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Evolution of Kitchen Robots: A Review

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Abstract

Robots are the machines designed and developed by humans which are more capable and efficient in doing such works and tasks which humans are unable to do or do with less efficiency. These machines are able to perform the tasks which are hard or impossible for humans. There are many robots which resemble like human, animal or even insects and are employed in different sectors. For example, dogs in bomb squad are now getting replaced by robot dogs which can smell and detect the location of bombs very efficiently. SPOT is the good example to understand the dog robot. SPOT is the name of this machine which is capable of detecting any noise anomaly from equipment being used in industries or factories. As it is equipped with microphone which can detect the noise of whirring or grinding so that those machines can get service done and can work properly. SPOT is also equipped with radiation sensor which can detect and warn about the abnormal levels of radiations which are dangerous for mankind. It can also detect temperature of the boilers by using thermal and IR (infrared) rays and showing extra hot regions. Talking about Insect robots, developed by the Defence Advanced Research Project Agency (DARPA), are now being used as detective or to keep an eye on enemy actions for military purposes. These are very difficult to distinguish among insects like bees as they can flap their wings and give a realistic sound of bee. Main goal of this insect- sized robot is to utilize them in military purposes like surveillance, security, search and rescue operations. So, in this paper we are going to review the different robots invented in order to assist humans in various activities related to cooking. Some of the robots don't even require human involvement in their entire working process. And these robots are reviewed on the basis of their technology, ease of use, versatility, level of automation and innovation.

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INTRODUCTION

Similarly, engineers are now working on humanoid which are basically the robots which just look like normal human beings. INDRO is the good example for studying about the humanoid [1]. It is the 6.5 feet tall robot which is made just like human. It can have movement same as of people around us, because it has 29 joints which makes this robot doing any work which may or may not be performed by humans with great efficiency. INDRO is able to do some household chores, can also be used for entertainment purposes or for educational work and research [2, 3]. Now in this developing era, engineers are trying to automate the homes by introducing automatic vacuum robot for cleaning the houses, other household chores robot which can do various tasks. Now going one more step ahead we have got robots for preparing food for us. Such robots can do whole process of making food including selection of vegetables, cutting and peeling of vegetables. Then the next step will be cooking which is already embedded in chip of robot. Fully Automatic Intelligent Cooking Robot [4]. The main principle of this cooking robot is to break the cooking program into many different blocks of work. It converts every action into program instruction by connecting it to electrical technology with hardware to start and successfully automate the cooking process. Kinematic Analysis of a Dual Arm Humanoid Cooking Robot is another great invention for making main household chores easier and reducing the work load from humans [5]. Novel Automatic Cooking Robot for Chinese Dishes was introduced in February 2007 [6].

It heats up the ingredients at same level. It is equipped with dispersing mechanism which allows the robot to stir the food. This robot is also able to pour the used oil or water into the oil or waste container. Cooky: A Cooperative Cooking Robot System was aired in 2010-11 equipped with more advanced features like Pouring liquid ingredients, adjusting the flame, or heating temperature [7]. Cooky is one of the mobile robots which saves space, small size improves flexibility, and it uses graphical user interface (GUI) for making any recipe. Intelligent Kitchen: Cooking Support by LCD and Mobile Robot with IC-Labelled Objects is another invention for providing cooking support by employing LCD and Mobile Robot with IC-Labelled Objects for enabling voice and gestures [8].

Cooking with Semantics is an innovative invention [9]. It understands the instructional text related to cooking the different recipes found on the internet. It's one of the main advantages was interpreting cooking recipes more precisely. Food Peeling method for Dual-arm Cooking Robot is another invention to automate kitchens [10]. This robot is able to peel the vegetables properly. This process of peeling is separated into two parts i.e.; peeling motion and the rotational motion. Robot Cooking with Stir-fry: Bimanual Non-prehensile Manipulation of Semi-fluid Objects [11].

This robot is able to stir the vegetables, as the Dual arms of the robot are programmed. They can perform different roles like picking up the ingredients and preparing them to cook. Cooking Behaviour with Handling General Cooking Tools based on a System Integration for a Life-sized Humanoid Robot [12]. This system uses the colour detection medium for perceiving the equipment and material required like vegetables, spices and oil etc. for cooking. An Online Task-Planning Framework Using Mixed Integer Programming for Multiple Cooking Tasks Using a Dual-Arm Robot [13]. Online piece of work in a proper arrangement is given to robotics arms which helps for the optimization of instructions and records the task performed by the robot. Dynamic Modelling and Performance Analysis of a 3-DOF Pan Mechanism for a Cooking Robot [14]. This invention provides the numerical analysis of mechanisms which are used for making Chinese cuisine. These mechanisms help to get the required motion and trajectory of pan. Improving Robotic Cooking using Batch Bayesian Optimization [15]. This model presents the methods and analysis them to provide better food quality to user. The optimization techniques used by a robot who can cook accurate omelettes to provide better food taste. Cooking State Recognition from Images Using Inception Architecture [16].

This presents the technique to recognize the different stages of cooking. They used the framework of Convolutional Neural Network (CNN). On the bases of their technique, experimental result shows the accuracy up to 75.65%. Cooking With Computers: The Vision of Digital Gastronomy [17].

This invention focuses on the 3D printed food which involves the recipe of the food, cooking agents, interactive software and so on. Using Computational technology, the waste of food is minimized. And proper nutrition, personalized diet can be provided. Digital Gastronomy: Methods & Recipes for Hybrid Cooking [18], this invention modernized the cooking experience by digitalization of food. This invention not only focusing on the digitalization, with respect to this, it also takes care of saving the traditional taste of food. Analysis of cooking recipes written in Japanese and motion planning for cooking robot [19], this model utilizes the different recipes from internet especially for Japanese recipes. Intellicook–the cooking robot [20], this invention presents the autonomous working of a robot which doesn't need human interaction for cooking. Its setup has a cooking environment which takes recipes data from the internet. Audio-visual scene understanding utilizing text information for a cooking support robot [21], this robot extracts the recipe data from the webpages. It acknowledges the recipes through text, image, audio and video concept available on the websites. And then successfully perform its given operation for making desired recipe.

DIFFERENT TECHNOLOGIESFOR COOKING ROBOTS

General approach for automatic cooking robots is the utilization of combination of different sensors, algorithms and other functions and many type of mechanical parts and equipments. These robots are also required a specific software so that user can access the different features and to input the recipes.

Internet of things (IOT) technology is used. This robot is equipped with single chip microcomputer to control the hardware and software part of the kitchen for performing different actions [22]. It is suppressed with distinct sensors as pressure sensor, temperature sensor, voice recognition, touch Display for giving different commands as reported by the client. This humanoid robot is mainly focusing on the functioning of its dual arm system which operates on the kinematic analysis [23]. This technology explains the task of humanoid arm structure whose function is responsible for the right positioning and orientation of 7 connections and 6 couplers of the robotic arm's manipulator. These connections and couplers contribute for the movement of arm's manipulator to work in accordance with tasks. This technology uses the object-oriented processing, fire control modules for evenly distribution of heat while cooking. Human robot interface which takes the user assistance when needed. It uses the movement module for motion and acceleration of working space at the specific portion [24].Speed is maintained so that the dish will not run off from the processing period. It applies the graphical user interface technology to provide the precise order of cooking steps to put on view for the user. Through this software the user is able to select the ingredients, its right quantity and steps for cooking dishes with the help of flexible assistive robot [25]. IC tags enable the trace of location of different equipment with the help of antennas placed over the working space [26]. Liquid crystal display (LCD) provides the direction of recipe to be followed by the user. Robot is for supporting purpose to help user by voice and gestures [27]. It comes up with next action to fulfil the recipe. The Semantic Role Labelling (SRL) technology. SRL is that in which the action words from the set of instructions are for the portrayed with the given task [28]. From this the robot will get the information about the required step to be taken by getting the right instruction in the form of semantic roles. This robot is only for the peel off the food. Trajectory method is taken in the usage for the removal of food skin. During the peeling process the cutting tool sticks to the food so that it covers the entire food by using force sensor and impedance control [29].

In addition to this, for securing the working piece one stick is fixed at the centre of the workpiece. Over and above that the establishment of the rotation axes for the revolution and location of the food to get every part peeled off. The robot here we are discussing is specifically for Chinese cuisine. This robot uses the graphe and transformer based neural network model. The trajectory shifting from pushing to pulling and turning of the food being prepared [30]. It grasps the set of actions from human demonstration. The technology used by this humanoid robot is recognizing and manipulating [31].

By the usage of this technology, the humanoid robot is able to detect various components. Recognition is done by using stereo cameras, the robot compares the object with 3D model to find the particular object [32]. For detecting vegetables and other materials required for cooking, it uses color-based method to find these materials. Manipulation of different action is made possible by using kinematics links with 7 degrees of freedom (DOF) at the arms. For the proper motion and working of the joints of humanoid robot kinematics analysis method is used. Kinematic Constraint is applied for the selection of task and motion of its dual arm system by using 5 degrees off reedom (DOF)and their joint sareinrotational motion [33]. To find the exact address of the components and the ingredients placed on the work place using relation matrix. This cooking robot used the concept of object-orientation for the analysis of planar multi-barmechanism. This provides more control on handling of the mechanisms as compared to previously used methods [34].

The feasibility and the reusability of planar mechanism is more than the previously used methods. Over and above that an effective way is developed to predict the parameters of servomotor by making use of the performance indices. This model presents the use of Bayesian Optimization technology [35], which takes the samples of food for the better quality. In this model, autonomous omelette cooking robot is mentioned. Number of samples are taken for the accuracy of the food for its flavour, appearance, texture.This process is done by two sections, firstly the two outputs are taken at once and one output is taken separately. Secondly the mean all the three outputs are taken at once. Here, in this invention an improved version of Inception V3CNN networks is used for detection of problem in cooking state. CNN deep model perfectly tunes the invention to detect several cooking states [36]. It studies the effect of several layers of the proposed deep model in terms of different parameters [37].

For the recipe, this invention uses the method of three-dimensional dish design and unified dish-recipe model [38]. In 3D parametric dish design method, the colour, taste, flavour of the food is given by flavour-structure, flavour-pattern, flavour- voxels. In unified dish-recipe model, the instruction for cooking dish is given in the form of high-level simplicial flowchart. And by using the parametric design, the connection between food and dish is clearly understood. Different technologies working together to fulfil the requirement for digital cooking like 3D printing, laser cutting, 2.5D milling machine, 3D scanner. 3D printer is having the capability to design parametric forms from food printing using paste extrude [39].

Along with this, it has an attachment of heating plate which provides the paste to get settle down. And for heating and cutting the food being prepared, this invention makes use of laser cutting method. This method provides the taste, flavour and required colour for the food by heat adjustments. 2.5D milling machine helps to cut the vegetables according to the requirement by proper holding the vegetables at one place. Database algorithm includes motion codes, object database, motion library. In this the motion codes are designed in such a way that letters are assigned things like utensils, ingredients, equipment, tools etc. Object database defines the location of the objects and the required action to be done on the object. Motion library contains the set of motions for the robot to complete the action given [40].

These set of motions are like mixing, grabbing, pouring, adding and so on. The main unit of their robot is the Arduino mega microcontroller, which is used to control the functioning of the robot. For managing the cooking process effectively, IOT is used according to the requirements [41]. Movement of different sections, which contain the ingredients required as per the recipe is done by the stepper motor. This robot used the Hierarchical Hidden Markov Model (HHMM) to acknowledge the steps of cooking recipe in a sequential order [42].

Firstly, the set of instructions given in the recipe are transformed into a flow graph. After that this flow graph uses HHMM which is divided into two subparts non-hierarchical HMM and hierarchical HMM. By using CNN model, the audio task is considered as log-scale spectrogramand visual task by RGB data. After extracting the information of the recipe by utilizing above models, this robot guides the user with next steps to be followed. Abbreviations of Robots can be referred to below.

From the Figure 1 we can figure it out that Robot 1, 3 and 11 have the highest level of structural complexity. These are full modular kitchen setup which means they don’t have the flexibility to work with already existed kitchen. Unlike those robotic arms which have comparatively less complexity. In the above figure they are named as robot 2, 5 to 10, and 12 to 14 falling under the category of medium complexity. They come under medium structural complexity because they take less space in the kitchen as they are designed to have human like structure. Along with this, they have the capability to interact with humans in more natural and intuitive way. Robot 4 is having least structural complexity as it is a small portable robot which can assist the user efficiently.

Techniques and Working of Robot

Methodical technique is used. For this, firstly this robot will select and separate the ingredients of the recipe into the section according to user's need [43]. It will assign work to the robotic arms such as selection of vegetables and cut them into the vessel and then heat the utensil on desired flame and temperature. Now other ingredients like spices, seasoning etc. will be poured in the utensil. After heating, cooking and stirring it for specific time, food will be incubated so that it remains warm and fresh to eat.

Denavit-Hartenberg convention technique which describes the motion and rotation of arms joints with the alignment of next joints in the form of coordinated frame by kinematic equations (Figure.2). In addition to this technique, the velocity of the joints of humanoid arm is scanned by the cartesian coordinated frame and space according to the Jacobian matrix. The robot has a stereo vision system to have all information of the surrounding [44]. For manual operations and to connect with the user, it has a touch screen display. And the body of the robot is having a movable wheel and the rechargeable battery which support up to 2 hours of working. This system of cooking uses the conveyor belt system for accessing the correct ingredients for Chinese cuisine [45]. Fully automatic system uses the working space motion technique [46]. This is designed in such a way that it has a spatula like attachment (cover) with frying pan which is used for two specific functions like stirring and for non-stickiness of food and cleaning the pan through its water outlets section. The procedure of cooking like deep frying, the oil used after the frying is feed to the oil tank. And for monitoring all the working of the system monitoring module is there (Figure 3).

This portable robot gets the instructions from the personal computer through wireless connectivity. The present cooky robot indicates the usage of specialized container by robot for supporting the cooking process. It gets the information about its specialized containers by the visual markers on them and can locate their position by the ceiling camera. This robot provides assistance to the user [47]. The user will place the components required for cooking according to recipe operated by robot and as well as by the user. And during the cooking process the need of different temperature controlling (Figure 4).

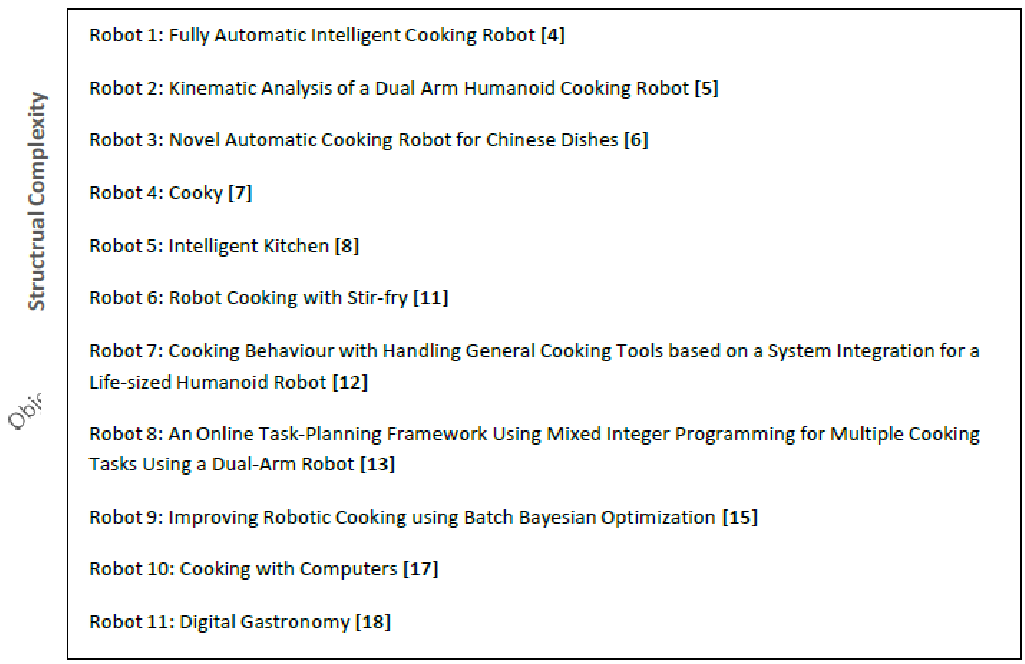

Figure 1. Structural complexity Vs technologies used in different kitchen robots.

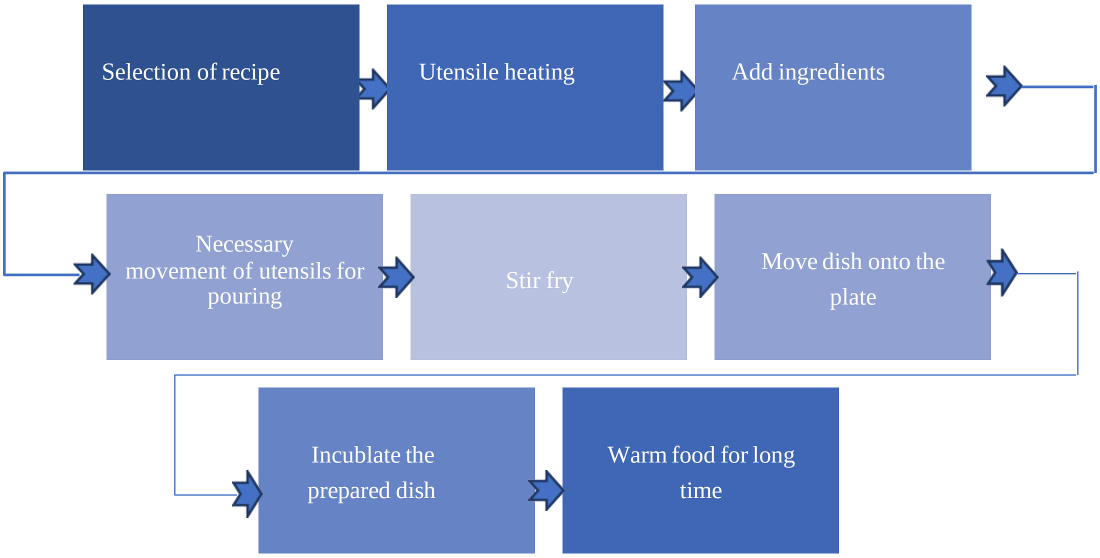

Figure 2. Block diagram of fully automatic intelligent cooking robot.

Figure 3. Flow diagram of Novel Automatic Cooking Robot for Chinese Dishes.

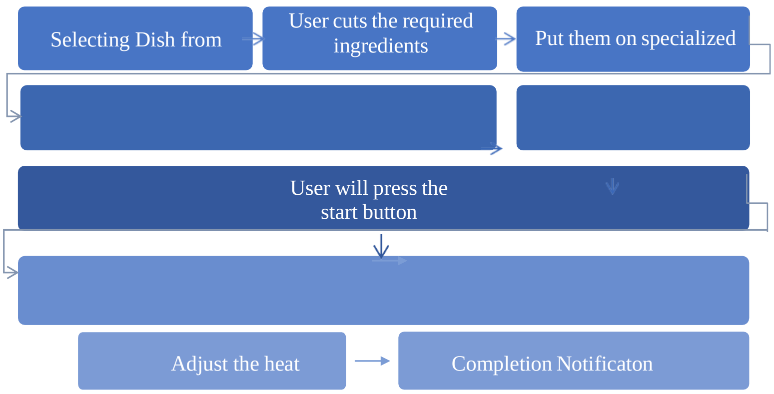

Figure 4. Block diagram of cooky robot.

This invention gives a separate code for each movement of human like for picking a spoon will be given a code A1, picking a jar will be given a code A2. These movements cum codes are synchronised with time and frequency i.e., the movement which needs to be done first will be done first and not according to the code number. Apriori and prefix Span algorithms are used for the activity's recognition of human actions [48]. Along with that this robot make use of voice and gestures to instruct the user about the next step to be done on the basis of past and current actions. It uses IC tags to detect location and identify the object according to the instruction. The kitchen is equipped with LCD screen to give instructions with pictures. It is basically the combination of robot, LCD, cameras which provide the path to the robot by utilizing this feature, it can track the human motion. So that, it can work efficiently with multiple instructions simultaneously (Figure 5).

Object-oriented Markov Decision Process is used to make the instructions from the sentences of recipe. This process is for the robot to understand the instructions clearly and perform task accurately. Each verb used for cooking dishes is presented in a SRL system. Like "add", "bake", "stir", "cut", "cool", and so on each verb has a specific frame-set for the role in SRL system. For complex instructions, it will provide detailed explanation with video clip [49]. And will provide necessary help when needed. Trajectory pre-generation technique is used to get the trajectory of food, to peel exactly on the food [50]. The rotational motion of dual arms is there to change the position of food to peel it from everywhere. The calculations form the above technique gives the accuracy of the product which comes around 80%. The working of this model is as, it firstly detects the trajectory of the food and starts peeling off the food. when one segment is done, then calculations for the rotational movement comes which rotate the food to peel it from other side. All these will be repeated until the whole food will not get peeled off. The present invention deals with the bimanual coordination mechanism of non-prehensile manipulation. In this technique, firstly the decoupled dual-arm act as a leader and a follower. Apart from each other, both arms acquire the knowledge from classical and neural network. After grasping the knowledge, both arms work in coordination along with wok and spatula. This robot will perform the same hand movement like so human does for cooking dishes. The required trajectory and motion for stir fry is done by combining the graph structure and transformer sequence learning [51]. To monitor the actions of robot the IMU sensors are used. And one of the actions like semi fluid contents camera is used as visual feedback. At last, stimulate the result of different actions performed by the dual-arm (Figure 6).

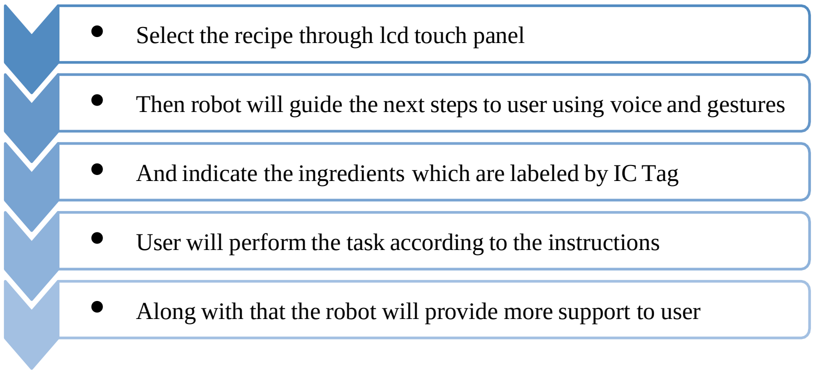

Figure 5. Flow diagram of intelligent kitchen.

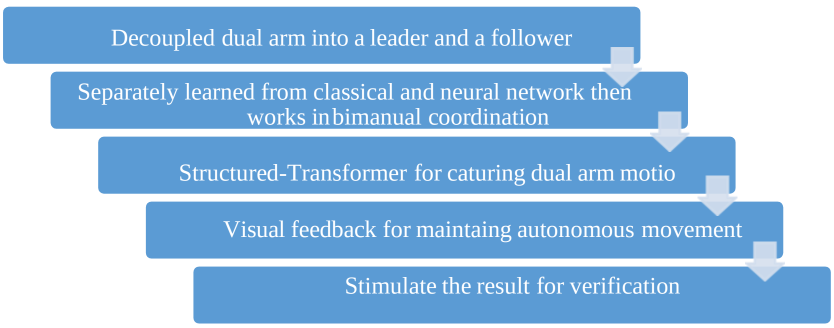

Figure 6. Flow diagram of robot cooking with stir-fry.

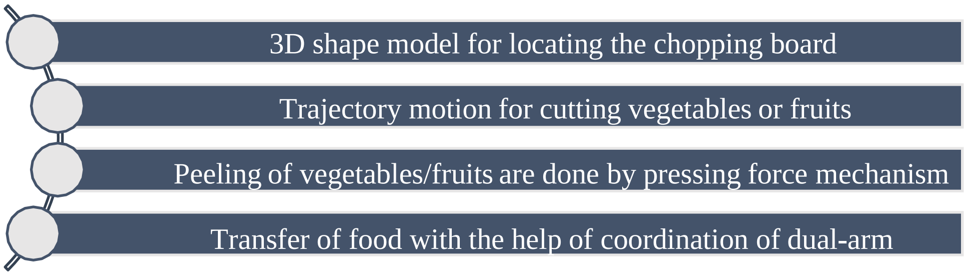

Figure 7. Functioning of cooking behaviour with handling general cooking tools based on a system integration for a life-sized humanoid robot.

Inverse Kinematics is used for the manipulation of different poses of the humanoid robot [52]. By analysing the inverse kinematics, torso motion comes into play which helps in particular motion of arms. This invention discusses the three particular action of humanoid robot. First one is to locate the cutting board using 3d shape model. It will detect the vegetables using their colour characteristics [53]. For peeling the vegetables, the force feedback mechanism is used. Along with this, kinematic analysis provides the necessary motion to robot for task like cutting vegetables. For cutting the vegetables or fruits, the robot will simply hold it from one arm and a knife in another arm. After cutting the vegetables or fruits, it will transfer the chopped vegetable into the bowl which has round edges. By using camera sensor, it is able to detect the containers in the kitchen which are having round edges (Figure 7).

This robot uses the mixed-integer programming technique for the generation of Multiple tasks at the same time. Subproblem optimization method is used for task planning [54]. For this task are divided in such a way that with correspond to the one arm the other one is for completing the upcoming task. The location of objects is solved by using inverse kinematics [55]. This model works on the kinematic constrains for providing minimum time for cooking and motion of dual-arm. Both arms work in such coordination so that maximum accurate output can be taken. As the tasks are in optimized way, this will reduce the multiple decision of variable by using feasible task for the same. All the work mentioned in this model is experimentally validate through test cases for the feasibility of tasks done by the robot. It has the 2 DOF pan mechanism for making pan in motion using kinematic analysis and improves factor of reusability and maintenance of program codes becomes easy [56].

It provides the step by step working of all the techniques used in this robot. The dynamic modelling of mechanism is for the motion of different links connected in the robot. The velocity and acceleration of each motion is done on the basis of which movement is currently being performed. All the techniques are validated for their performance. The whole cooking procedure is divided into small steps to control each input for the effective results. The user will check the prepared dish according to several factors like taste, appearance etc. The robot uses the UR5 arms from universal robotics for the whole cooking procedure. And the movement of robotic arms such as their connection of links, locations, angle of motion etc. is done by API [57] which uses the python script. The holding of tools is done by force feedback mechanism. They conduct the several experiments and compare with the Sequential Bayesian Optimization. The final optimization of Batch Bayesian Optimization provides better user feedback. This invention takes the number of samples of the food in its different states using the CNN model [58]. Python, TensorFlow, keras, all these techniques are used by this model. For better optimization Stochastic Gradient Descent (SGD) [59], RMS prop and Adam are considered and comparison among them is taken. They also use the Confusion matrix and Classification report for the overall result of the samples. This model has multi-robotic arms which uses the DOF of kinematic analysis for the movement of arm joints. One arm is doing the job of food printing [60]. For printed food, it uses the pastes of rice, mung beans, and methylcellulose. For the variety of food shapes, it uses the silicon based programmable mold. After the food shapes, another arm will position the food in the dish. At last, third one is for heating the printed food with laser technology. This invention explains the working by means of an example of coral reef soup. After printing the paste, the parametric designs are filled with required liquids using generative algorithms in the CAD environment. Laser cutting machine is used to print the 2D shapes of nori seaweed, and as per the soup recipe other ingredients are being added. And laser is also used to heat the food according to their chemical composition. During heating process number of reactions are taking place, though at a greater degree Maillard and caramelization reactions are being processed [61]. These reactions are essential for the taste, flavour, and colour of the soup. For heating the food using the above reactions at particular portions, circle-packing algorithm are being used. For extracting the motion codes, MeCab (open source) is used to convert the action into codes which is in the form of words [62]. To know which action is going to be performed first according to the internet recipe, motion codes are considered as array. After that sorting and insertion process gives the information about the sequence of the recipe. In motion planning, there are certain functions prepared for the robot. And along with this, the robot gets trained by cooking robot simulator in offline mode. This robot is based on microcontroller which includes the working of its different parts [63]. Different parts of this robot are as movable wheel which has a gear setup for the rotation of ingredient containers. For liquid elements, they have a separate dispenser which is connected through a pipe. Induction stoveis used to provide the necessary heat during cooking and heat is adjusted by the assistance of induction stove. And User has a flexibility to modify the recipe according to their specific taste, quantity and so forth. The user will select the recipe from the website and then robot decodes this recipe information by using the flow graph [64]. Event model describes the action need to be completed with accordance to the instruction given. Procedure model uses the HHMM to recognize the recipe and cooking procedure recognition model uses the above same HHMM to grab the cooking procedure information by real demonstration. Robot will tell the user about cooking procedure with the help of message support system. And acknowledged recipe to show its instructions for cooking. They experimentally express their result of accuracy and precision for above models.

DISCUSSION

The idea of employing robots for cooking food looks like science fiction, but now it's becoming a reality. With the rise of kitchen robots, the future of cooking is changing. In this review paper, we explore the current state of different kitchen robots, their capabilities, and their various factors. For number sequence of robots refer to abbreviation chart.

Versatility

Versatility means the performance given by the robots to perform various tasks like chopping, mixing, blending, grabbing, peeling and pouring the ingredients during cooking procedure and with cooking.

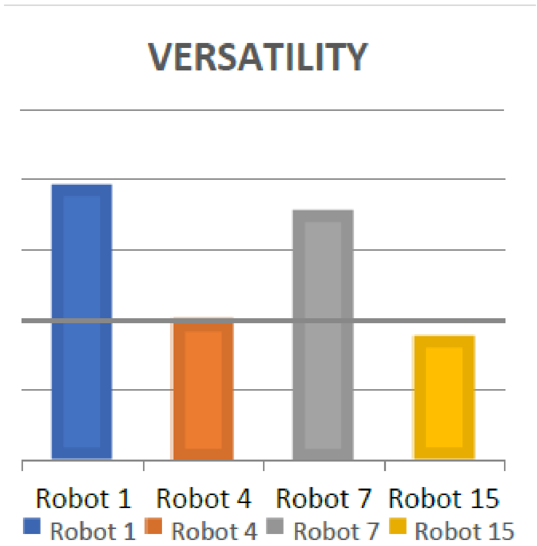

Figure 8. Versatility of cooking robots.

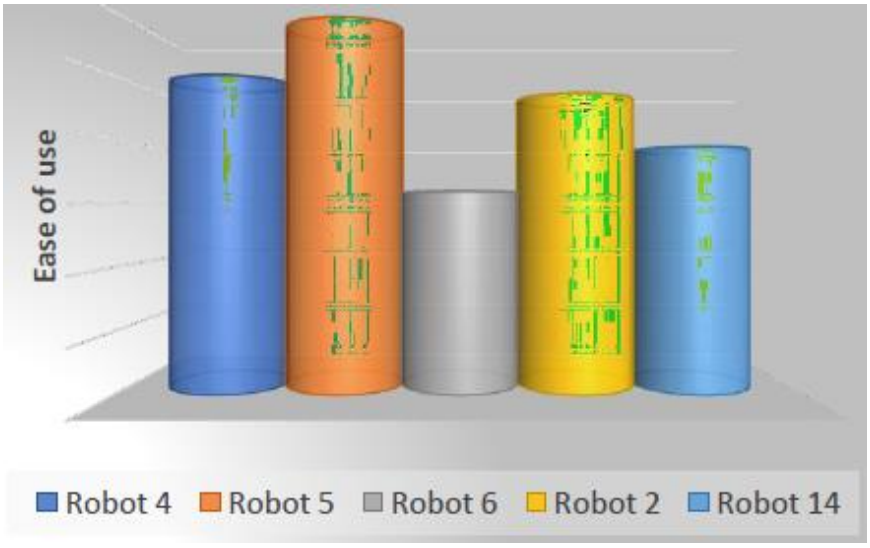

Figure 9. Ease of use of different kitchen robots.

Figure 8 shows the versatility comparison of distinct cooking robots. So, corresponds to above mention tasks, we compared some cooking robots. In which Robot 1 has the highest versatility, this is due to the reason that it is a modular kitchen environment, which can execute different task effectively. Robot 7 has moderate versatility or we can say its versatility is nearer to robot 1. It's a dual arm humanoid robot which performs the function like grabbing, pouring, mixing etc. just like human do. Robot 4 has lower versatility as compared to first two robots. It's a portable assistant robot, which can perform the tasks like pouring, mixing etc. This robot is not capable of functions like chopping, blending, peeling. Robot 15 has comparatively less versatility than other because this model gives the information about only one part of cooking procedure that is peeling off the vegetables and fruits.

Ease of Use

Ease of use talks about the features of robots. Some of these features are like display to present the recipe, cameras to get information from demonstration. Provide assistance and easy interaction to user and portable so that easily move around kitchen environment.

Figure 9 Shows the comparison of kitchen robots on the bases of their ease of use.Robot 2, 4, 14 has average ease of use as compared to others. Robot 2, a humanoid robot which has the capability to show and edit the instructions through touch screen according to the users need. Stereo vision cameras to detect the surrounded area of workplace and is equipped with the movable bottom. It gives services to the user at larger level. Robot 4 is a small portable robot which comes with touch screen display to edit the recipes, display the recipe and give assistance support to the user. Robot 14 has uncomplicated interaction with user and help user to do task to get fruitful results. Level of ease of use of Robot 5 is highest among others as it is providing the assistance by voice and gesture feature. And the recipe is being displayed on the lcd panel which is situated in the kitchen. Number of cameras are placed at the workstation to observe the human current and next action. As it's a humanoid robot, it has a portability to move all over the workplace. Robot 6 has ease of use lower than average ones. Robot 6 has a feature of camera setup for the detection of human demonstration for making recipes from above mention features.

Recipe Category

It contains the Recipe customization, Recipe library, Recipe accuracy, Recipe sourcing which involves printed food, flavoured dishes, recipes modified by user, simplified instructions for complex recipes, multiple or wide area of recipe search, step by step guidance of recipe implementation.

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Figure 10. In this part, we are explaining the recipe categories of various cooking robots. Recipe customization of robot 10 is higher than other robots. This robot prints the food according to the user preference, flavour and taste. After this, robot 1, 4 comes whose customization of recipe is nearer to robot 10, in view of the fact that this model has capability to perform instructions as per given by user. Robot 4 is able to modify the set of instructions of dish and adjust the heat given manually through the touch screen. Thenrobot 16 has lower than robot 1, 10. Robot 16 clarifies the complicated steps of recipes and provides the minimal changes in recipe as compared to others .Recipe library of robot 4 is lowest because the recipe is entered by the user, which means it itself not able to take recipes from the internet or other platforms. The level of recipe library of robot 5, 16 is slightly higher than the robot 4. This robot 16 has used the fixed number of recipes, i.e., 260 recipes from websites and robot 5 presents the task to be done and its data is available on the lcd screen. As robot 1, 10 take the recipe data from the internet which make their recipe library section wider than others.

Recipe accuracy of robot 4 is higher than others. Steps are given by the user for cooking dishes which is not in text form but uses the symbol of ingredients to simple drag and place on the screen. Robot 1, 5, 10, 16 has above moderate accuracy as they are capable of showing recipe on the screen and give necessary support to the user. Robot 10 uses the parametric method and different heating method using laser for cooking. Robot 16 uses the semantics role method for recipe directions.

Level of Automation

It involves the features like new technologies, advance and smart processors, new techniques and method for robot understanding to perform well. IOT based working of robots and systematic approach of robots.

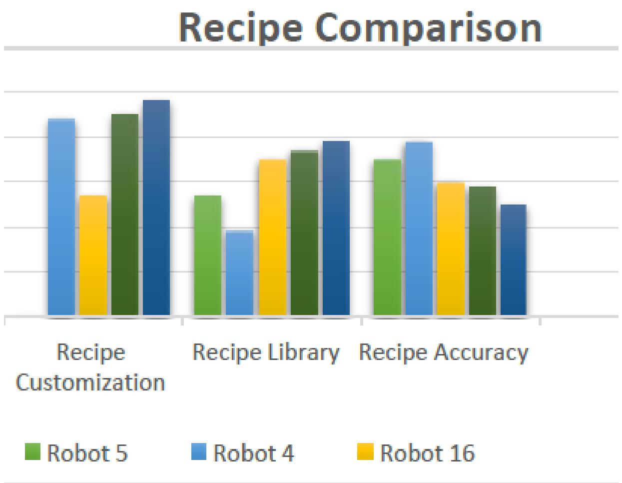

Figure 10. Recipe categories of distinct cooking robots.

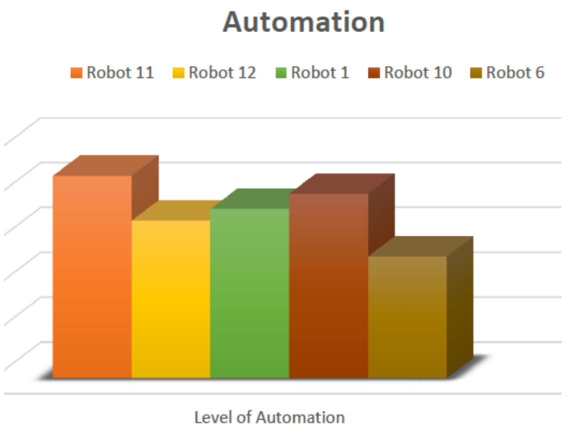

Figure 11. Automation level in Cooking Robots.

Figure 11. shows the automation level of discrete cooking robots. Robot 11 has the highest level of automation; it is equipped with advanced tools and machines which helps the user during cooking procedure and focusing on 3D printed food. Robot 10 is having the level less than the robot 11 as it pays attention to the 3d printing of food and has multiple attachments for shapes and heating procedure. Robot 1 is the modular kitchen comes with different compartments, having advanced appliances for kitchen and for automatic cooking. Then comes the robot 12, it utilizes the direction of recipes in the form of algorithms which itself give the steps of ingredients in order. Robot 6 is having lesser automation than others. This is due to the fact that, this robot has the advance technology of learning from watching human actions during cooking and repeats that motion. Also, for its dual arm advance techniques and method are used.

Level of Innovation

We define the level of innovation of some kitchen robots into 5 major categories. These categories are Basic, Advance, Smart, Collaborative and Modular. Basic kitchen robot includes the common task need to be done before cooking and during cooking process, these are like cutting, peeling, stirring and so on. Advance kitchen robot involves the task like multiple tools, attachments, techniques and so forth. Smart kitchen robot comprises of new technologies like internet of things (IOT), recipes from internet, display attachment for guiding, recipe customization etc. Collaborative kitchen robot contains the things like providing assistance in advance way, robotic arms and more. Modular kitchen robot includes the whole kitchen environment which has every necessary section for making cooking process easier and even work without the human involvement.

Figure 12 gives the idea about the existing innovation of kitchen robots. For this, we are explaining the above graph at the level of individual robot. Robot 14 has the moderate innovation in the categories of basic, advance and modular. It's an assistive robot which gives only guidance to user. Its smart and collaborative categories have high innovation-level. It is smart as it takes recipes from the webpages which has unlimited source of recipes and collaborative in terms of helping the user in every step. Robot 12 is smarter as it takes set of instructions for cooking from internet itself. The advance and modular category of this robot is slightly less than the smarter one. As it uses the advance technique for selecting the recipe in the sequential way and can complete some of its tasks without human interference. The basic category of this robot is normal. Robot 4 has the higher basic level as its basic functions are performed by human and robot. Its advance and modular category is low as mostly the work is completed by the user. Smart and Collaborative category of this robot is slightly higher than the advance level because the customization of recipe is simpler.

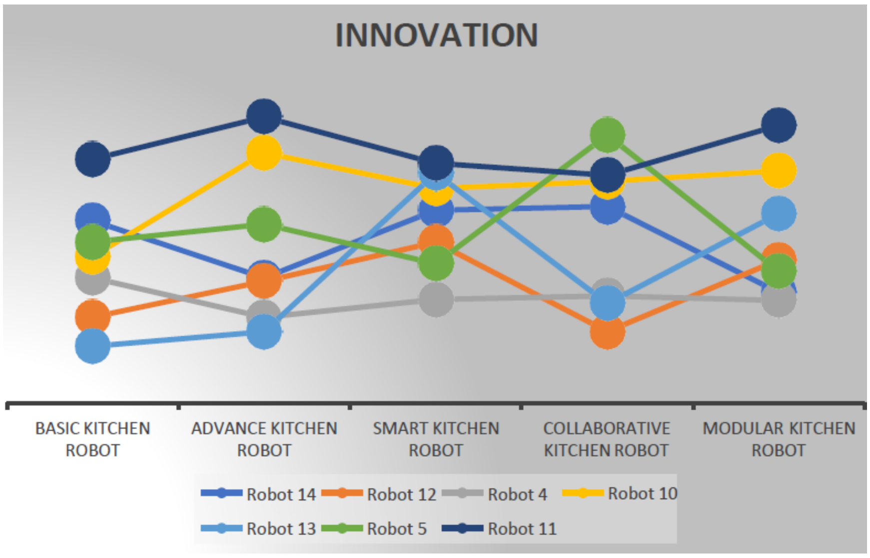

Figure 12. Innovation present in various kitchen robots.

Robot 10, basic level of this robot is medium as in 3D printing food, there is less usage of cutting, peeling etc. Its advance and modular category has high level because it has multiple attachments to do different tasks and versatility of the dishes as per the diet required. Smart and collaborative category of this robot is slightly lower than the high level. Robot 13, its basic and advance level is low as cutting, peeling, grabbing etc. is not there and doesn't have advanced attachments like mixier, grinder, more tools. Collaborative category is little bit higher and modular category is at moderate level than the lower ones. As this robot is able to provide successful change of recipe as per the requirement and comes with rotatable different sections. Presence of smart level is higher than all categories since it has ability to use internet for cooking instructions. Robot 5, in this, the 4 categories which are basic, advance, smart and modular has approximately same level i.e., the medium. It helps user at every stage of making dish and it's a smart robot as it understands the concept of task easily. Its collaborative category is highest among all robots on the account of its supportive-ness. Robot 11 has every category at highest as compared to others robot except the collaborative- ness. It's a fully kitchen setup which involves the advanced food processors and multiple tools for cooking, dishwasher and so on. Collaborative-ness is lower than the rest as this model still needs human assistance to do cooking efficiently.

CONCLUSION

Cooking robots are evolving at a high pacewhich is leading humans on the way to revolutionize the method of preparing and cooking food. These robots are capable of performing a vast range of tasks like chopping vegetables and preparing complex dishes, and can help humans to save time and effort in the kitchen. The accuracy of at least 70% has been verified in all the classes of status recognition of food while cooking. Acceleration optimization efficiency of trajectory planning of pan mechanism is improved by approximately 40%. Experimental results of arrangement of piece of instructions done by the robot comes to be 76% corrected. But every technology has their own advantages as well as disadvantages. And same goes for these cooking robots, on the one hand we have limitations including high cost of robots and limited functionality, less creativity. And on the other hand, these robots not only can help us prepare delicious and healthy meals with ease, but they can also help people with disabilities or limited mobility to become more independent in the kitchen. As the technology continues to evolve and become more affordable, we can expect to see more kitchen robots in homes as well as restaurants around the world. But also, these robots can't replace human chefs entirely as they have the potential to make cooking more efficient, enjoyable, and creative for everyone.

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