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Design and Implementation of Assistive Feeding Device for Disabled

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Abstract: The purpose of this project is to design and implementation of assistive feeding device for disabled. Outcomes of the design process involves, learning how to design and how to successfully design and implement of assistive feeding device.

The project system consists of hardware configuration, which is servomotor, power supply, Bluetooth, microcontroller, and spoon. Where the software configuration is Arduino, software and application in the phone used to control the system.

The Performance of project system is experimentally tested by sensitivity and overall accuracy evaluation depending upon the classification models of true positive [TP], false positive [FP], true negative [TN], and false negative [FN]. Values of 99% sensitivity and 98.5% of overall accuracy are reflected to high efficiency in fabrication process of project system.

INTRODUCTION

Quadriplegics can gain more freedom by employing an assistive robotic manipulator (ARM). However, because of their limitation, the types of interfaces that may be utilized to control such devices are limited. Parkinson's disease is a neurological illness that worsens with time. Resting tremors, bradykinesia, stiffness, and postural instability are the characteristic motor symptoms, which are accompanied by dopaminergic neuron loss and Lewy pathology. A comprehensive review of Parkinson's disease and the diagnosis and treatment of dysphagia and aspiration was presented. Parkinson's syndrome, one of the most prevalent brain disorders. Motor signs such as tremor, rigidity, bradykinin, and postural dysfunction characterize the conditions [1]. Also, a systematic review of disorders disease involving eating disorders was presented. The characteristic activity in eating disorder (ED), bulimia nervosa (BN), and the anorexia nervosa subtype of binge-purge. The prevalence of loss of control (LOC) feeding even in people who do not fit medical standards for an eating disorder confers a risk of elevated eating disorder psychopathology, psychosocial anxiety, bodyweight in excess, and clinical disability. Therefore, mechanisms that contribute to the etiology and/or persistence of eating disorders habits must be established such that for tailored therapies, potentially modifiable risk factors may be identified [2].

In [1-3] Parkinson's disease (PD) is a multifaceted motor and non-motor condition that can be difficult to control. Also, PD is a long-term illness that manifests itself in a variety of ways. Bradykinesia, tremor, stiffness, gait freezing, imbalance, postural abnormalities, micrographic, dystonia, and speech and swallowing difficulties are all movement-related issues. As a result, specific knowledge and skills, as well as a clinician's desire to spend enough time with patients and cares, are essential. So, technologies are further important devices that need to be addressed at individual, as well as societal levels to improve their life [1-3]. These days, the Internet of Things (IoT) and robotics cannot be regarded as two distinct fields. The Internet of Robotic Things (IoRT) is a term that was recently coined to characterize the integration of robotics technology into IoT situations. As a result, these two study fields have begun to interact, therefore connecting research communities [4, 5].

THEORETICAL BACKGROUND

Introduction

- **A systematic review of the literature on assistive devices**

The systematic literature review to answer the research question was performed as daily life activities (DLAs) are necessary for quality of life so a lot of features allow users not only to enjoy meals with family and friends at home but also to go out with them. The research was summarized and classified into four groups according to the used mechanism or method:

- **Assistive device based on Biosensor**

The biosensor system has seen growth in the last few years and has been used to help the disabled. There are many methods and designs for non-invasive brain-computer interfaces BCIs. Applied a fuzzy decision for an automatic feeding robot using a single channel steady-state evoked potential (SSVEP) -based brain-computer interface (BCI). The system consists of visual stimulation, data acquisition, decision model, signal processing, and the feeding robot. The experimental results have been shown an average positive predictive value of single visual stimulus test (SVST) about 90.45% and multiple visual stimuli test (MVST) about 91.45%, with F-score are 0.5889 and 0.6038 in SVST and MVST. The fuzzy decision model was used to determine which food should be picked by the feeding robot [6]. Designed a wearable robotic arm for people with mobility disabilities. The authors present a wearable control interface for persons with mobility impairments. The system was used a muscle's residual motion capabilities, through a Machine-Body Interface based on a merge of head tilt and electromyography signals. The system consists of a MARG sensor, EMG electrodes, XBee module, and microcontroller. However, the design should be a more compact electronic system, and force feedback methods would be evaluated to improve the performance [7]. Designed a system for a brain-controlled robot arm that was used to create this model in an experimental environment. The system consisted of three main modules: a brain-machine interface (BMI) module, a network module, and a control module. The experimental results have been shown tested with six healthy subjects and six directions (up, down, forward, backward, left, and right), hand grasp/spread, wrist-twisting pronation/supination. The accuracy averaged of classification for each task are 22.65%, 50.79%, and 54.44%, respectively. However, it is difficult to analyses brain signals to control the robot arm so, it must be an improvement in the interaction effect between the user and the control system [8].

Other techniques used include an assistive robotic framework with Free-View, and 3D Gaze-Guided. Two operational modes have been used to cater for different eventualities (automatic mode and manual mode). The system consists of a robotic arm, a Kinect sensor, and eye-tracking glasses. The experimental results for a manual pick and place task were achieved with a success rate of 91.67%. However, additional hardware, such as AR glasses, would enhance the user experience and allowed further independence to the user [9]. Bio-Robotics is an emerging field to aid persons with special needs to improve their quality of life. People with hands-related incapacity or immobilization experience several life issues. Essen, a fundamental requirement is a difficult effort that affects these people badly. Evaluated the performance of the JACO robot by the ease of use, task completion time, and participants' perception of usability. Three new algorithms were applied to the JACO (predefined position, fluidity filter, and drinking mode). The author's objective was to evaluate differences in performance between proportional and non-proportional control modes. The results have been shown significant improvements in performing daily living activities. However, the system could use the algorithms in the participants' daily lives, at home, and in the community [10]. Multi-sensor robotic assistance for drinking. The authors were presented a robotic to enable independent, straw-less with a smart cup and no physically attached elements on the person. The system consists of the Kinova Jaco 2, camera, and smart cup with force sensors. However, the system could be a focus on replacing the current smart cup with a standard cup for the tetraplegic user. The system should be tested within a larger person study with a higher ratio of potential [11].

There are also, a robotic arm based on Brain-Machine Interface (BMI) and vision Guide using Neural Network. The system contains three components the BMI module, vision-guided module as well as refine the position of the robotic arm, and robot control module. The experimental results have been shown an averaged about 78% success rate. However, the system could be developed with a higher degree of freedom to improve daily life not only for disabled patients but also for healthy persons [12]. Provide a robotic feeder for disabled (RFD) using blink detection technique. The RFDP consists of an eye blink detection system, camera, as well as robot arm with five degrees of freedom, table, and four plates. The experimental accuracy was important in this system because the process of detecting the number of blinks of the person was sensitive [13]. Proposed an EOG-depend on wheelchair robotic arm for drinking task. The authors used a robotic arm, shared control, and two cameras. The system has been shown an average accuracy of 99.3%/97.3%, with an average response time of 1.91 s/2.02 s per command. The system could be expanded for more application range and the test would be for more patients [14].

Quadriplegics with a semi-autonomous tongue control of an assistive robotic arm. The system consisted of a ferromagnetic half sphere, tongue interface, the control signals are transferred wirelessly, JACO2 ARM, color as well as depth camera and PC. A pick-and-place job was used to test the system, using alternative control methods relative to the manual command reference. However, in such a system, there should be a continuous blending of control between the user input and the autonomous behavior [15]. Framework for an assistive robot using physics simulation. The authors have presented an assistive Gym, with an open-source physics simulation system that does multiple tasks. The system includes six simulated environments itch scratching, body manipulation, drinking, feeding, dressing, and bathing. Furthermore, the assistive Gym was a promising tool for assistive robotics research. However, the assistive Gym could be improved models of realistic human movement during assistive scenarios [16]. A new brain/neural control paradigm for guiding an exoskeleton whole-arm was developed for the guidance of new hybrid electro-encephalography/electro-oculography.

Figure 2.1, shown the general block diagram of the assistive device based on biosensor. As illustrated in Figure 2.2, assistive device based on biosensor (human–computer interaction). It offered the advance in assistive device based on biosensor.

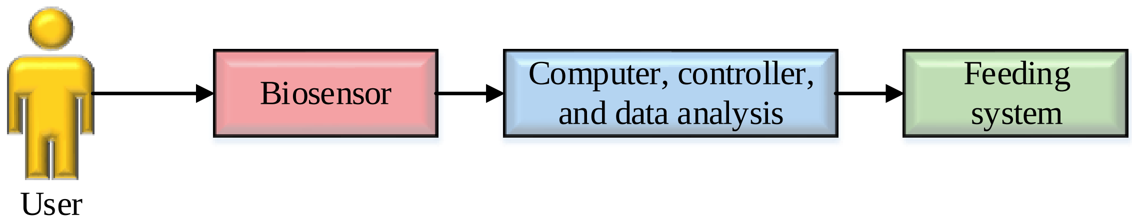


Figure 2.1 Block diagram of the assistive device based on biosensor.

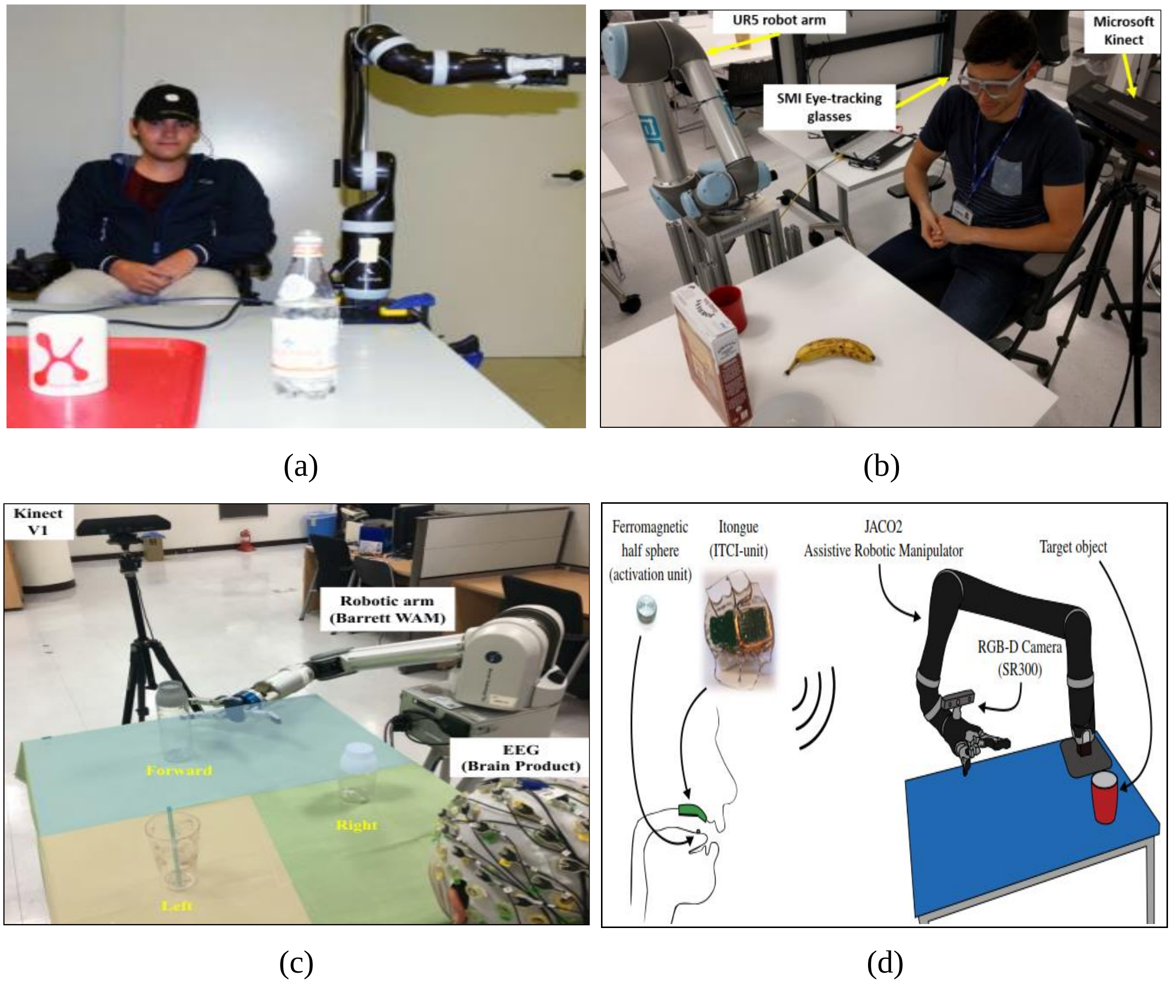


Figure 2.2 Snapshot assistive robotic device: (a) wearable control interface [7], (b) 3D Gaze-Guided [9], (c) arm based on brain-machine interface [12] , (d) tongue control of an assistive robotic arm [15].

- **Assistive device based on Smart phone and Computer**

Numerous works have utilized smart phone and computer to assist and aid the disabled. Much research has been initiated in this field. For example, designed a self-feeding prototype for increasing the independence of Parkinson's people and elders. The system could help patient’s self-control with their meal for the care of a family member or worker thereby saving a lot of time and effort of caregivers. The system was operated autonomously by itself and sent food data with relative information to monitoring computers based on the internet. The structure is described as a robotic arm designed to feed the foods to an elder person/Parkinson's patient, who was unable to use his/her arm for self-feeding. User ingests the food from the index dish transferring to his/her mouth by spoon held and choose the favorite food by rotating the index tray [17]. Enhance the independence of an elderly person or of a person with Parkinson's who cannot use his arm to feed himself. Such as designed a FeedBot to improve self-feeding prototype for Parkinson patients. The FeedBot was an intelligent device especially for Parkinson's patients, who have difficulty feeding the foods while eating. The system consists of a spoon, an index tray, a manipulator, remote control, and three bowls put into the tray. The robotic arm consists of a 2 DOF robot arm, a spoon holder, a rotation dish including 3 bowls, and a remote controlling device. Besides, a smartphone app to manage a meal's nutrition. Experiments were evaluated at lab and surveys at the nursing home. The results shown provided a viable alternative to assisting independence in self-feeding as measured by the cost-benefit ratio and nutrition intake [18]. Electroencephalography (EEG) controlled using SSVEP with a camera for meal assistance-based automatic position tracking as well as open detection mouth. The user could select any solid food item that desires to eat from three different containers. The system consists of four subsystems (Feeder robot arm, LED panel system, EEG signal acquisition system, and camera system). However, depth-sensing was an important aspect that should be used to achieve the full potential of the system. Although, used an EOG together with EEG could be explored to enhance the usability and improve the effectiveness. Moreover, the safety aspects of the users and obstacle avoidance should be used [19].

Proposed a robotic arm control using BCI System. The system consists of a robotic arm, RGBD camera, computer vision module. The results have been shown for a complete task at least 90% in the ten trials [20]. Proposed an automatic mouth detection for self-feeding called meal assistance robot (MAR). The system was developed and evaluated algorithms that detect and track the mouth of persons in real-time and classified if the mouth was open or closed. The results have been indicated a high classification accuracy with ~89% and the algorithms could be detected the mouth postures of a person in time <1sec while they have a robot-assisted meal in a social setting. However, the limitations of the system included small sample size, testing in individuals without a disability, and data collected in a laboratory setting [21]. Designed a brain-machine interface (BMI) for manipulation of a robotic arm. The framework consists of a wireless headset, raspberry pi, robot arm, GUI, and PC. The BMI framework has a high success rate of 70% in manipulation tasks after a time of training (10 min). However, to improve the control for persons with BCI illiteracy, its need more advanced machine learning methods. Also, more subjects to improve the robustness and accuracy of the system [22]. Introduced a review for the challenge that has been addressed by brain-computer interface (BCI) researchers and how new solutions might improve the system with robotic effectors. The components for the robotic arm control a sensor to capture a neural activity, a decoder to record commands as well as intend action, and visual feedback that allows the user to intervene and correct the motion [23]. Figure 2.3, shown the general block diagram of the assistive device based on smart phone and computer. As illustrated in Figure 2.4, assistive device based on smart phone and computer. It offered the advance in assistive device based on smart phone and computer.

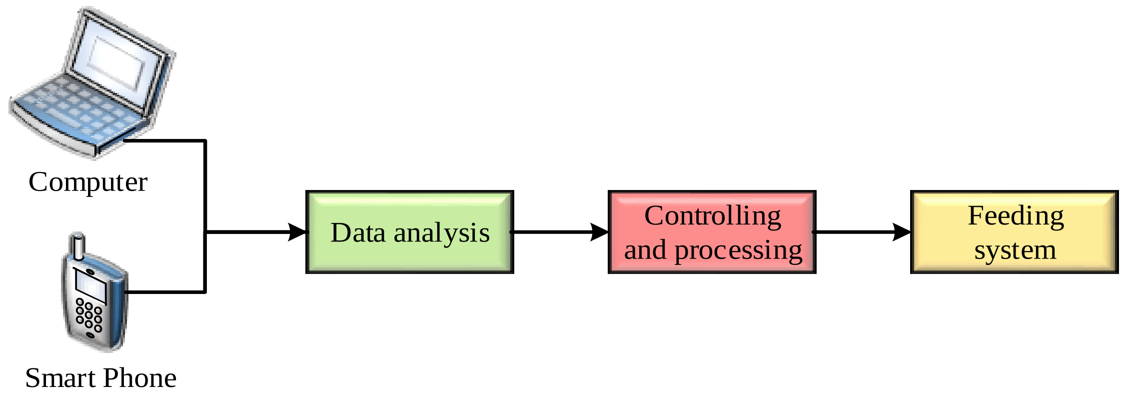
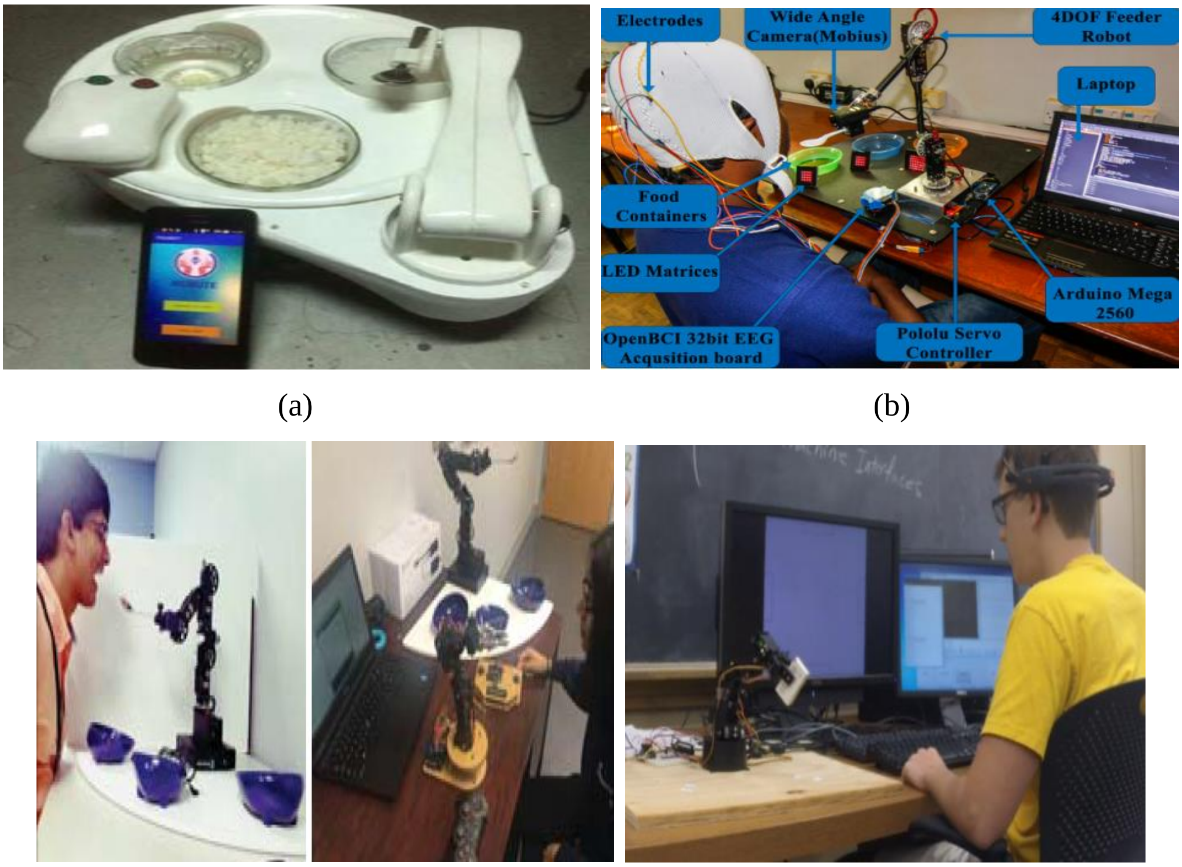


Figure 2.3. Block diagram of the assistive device based on smart phone and computer.



(a) (b)

(c) (d)

Figure 2.4. Assistive device based on smart phone and computer: (a) application for smart phone for self-feeding [17], (b) meal assistance robot [19], (c) arm robotic for self-feeding [21], (d) robotic arm feeding[22].

- **Assistive device based on Camera**

Here, the camera is used to assist people with disabilities who cannot move or eat, and so on. Many researchers have used algorithms and designs such as in based on camera. Approximating an assistive robotic arm for disabilities based on food detection was introduced. The system consists of a Web camera, laptop computer, 6-axis robotic arm, and microcontroller. However, further experiments with severe disabilities should be applied for future work [24]. Provided an evaluated how the vision could be used to improve food acquisition and delivery. Also, shown how Discriminative Optimization (DO) could be used in tracking so that the food could be effectively brought to the user’s mouth, rather than to a preprogrammed feeding location. The system consists of a MICO robot arm, an RGB-D camera, and an RGB camera. The classification results have been shown an accuracy of 95.8% with the logistic regression and 98.6% with the linear SVM. The system was capable of feeding a person using a spoon with different types of food like rice or peanuts, as well as uses visual feedback to ensure spoons were full of food when presented to the user [25]. Proposed a multimodal detector for assisted feeding robot using long short-term memory-based variational autoencoder (LSTM-VAE). The robot-assisted feeding system consists of a camera, encoder, microphone, force sensor, 5 utensil handle, fork, and spoon. The system has a feeding execution, from 5 sensors: (sound energy, force applied on the end effector, joint torque, spoon position, and mouth position. The LSTM-VAE with the state-based decision boundary was showed a beneficial for more sensitive anomaly detection with lower false alarms [26].

Presented an execution monitoring framework for multimodal detection during assistive robot manipulation. The system sensory has detected an anomaly when a log-likelihood was lower than a varying rejection threshold. The authors have introduced two methods, a clustering-based classifier (HMM-D) and a regression-based classifier (HMM-GP). The evaluated results were by a PR2 robot performing object pushing and robot-assisted feeding tasks [27]. Designed an active robot-assisted feeding with a general purpose, evaluation, and lessons learned. The system consists of a camera for food observation, a camera for face observation, a bowl, a feeding tool, and a tablet for GUI. The experimental results were applied on robot appearance, user interface (UI), slicing food, amount of food, speed of feeding, delivery motion, and emergency alarm. The evaluation of the system has a good result which was implemented on persons with serval disabilities [28]. Designed an intelligent assistive robot arm for object detection and grasping using deep learning. The system was experimentally tested on the Kinova Jaco robotics arm. However, it should be focused on enhancing the system performance in an accurate robot motion planned and executed, as well as the extension of detected object classes [29].

Developed robotic feeding using various manipulation strategies. Which a feeding system could acquire food items and feed a person autonomously using multiple vision and haptics. Also, designed various discrete manipulation fundamental for reliable bite acquisition. However, it could investigate the capabilities of the system for both people with disabilities with no neck movements where the system could need to bring the food item close enough to the mouth [30]. Designed of mechanism for meal-assistance robot based on vision system and multi-gripper. The gripper was designed with the concept of a planar 2-DOF under-actuated mechanism. The system consists of a camera, arm, chopstick-type gripper, and a mini PC. The experiment's result used a three-dimensional (3D) printed prototype, to measure the gripping force by varying the contact position and the stiffness. However, it should apply more experiments to grasp many kinds of food that would be carried out. Besides, a control system using some feedback signal to achieve more stable and appropriate gripping [31]. Implemented a low-cost vision system-based feeding robotic arm using image processing and artificial intelligence technology. The system consists of a Raspberry Pi 4 Model B, A 6-Degree of Freedom (DOF) robotic arm, servo driver board, camera, spoon, bowl, control box, and speaker. However, the system should be enhanced in both software and hardware parts. In the hardware part, must be more sophisticated electronic components such as stepping motors or ultrasonic sensors. In the software part, the algorithm for locating the user’s mouth position must be developed and implemented. Also, the Speech Recognition method must be used in case of more natural operability [32].

Figure 2.5, shown the overall outline of the assistive gadget dependent on camera. As delineated in Figure 2.6, assistive gadget dependent on camera. It offered the development in assistive gadget dependent on camera.

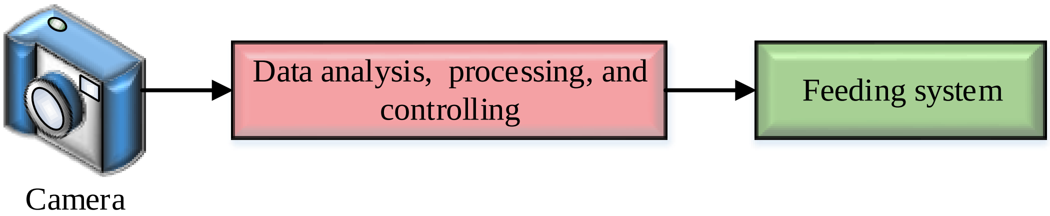


Figure 2.5. The overall outline of the assistive gadget dependent on camera.

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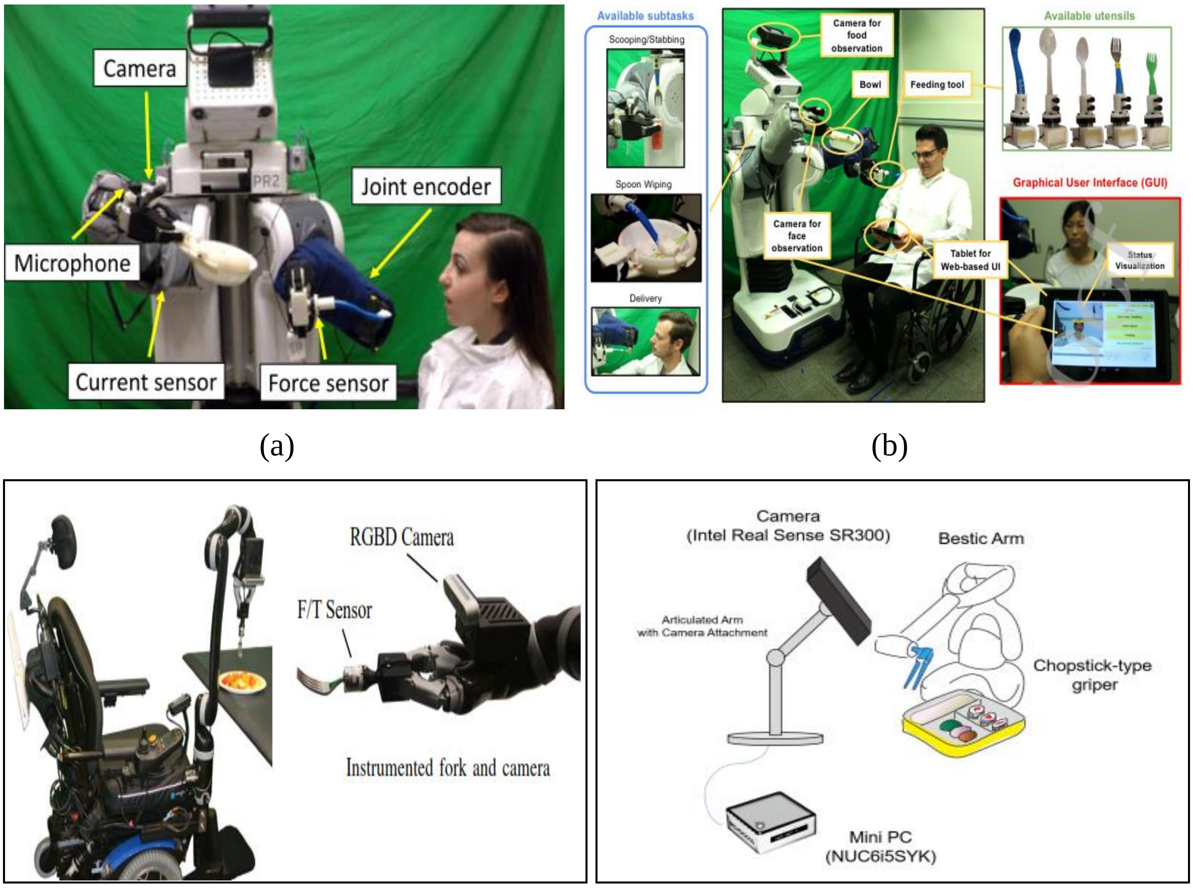

(a) (b) (c) (d)

Figure 2.6. Snapshot for: (a) robot-assisted feeding system [27], (b) meal-assistance system [28], (c) Robotic feeding [30], (d) Gripper mechanism for meal-assistance robot [31].

- **Assistive device based on Other system**

The research was summarized based on several component such as Kinect sensor, Force sensor……etc. Developed a feeding assistive robot for eating. The authors used a forward kinematics equation and trajectory planning for the robotic arm, checked the forward kinematics equation, and analyzed the trajectory in the MATLAB program. Besides, a simulation experiment was used as SolidWorks Motion. However, the system needs to enhance it is the practicality of the system through additional evaluations and improvements [33].A developed robot-assisted system with a multimodal execution monitor and anomaly classification. The feeding system provides a general-purpose mobile and a high-level web-based interface for persons with disabilities. The experimental results have been demonstrated successfully detected and classified anomalies. Also, found multimodal features for classifying the causes of anomalies. Moreover, evaluated the system in the home [34]. Designed a robotic arm for meal assistant by an intelligent system. The system consists of a feature algorithm, inverse kinematic algorithm, 4-joint robotic arm, and controller algorithm. The controller has used a new weight updating rule of the neural network which could optimize the inside predicted state to improve the controller performances. The performances were evaluated with the MatLab program. The experimental results have shown that the meal assistant system was able to track the human mouth in the 3-dimensional [35].

Developed a power feeder design and simulation for persons with disabilities (PwD) using Autodesk tinker-cad. The design was manually controlled to feed which was done and fabricated for testing. The system was done by SolidWorks. The circuit builds by using a microcontroller Arduino Uno designed for the push-button control of all motors. The code was written and simulate tinker-cad. However, stepper motors will deliver better precision for arm movement. Kinematic Synthesis is better to control motors could be attained by an android interface or a joystick [36]. Applied feeding device via learning from demonstration. The prototype was modeled as a mixture of the data collected via kinesthetic teaching, the parameters of the Gaussian Mixture Model (GMM) were learned using Gaussian Mixture Regression (GMR) and Expectation-Maximization (EM) algorithm. The performance of the system was evaluated in two feeding scenario experiments: one considered obstacles in the path between the bowl and the mouth and the other without. However, the system planned to address the full collision avoidance and challenging problem of transferring the feeding task to a similar robot [37]. Presented a prototype of an assist device using machine learning and IoT for Parkinson's disease. The system gave a counter-motion to the tremor actions of a patient's hand, to not spill food. Also, the system consists of a gyro-sensor, accelerometer, mixed-signal, servo motors, and microcontroller PID controller. Tools such as IoT and machine learning have been introduced into the system, which allows the product to monitor changes [38].

Developed an eating helpful device to help patients with special needs. The authors were investigated how to evaluate an eating assistive prototype by estimating the interaction forces between the robot and the human while eating. The system consists of an acceleration sensor, spoon, force sensor, and an eating assistive device. The experimental results have shown that the evaluation was feasible using a mass and an accelerometer. However, the system should include further testing for the human effort to reach the food location and subjective evaluation. Moreover, various eating habits should be also studied [39]. Implemented a meal-assistance robot worked by head motion. The system consists of a Kinect sensor, Raspberry Pi, control unit, and spoon. The experimental result showed a consistency rate of 90% was obtained. However, it was to prevent chattering that was a cause of false recognitions and operability [40]. Introduced an evaluation of an eating assistive robot based on forces estimation using an accelerometer sensor. The particular experiments have been shown to investigate the influence of the food-delivery location. However, the system could include a correlation between interaction forces and the user's posture. Also, it should be complemented with a subjective evaluation, as well as the assumption that higher interaction forces [41].

Designed a robotic arm for disable. The system consists of a robotic arm, three servos motor, pushbuttons, and a microcontroller. The analysis results, have been shown robotic arm was capable of not only for performing a series of tasks good precision. However, to develop the system could be the use of a gyroscope for the arm and used six servos motor rather than three[42]. The elderly and their food demands have not been fully investigated in situations such as senior households, where many elderly people eat at least three times a day. This is prompted by the availability and lack of research linked to the multiple-user feeding systems. A taxonomy of manipulation techniques for feeding was proposed. A set of classifiers for compliance-based food types from motion signals and haptic. The system compared human manipulation techniques with fixed position-control policies through a robot. As long as, the future autonomous system would use the taxonomy and data from the human experiments, methods from the haptic classification, with insights from the controlled robot experiment to devise various manipulation techniques for feeding people food items of varying physical characteristics [43]. Designed a meal assistant robot with an omnidirectional moveable plate and a vertical coordinate type was proposed. The meal support could be performed with an easy and stable movement. Omni-wheel was used for omnidirectional move plate. The system consists of three units (food pickup unit, food supporting unit, and omnidirectional moveable plate unit). However, the food with large size could not be cut were difficult to put on the spoon and could fall and it was necessary to improve the system [44].

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Proposed a mechanical device to assist eating in people with disorders movement. The objectives were to establish the current situation related to autonomous eating, to design an assistive prototype that would stabilize the user's motion and enable them to eat independently, and to perform a preliminary evaluation of the assistive prototype to evaluate its performance and to guide the development of future work. However, the dampers would be replaced by smart electronic dampers that allow modifying the damping ratio in real-time based on the evaluation of the user's motion smoothness with sensors. Designed a mechanical device to assist eating in persons with movement disorders. The assistive device was designed to be fixed on a table and to support a spoon. However, the system could include smart electronic dampers that would allow to enhancing the damping ratio in real-time depending on an evaluation of the user's motion smoothness with sensors [45]. Functionality designed for self-feeding evaluation for upper limb disorder. An accelerometer sensor, a Wi-Fi module, a rechargeable battery, and a mobile phone were included in the device. The result of experiments showed that movement variability measured by Dynamic Time Warping (DTW) resulted in an average of 96 % accuracy. Although the overall findings presented an analytical way of capturing intrinsic abnormalities dependent on everyday life, the multiple parts of the task revealed the existence of ataxia in a spatial sense concurrent with specific clinical findings. Further experiments were needed to test the system's performance in a larger cohort of people [46]. Described an assistive robot that primarily focuses on feeding liquids from a container using tactile input with direct human-robot interaction (HRI) by force sensors. The significant focus was on the implementation of reinforcement learning (RL) focused on the best robotic practices to understand what the best robotic actions were. Five different algorithms were applied to avoid straws and provided the person as well as the ability to freely manipulate the container. However, the system should use shear force sensors that would allow the person to not only control the up/down rotation of the container but also forward/backward translation. Furthermore, redundant safety sensors would be included [47].

Proposed an interaction with real people to improve virtual robots (VR). Which used for assisted itch scratching, feeding, drinking, and bed bathing. The results suggest that VR could be used to improve the performance of simulation-trained control policies with real persons without putting persons at risk, so this serving as a valuable stepping stone to real robotic assistance [48]. Proposed feeding assistance system using faster R-CNN oriented for obstacle detection. The authors have used 3 architectures of different depths with an accuracy, of 77.4%. However, the system could be enhanced by selected architecture in the complete system, to give greater autonomy to the robot arm at the time when there was an obstacle made by the user or someone external, and could make a decision against it [49]. Designed a Shared Control Template (SCT) for an assistive robot. The authors were defines task-specific skills. The experiment results provide a safe, axiomatic way of reducing the workload of the person. Task-dependent command based on personal preferences should expansion system use [50].

The literature refers to several aspects which restrict user acceptance of these devices in general, including expensive costs, operating device challenges, a performance that does not meet user expectations, and inadequate adaption to user demands, while a range of remedies was presented. This study is developed and researched based on the history and talks above, to promote independent lives for the elderly through a multi-grip tool for eating. Figure 2.7 shows the layout of the other system-dependent assistive device. As shown in Figure 2.8, the assistive device based on other system. It offered another system-dependent improvement of the support device.

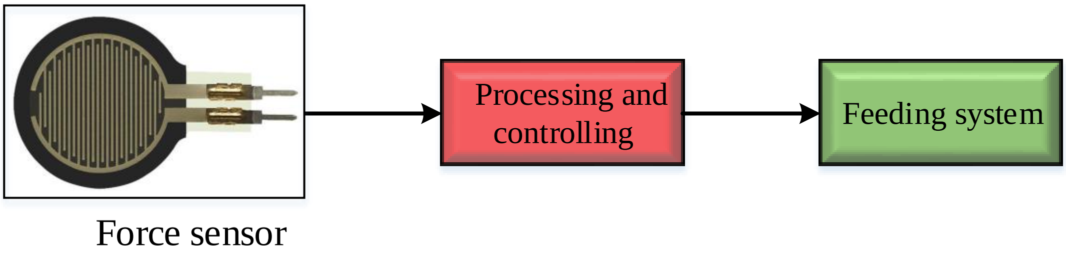

Figure 2.7. Layout of the other system-dependent assistive device.

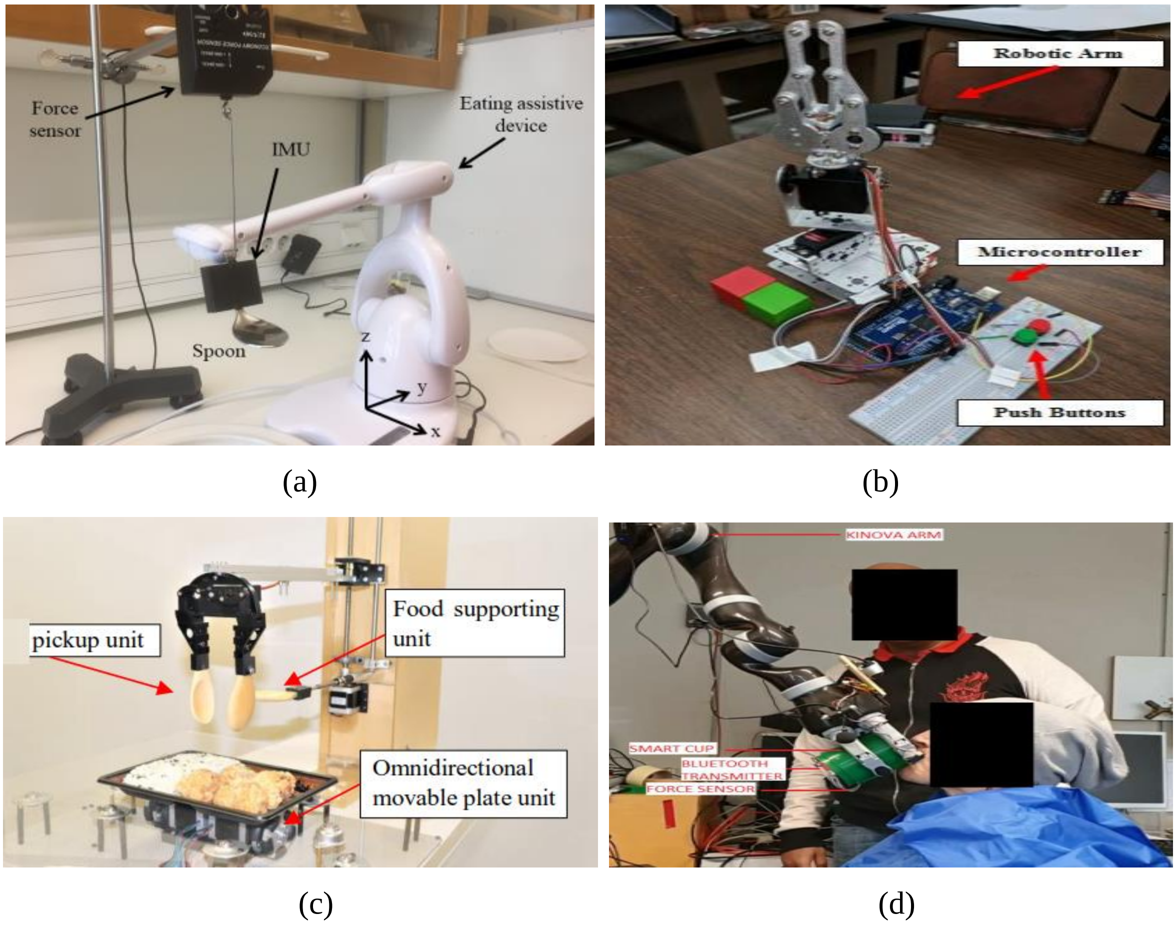

Figure 2.8. Assistive device based on other system (a) eating assistive device [40], (b) Trainable Robotic Arm [41], (c) Trainable Robotic Arm [42], Robotic Drinking Assistant [44].

Methodology

➢ Introduction

This chapter covers the hardware and software configuration of this study as well as it presents the methodology used to accomplish the work goals. The methodology included in this study is organized into three phases. The first phase is the design and implementation of assistive feeding device. The second phase is controlling a assistive feeding device by algorithm. The last phase is performance metrics evaluation by optimization of the measurement accuracy for executing orders based on the sensitivity and specificity in addition to the performance accuracy information of the design and implementation of assistive feeding device.

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➢ **System Design and Development**

This section describes the system design and development of the proposed design and implementation of assistive feeding device.

➢ **System design**

The proposed system comprises a servomotor, three servomotor used to transmit the and rotate the spoon. Figure 3.1 presents a block diagram of the design and implementation of assistive feeding device. The framework is designed to keep in view any demands for future development and can be simply modified by adding and replacing the input or output parts. Figure 3.2 shown the schematic diagram of the system

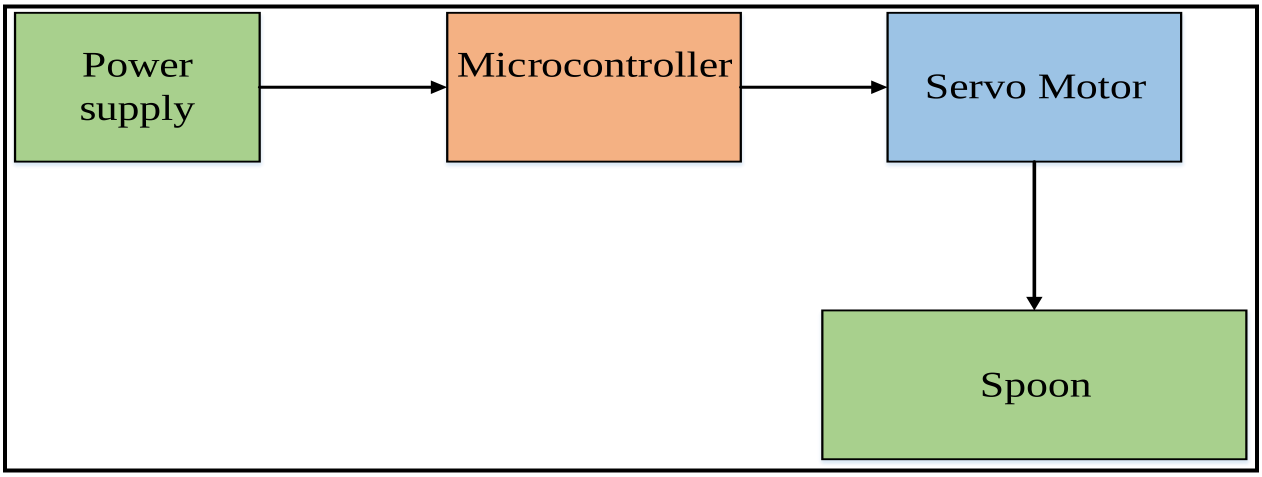

Figure 3.1 Block diagram of the design and implementation of assistive feeding device.

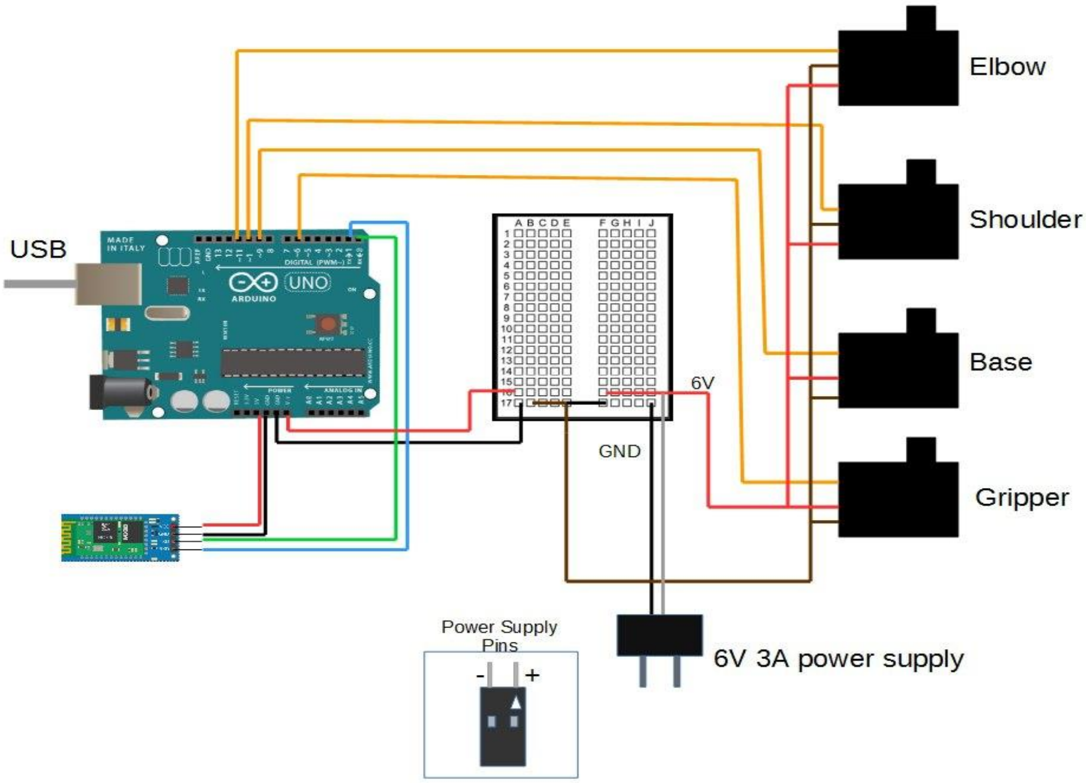

Figure 3.2 schematic diagram of the design and implementation of assistive feeding device.

- **Hard ware configuration**

In this stage, the hardware implementation of the design and implementation of assistive feeding device can be divided into several units as discussed below:

- **lithium-ion battery:**

An 18650 battery is **a lithium-ion battery**. The name derives from the battery's specific measurements: 18mm x 65mm. For scale, that's larger than an AA battery. The 18650 battery has a voltage of 3.6v and has between 2600mAh and 3500mAh (mili-amp- hours).

Figure 3.3 18650 Lithium Batteries [22].

- **Microcontroller**

The Arduino UNO is the best board to get started with electronics and coding. If this is your first experience tinkering with the platform, the UNO is the most robust board you can start playing with. The UNO is the most used and documented board of the whole Arduino family[53]. The schematic diagram of the circuit for the microcontroller shown in figure 3.4. The pin configuration shown in Appendix A.

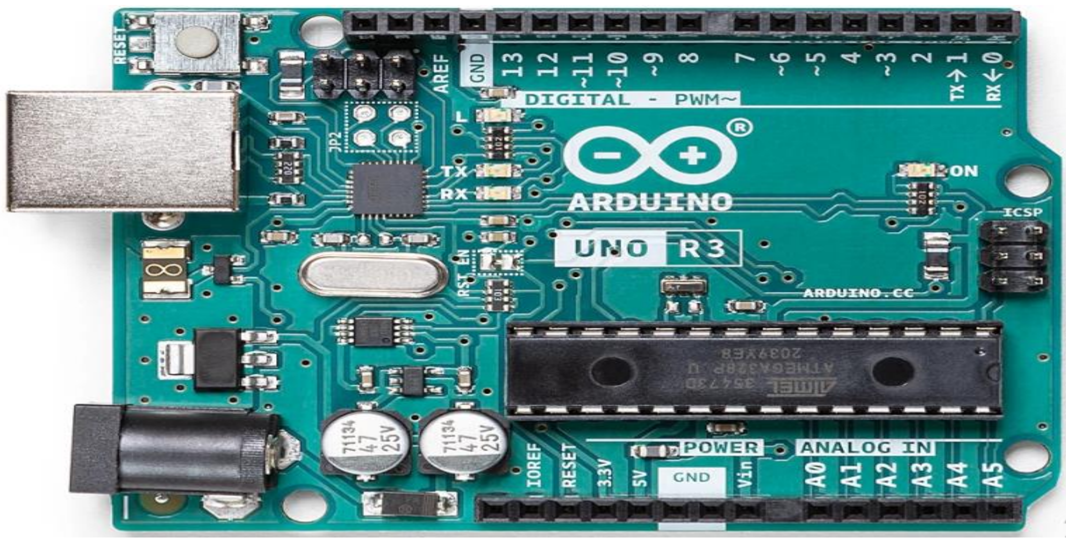

Figure 3.4 schematic diagram of the microcontroller.

➢ Servo motor

A servomotor (or servo motor) is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. [54]. Figure 3.5 shown the motor and the way to control it. The datasheet shown in Appendix B.

Figure 3.5 shown the stepper motor [25].

➢ software configuration

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them.[55]. Figure 3.6 shown the Arduino Software the main site of the program. In addition, the system used an application to control the arm of the robot is shown in figure 3.7.

```
#include <SoftwareSerial.h>
#include <Servo.h>

Servo servo01;
Servo servo02;
Servo servo03;
Servo servo04;


SoftwareSerial Bluetooth(3, 4); // Arduino(RX, TX) - HC-05 Bluetooth (TX, RX)

int servo1Pos, servo2Pos, servo3Pos, servo4Pos; // current position
int servo1PPos, servo2PPos, servo3PPos, servo4PPos; // previous position
int servo01SP[50], servo02SP[50], servo03SP[50], servo04SP[50]; // for storing positions/steps
int speedDelay = 60;
int index = 0;
String dataIn = "";

void setup() {
  servo01.attach(5);
  servo02.attach(6);
  servo03.attach(7);
  servo04.attach(8);

  Bluetooth.begin(9600); // Default baud rate of the Bluetooth module

  delay(20);
  // Robot arm initial position
  servo1PPos = 90;
  servo01.write(servo1PPos);
  servo2PPos = 150;
  servo02.write(servo2PPos);
  servo3PPos = 35;
  servo03.write(servo3PPos);
```

Figure 3.6 the code of the program.

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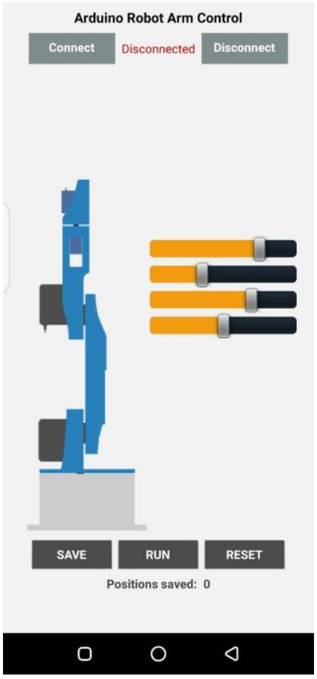

Figure 3.7 application of the sysytem

- **System Algorithm**

The system is work when the power is ON so the motor is working according to the select speed and program. Figure 3.8 illustrate the algorithm for the system.

```
#include <SoftwareSerial.h>
#include <Servo.h>

Servo servo01;
Servo servo02;
Servo servo03;
Servo servo04;


SoftwareSerial Bluetooth(3, 4); // Arduino(RX, TX) - HC-05 Bluetooth (TX, RX)

int servo1Pos, servo2Pos, servo3Pos, servo4Pos; // current position
int servo1PPos, servo2PPos, servo3PPos, servo4PPos; // previous position
int servo01SP[50], servo02SP[50], servo03SP[50], servo04SP[50]; // for storing positions/steps
int speedDelay = 60;
int index = 0;
String dataIn = "";

void setup() {
  servo01.attach(5);
  servo02.attach(6);
  servo03.attach(7);
  servo04.attach(8);

  Bluetooth.begin(9600); // Default baud rate of the Bluetooth module

  delay(20);
  // Robot arm initial position
  servo1PPos = 90;
  servo01.write(servo1PPos);
  servo2PPos = 150;
  servo02.write(servo2PPos);
  servo3PPos = 35;
  servo03.write(servo3PPos);
```

```
  servo4PPos = 140;
  servo04.write(servo4PPos);

}

void loop() {
  // Check for incoming data
  if (Bluetooth.available() > 0) {
    dataIn = Bluetooth.readString();  // Read the data as string

    // If "Waist" slider has changed value - Move Servo 1 to position
    if (dataIn.startsWith("s1")) {
      String dataInS = dataIn.substring(2, dataIn.length()); // Extract only the number. E.g. from "s1120" to "120"
      servo1Pos = dataInS.toInt();  // Convert the string into integer
      // We use for loops so we can control the speed of the servo
      // If previous position is bigger then current position
      if (servo1PPos > servo1Pos) {
        for ( int j = servo1PPos; j >= servo1Pos; j--) {   // Run servo down
          servo01.write(j);
          delay(60);    // defines the speed at which the servo rotates
        }
      }
      // If previous position is smaller then current position
      if (servo1PPos < servo1Pos) {
        for ( int j = servo1PPos; j <= servo1Pos; j++) {   // Run servo up
          servo01.write(j);
          delay(60);
        }
      }
      servo1PPos = servo1Pos;   // set current position as previous position
    }

    // Move Servo 2
    if (dataIn.startsWith("s2")) {
```

```
      String dataInS = dataIn.substring(2, dataIn.length());
      servo2Pos = dataInS.toInt();

      if (servo2PPos > servo2Pos) {
        for ( int j = servo2PPos; j >= servo2Pos; j--) {
          servo02.write(j);
          delay(60);
        }
      }
      if (servo2PPos < servo2Pos) {
        for ( int j = servo2PPos; j <= servo2Pos; j++) {
          servo02.write(j);
          delay(60);
        }
      }
      servo2PPos = servo2Pos;
    }
    // Move Servo 3
    if (dataIn.startsWith("s3")) {
      String dataInS = dataIn.substring(2, dataIn.length());
      servo3Pos = dataInS.toInt();
      if (servo3PPos > servo3Pos) {
        for ( int j = servo3PPos; j >= servo3Pos; j--) {
          servo03.write(j);
          delay(60);
        }
      }
      if (servo3PPos < servo3Pos) {
        for ( int j = servo3PPos; j <= servo3Pos; j++) {
          servo03.write(j);
          delay(60);
        }
      }
      servo3PPos = servo3Pos;
```

```
}
// Move Servo 4
if (dataIn.startsWith("s4")) {
  String dataInS = dataIn.substring(2, dataIn.length());
  servo4Pos = dataInS.toInt();
  if (servo4PPos > servo4Pos) {
    for ( int j = servo4PPos; j >= servo4Pos; j--) {
      servo04.write(j);
      delay(60);
    }
  }
  if (servo4PPos < servo4Pos) {
    for ( int j = servo4PPos; j <= servo4Pos; j++) {
      servo04.write(j);
      delay(60);
    }
  }
  servo4PPos = servo4Pos;
}


// If button "SAVE" is pressed
if (dataIn.startsWith("SAVE")) {
  servo01SP[index] = servo1PPos;  // save position into the array
  servo02SP[index] = servo2PPos;
  servo03SP[index] = servo3PPos;
  servo04SP[index] = servo4PPos;

  index++;                        // Increase the array index
}
// If button "RUN" is pressed
if (dataIn.startsWith("RUN")) {
  runservo();  // Automatic mode - run the saved steps
}
```

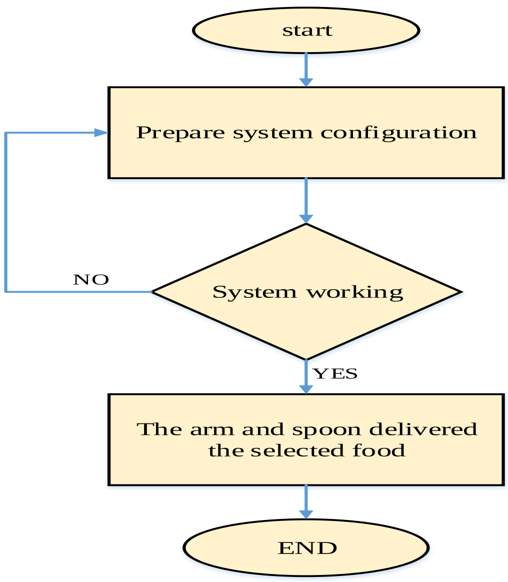

Figure 3.8 algorithm for the system.

➢ Performance Classification

The performance classification of the system has been derived from three statistical analyses, namely, sensitivity, specificity, and accuracy [56, 57]. These measurements are based on four indices that have four possible attempts, which are: the true positive (*TP*) is the motor is ON and the spoon is active, false positive (*FP*) is the motor is OFF and the spoon is active, true negative (*TN*) is the motor is ON and the spoon is not active, and false negative (*FN*) is the motor is OFF and the spoon is not active. Sensitivity (*SN*) refers to the ability of the system to perform the function of the system (the sensitivity is also known as a recall), as shown in Equation (3.1) [27].

$$SN.\% = \frac{TP}{TP + FN} \times 100 \qquad (3.1)$$

Specificity (*SP*) refers to the ability of the function of the system, as shown in Equation (3.2) [27].

$$SP.\% = \frac{TN}{TN + FP} \times 100 \qquad (3.2)$$

Accuracy (*AC*) refers to the overall ability of the function of the system, as shown in Equation (3.3) [27].

$$AC.\% = \frac{TP+TN}{Pn+Nn} \times 100 \qquad (3.3)$$

where *Pn* and *Nn* denote the number of positive and negative attempts, respectively.

Likewise, for evaluating the overall system, F-measure accuracy (overall accuracy) has been computed to evaluate the overall performance [58]. F-measure accuracy represents the combination of recall (sensitivity) and precision, which is defined, as follows:

$$Precision\,\% = \frac{TP}{TP + FP} \times 100 \qquad (3.4)$$

$$F - measure\ accuracy\,\% = 2 \times \frac{recall \times precision}{recall + precision} \times 100 \qquad (3.5)$$

CHAPTER 4

RESULTS AND DISCUSSION

➢ Introduction

In this chapter, the results of the methodology is presented as a validated measurement of the proposed system are investigated statistically (i.e., accuracy, sensitivity, and specificity).

➢ Performance Results of the system

In this section, the performance results of the system can be discussed below:

The classification models (true positive [TP], false positive [FP], true negative [TN], and false negative [FN]) are evaluated. These classification models are, illustrated in Tables 4.1 to 4.2. All test cases are carried out by repeating for many attempts.

Table 4.1 Experimental evaluation for test 1

Test 1	Motion 1	Motion 2
Attempts	100	200
TP	99	198
FN	1	2
Sensitivity (%)	99	99

Table 4.2 Experimental evaluation for test 1

Test 2	**Motion 1**	**Motion 2**
Attempts	200	300
TN	199	299
FP	1	1
Specificity (%)	99.5	99.6

Table 4.1 and Table 4.2 shows the experimental evaluations. Accuracy, sensitivity, and specificity are statistically analyzed to validate the performance of the proposed system. These statistical analyses are measured according to Equations (3.1–3.3) (Chapter 3). The average sensitivity, specificity, and accuracy for the test one are 99%, 99.55%, and 99.33%, respectively.

Table 4.3 indicates the overall performance accuracy information of the system. The accuracy validation is expressed as a confusion matrix. The confusion matrix gives a clear illustration of the number of experiments and the accuracy of the system. There are 50 numbers of experiments for the total system. The experiments are implemented by collecting 50 trials and measure the value of accuracy from the confusion matrix. The overall accuracy of the system is determined from Equations (3.4-3.5) (Chapter three). The overall evaluation accuracy is estimated to be ≈ 98%.

Table 4.3 Overall accuracy of the system

Parameters	Test 1	Test 2
Total number of experiment	100	100
TP	96	97
FP	1	1
TN	2	1
FN	1	1
Confusion matrix= $\begin{matrix} TP & FN \\ FP & TN \end{matrix}$	Confusion matrix= $\begin{matrix} 96 & 1 \\ 1 & 2 \end{matrix}$	Confusion matrix= $\begin{matrix} 97 & 1 \\ 1 & 1 \end{matrix}$
Precision (%)	98.9	98.9
Recall (%)	98.9	98.9
WCS accuracy = $2 \times \frac{\text{recall} * \text{precision}}{recall + precision} \times 100\ \%$	98.9	98.9
Overall Accuracy = 98.9 %		

Also, figure 4.1 illustrate snapshot for the real system from different angles

Figure 4.1 snapshot for the real system from different angles

CONCLUSIONS AND RECOMMENDATIONS

The goal of this project is to develop and build an assisted feeding apparatus for the handicapped. The design process's outcomes include learning how to design and effectively designing and implementing an assistance feeding equipment.

The hardware configuration of the project system includes servomotor, power supply, Bluetooth, microcontroller, and spoon. Where the software configuration is Arduino, software, and the phone application used to operate the system.

The sensitivity and overall accuracy of the project system are evaluated experimentally using the classification models of true positive [TP], false positive [FP], true negative [TN], and false negative [FN]. Values of 98.5 % total accuracy demonstrate outstanding efficiency in the project system fabrication process. For future work it is expected that increasing the accuracy of the system.

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