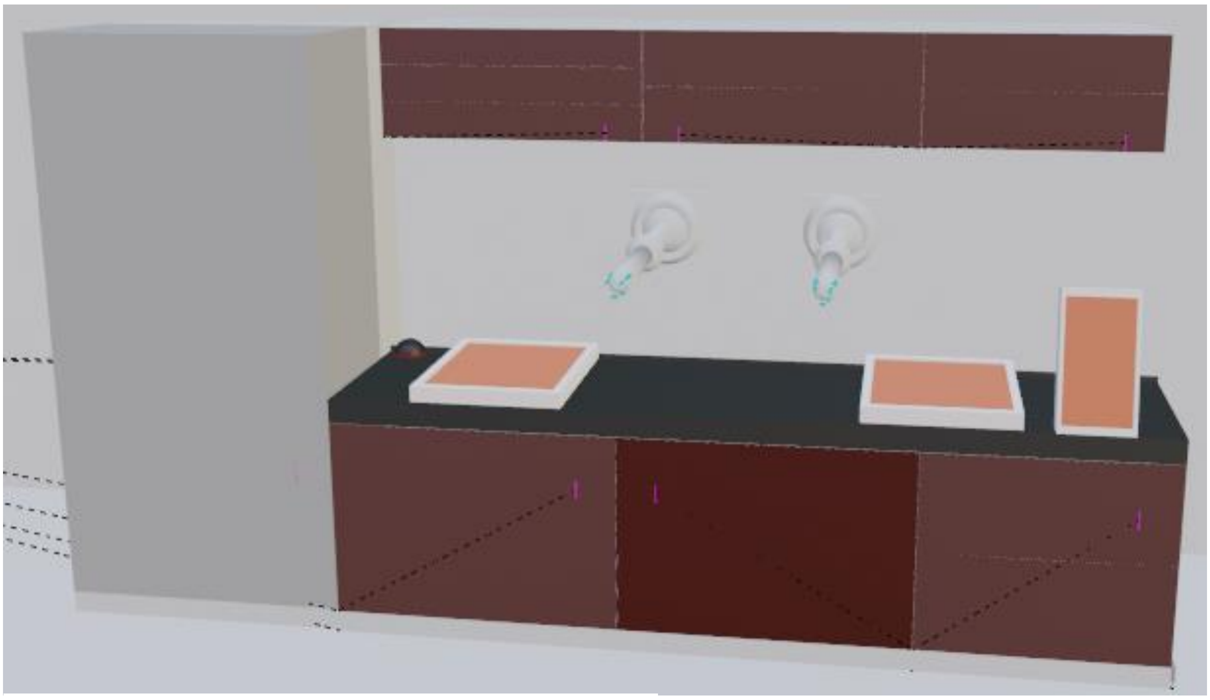

Figure 16c Model IV in Coloured Environment

6.3 Results

To test my hypothesis, I tested the ease of cutting an apple in the real world with straight fingers, against fingers that can bend.

This obscure experiment led by me involved cutting apples of similar size down into 8 segments.

When cutting the apples normally, with fingers that can bend, I found the average time to be 14.942s as shown in Figure 17. Meanwhile, when cutting using straight fingers [presented by Figure 18], the mean time was drastically higher, sitting at 27.912s. This piece of information suggested that having segmented fingers is

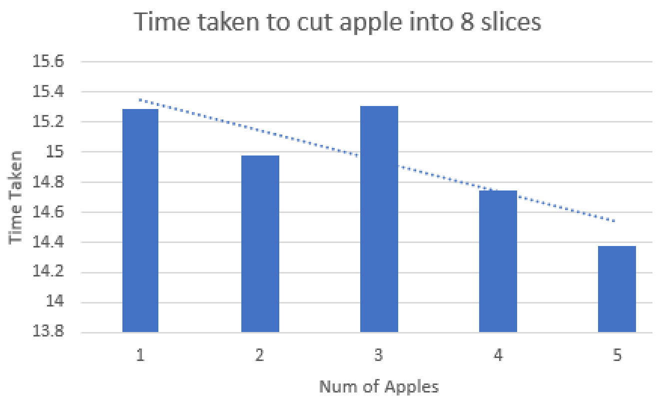

Figure 17 Column Chart of Fingers that can bend

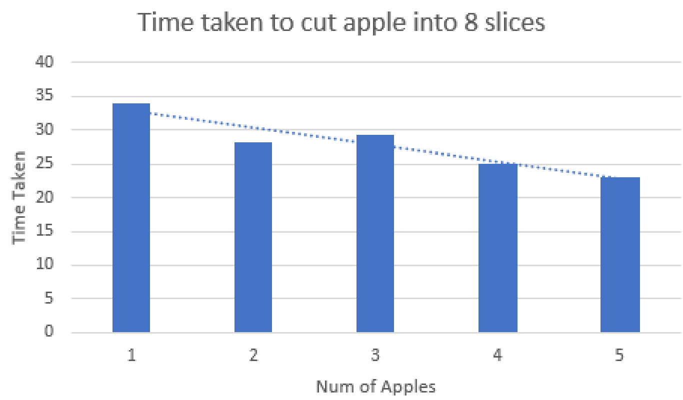

Figure 18 Column Chart of Straight Fingers

much more efficient than having straight fingers. Although both graphs showed improvement over time, the initial base of Figure 18 is too high. One factor which could have played a part is the different sizing of apples. Although they were acquired from the same store and seemed similar in size, there must have been a minor discrepancy. However, as the difference in mean is so colossal, these differences don't play a big enough role to imply these results are invalid.

Additionally, the size of the sample used was very small. This was due to this being primary research and I did not want to waste any food throughout. However, due to such a small sample, an argument could be made that these results aren't as representative.

Nevertheless, the results achieved matched that of my hypothesis and therefore the human-like fingers where a huge addition to Model IV to further improve its efficiency when working with cooking appliances.

6.4 Comparison

Visibly, Model IV seems very similar to Model II due to the interchangeable components that make up each of them. However, the addition of cameras has been added from Model III and each of these models were built from the ground up thanks to Model I which allowed me to get a strong understanding of how a robotic arm may move.

Some unique concepts it has in addition, would consist of the touchscreen which acts as a user interface. This would allow the user to input their personal tastes which the AI would then specialise the dishes to complement each individual. The screen could also be used to differentiate users in case if the robot is used by multiple people (similar to how Netflix and their suggestion system works). There is also sectioning for raw ingredients which is used to overcome the weakness of infrared emission. As the ingredients are visible, the sensors should be able to detect the items and pass the information to the robot. One extinguishing factor from Model II would be how much more replicable the bot fingers are to human fingers. As shown in the previous section, this helps with picking up appliances and using them optimally. Overall, the changes implemented in Model IV have been done to overcome the drawbacks of previous models and this final model works to bring into light the benefits of each.

6.5 Conclusion

Ultimately, Model IV encompassed all the features the success criteria detailed. The first point of creating a 'physically capable model' could only be proven by physically making the model in the real world, however as the goal for this project was to simply design the model, I feel this has been covered. As the model has been created in blender, I believe recreating it in real life should be possible. Then onto movement, due to the spherical and smooth nature of the model, it seems to have a good sense of mobility. This becomes more apparent when observing other similar mechanically moving models, such as Moley Robotics' Robot Chef. The third criteria of being able to handle different cooking techniques was proven by the real-world testing with eggs and apples. It's capacity to work in any given environment is then tackled with the camera and the robot arms working synonymously to detect the ingredients placed in their corresponding platters. As long as these elements exist, they should be able to detect items spotlessly and hence work in most environments. Finally, the materials used are specifically done so to take advantage of their properties: steel for the base of the arm as it is strong and provides a good foundation; then aluminium for everything aside from the 'fingers' due to its higher malleability can be used; finally, Kevlar is to be wrapped around the aluminium closest to the fingers to substantially increase sustainability by increasing heat resistance and ultimately the fingers are to be made up of rubber due to their tenacity. Each of these items can be bought in bulk and even Kevlar should be easily obtainable for a robotics company despite it being mostly used by the military. Hence, all factors of the success criteria have been covered.

7 The Winter Olympics Robot

In early 2022, there had been huge advancements in the field of AI chefs as in the Winter Olympics held in Beijing, China a new machinery was unveiled. The Olympics are unrivalled when it comes to revealing all new high tech as the hosting countries hope to improve their reputation when put on a pedestal in front of the whole world.

Figure 19 China's AI Robots introduced at the 2022 Winter Olympics

This was seen in the 2022 Winter Olympics where China showed off their robot chefs. They were an integral part of the organisers plan to keep the event from being derailed by Covid-19. As shown in Figure 19, the exterior design was smooth, with no blunt edges and the colour of white to give it an unthreatening feel. Although these machines have been described as AI from Morillo's report [19], each robot seems to have a specific task, e.g. to make drinks or to make a sandwich, and therefore the question arises. If the robots are essentially repeating a task, is the implementation of AI necessary? To that two answers could be given: visually-recognitional software could work alongside an AI bot to give a better customer experience, such as by offering drinks to their hands; or AI would help specialise certain drinks or foods to specific customers based on their taste. However, this doesn't seem to case [20] and hence these robots have been created to handle an insatiable repetitive task.

Some things to notice about the design of their drink machine [Figure 19] is the two-finger system. One would assume this had been implemented after strenuous testing but seeing as this machine is simply only designed to handle drinks, its applicable. Additionally, the cutlery surrounding the robot seemed to have been specially made to work alongside it, which in a random environment, wouldn't be viable. The movement of the robot is also intriguing – it consists of a rotary arm which seems to provide extraordinary smooth movements. Although, this system seems rather fragile and seems like it may not be able to handle the movement of heavier items.

Further, these robots are not ready to go out into the consumer market due to their unreliability. As shown by Figure 20, the tweet exclaims the distraught a user had to go through due to the robot consistently breaking down. This may be due to other external factors, however, it's important to keep in mind when figuring out how close the world is on completely autonomous robot chefs.

Figure 20 Tweet from British Director at the 2022 Winter Olympics

Comparatively, Model IV [Figure 16] seems better equipped to make a dish autonomously and does not need to rely on as much machinery surrounding it. As it is not being put into use practically in the real world, we wouldn't know how successfully it can operate without breaking down and hence a real comparison can be made. However, looking at the exterior design, both use the separation of a 'finger' and a 'hand' for increased rotary movement and to for the ease of picking up items. They each differ in the number of fingers used, as Model IV uses 3, however each are specifically tailored for different purposes; the Olympic robot was designed to work more with beverages while, I intended for my design to work alongside all food and drink items. Another intriguing difference is the implementation of a body alongside with the arms. This allowed the robot to be able to move around and create drinks in any locations as long as it had its workstation. However, for an average user this would increase costs exceedingly for an addition which is not as necessary as most people have a designated room for cooking, e.g., a kitchen. Each of these items have been designed with their target audience in mind, and therefore have a specific skillset tailored for that experience. Hence, both models are proficient in handling their given tasks.

One thing to elaborate is the use of colour white when making the robot. The colour symbolises peacefulness and simplicity which in a manner juxtapose the robot. However, as the implementation of AI is relatively new, many fear its drawbacks and hence having the robot in such a passive colour sends more soothing messages. Therefore, for the customisation of Model IV, the majority of the design should be made up of white but having the ability to customise the easily replaceable rubber fingers gives another source of revenue and therefore would be encouraged.

8 Evaluation

Throughout this project, I have encountered many unforeseen challenges, the hardest being making comprehensive executive decisions based on the little information I could collect from Blender renderings of models and my practical done in the real world. When I initially set out to tackle this project, I wished to understand the technical excellence which came about when choosing different shapes and sizes for different parts and the reasons revolving around these choices. The vision I had was to test many different models and then collectively use the best attributes of each to make up the final model. However, one thing I have learnt is that no model is perfect, there are still drawbacks to each and every one – hence the naming of the final model did not change the pattern I had started. It was called Model IV to symbolise that latter model can be made that will improve upon the one I created. These may have a lower reliance on external peripheral devices such as cameras, but I believe this comes with the advance of technology.

Overall, having accomplished all the itinerary stated in the success criteria, I would declare the project a success. Although lots more work needs to be done to create a finalised product, such as software integration and wiring additions, the goal which was to create a strong design for an AI chef, has been accomplished. In the future, I hope to be able to tackle the implementation of the visual tracking technology alongside the AI elements of code into the robot itself. Furthermore, I hope to tackle the interior designing for the robot (such as wire placements etc.).

One thing I do regret after having accomplished the design would be the lack of coding required for the general design element of the robot. I would often have to use python to do actions however, none related to the actual artificial intelligent element of it.

I look forward to what may conspire after having accomplished the project and I hope this has brought into light, solutions to our ever-going food crisis and alternatives to help people become more productive…

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