University of Nairobi

School of Computing & Informatics

Project Proposal

Kenobi (Robotic Arm)

Collaborative Robots as a Catalyst for Industrial Growth in Kenya

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CHAPTER 1: INTRODUCTION

1.1. BACKGROUND

Over the last three decades, a growing group of manufacturing firms in the industrialized world have been spending enormous resources in upgrading their production technology to cope with the increasing competition from non-industrialized countries where production costs are much lower. As a result of this, there has been a transition of the manufacturing sector from labor intensive production to capital flexible specialization in the industrialized world (Skaksen, et al., 2011).

Automation is a known tool for improving competitiveness, especially in the manufacturing industry. There are many reasons to justify this automation. These are: to increase labor productivity; to reduce labor cost; to mitigate the effects of labor shortages; to reduce or eliminate routine manual or clerical tasks; to improve work safety; to improve product quality; to reduce lead time; to accomplish processes that cannot be done manually (Jackson M. & Zafarzadeh M, 2013).

Robots are an element of automation as they provide a measurable indication of levels of automation, and one that is reported internationally. Industrial robots are programmable devices consisting of mechanical actuators and sensory organs that are linked to a computer (Frohm J., et al., 2008). The international Federation of Robotics (Robotics, 2010) report that Germany has an installed base of 144,100 robots, Italy 62,200, France 34,100 and Spain 28,800 whereas the UK records 13,900. In 2007, the number of robots increased to 6.5 million worldwide. Around 1 million of these are used in the manufacturing industry (Skaksen, et al., 2011)

Robotics is a key enabling industry for manufacturing. Without robotics, Europe would quite easily not be able to maintain or expand its current level of manufacturing. To maintain a strong base in manufacturing, it is thus imperative to develop the next generation of industrial robots that can work in close proximity to humans (collaborative robots - cobots), are easy to program and can also be adapted to the needs of manufacturing firms (Noland M. & Park H., 2003). Robots can provide a solution to ongoing operational costs and can also respond flexibly to changes in volume demand and product type (Semple, 2010). Frost and Sullivan, (L.A & D.L, 2011), noted that robotics has the potential to transform lives and work practices, raise efficiency and safety levels, provide enhanced levels of service and create jobs. Its impact will grow over time as will the interaction between robots and people.

In Kenya, firms have struggled to attain competitive cutting edge over multinational firms operating in the local market (Kinyanjui S., et al., 2014). Use of industrial robots as a form of automation is a well know means to increase productivity and cut on costs, thus improving competitiveness. Currently, competition is based on better quality products, faster and cheaper production (Nyori & Ogola, 2015) and manufacturing companies in Kenya cannot afford to do otherwise, else they will not be locally and globally competitive. Considering the increasing global competition, competitive manufacturing capability is a critical and urgent matter in manufacturing firms. Industrial robots in manufacturing firms are often regarded as highly efficient, potentially improving the competitiveness of manufacturing companies. However, they often increase the complexity in structures and control systems, resulting in inflexible monolithic production systems (Zuehlke, 2010). It is thus important to ensure that the choices made for automation to be appropriate for use.

A review of an existing literature shows that there is limited knowledge and research on the use of industrial robots in developing economies such as Kenya. Such developing economies, with proper guidance, can be made to appreciate the advantages of robotics in industrialization and adopt the use of programmable robots in their manufacturing pipelines and other areas such as in agriculture and construction. Therefore, to understand the fundamentals of robotic science and also finding solutions for the problems that prevent the wider use of robots in industries, industrial robotics should be studied with special attention.

1.2. PROBLEM STATEMENT

Although Kenya's manufacturing enjoyed relatively rapid growth in early post-independence years, it has generally been sluggish without dramatic shifts in performance. However, a change came when in the mid-1980s the government eventually recognized the need to shift focus towards export promotion. But, immediate efforts to encourage exports were overshadowed by macro-economic challenges and externally driven SAPs that were implemented half-heartedly and opportunistically. (Corporate Author (UNI-WINDER), 2016).

In order for Kenya to start an upward recovery trend in industrialization, it is important for existing manufacturing companies to consider adoption of industrial robots to help in production and/or assembly processes. As seen from more developed economies, without industrialization, economic growth can be a challenge. The benefits of economic growth are numerous and extend far beyond solving the primitive food, shelter or even job security issues Kenya is facing now.

Facilitating the design procedure of robots can increase their popularity in industries. The process of designing a robot is mainly comprised of geometry generation, kinematic analysis and optimization. During the design process, tools from different engineering domains are required and the output results of each tool act as the inputs of the next one. For example, after determining the final geometry of the robot in the geometry modeling tool, the geometry properties such as mass and moments of inertia are required in the tool which is performing the dynamic simulation. Also, it is important that the operations inside any of the tools be fully automated so that the tool can be integrated with other tools in a holistic design framework.

The issue of minimizing the mass while the maximum stress is not allowed to exceed a certain value can be considered as an optimization problem. In this problem, the objective is minimization of weight and cost, and maximization of the robot performance, and the constraint would be the maximum stress in the robot structure.

1.3. GOALS AND OBJECTIVES

The goal of this project is to design a simple procedure for Kenobi (robotic arm) to enable it pick an object, move it and place it in another location.

With more research and development on the same, more sophisticated procedures will be built on top of the simple procedure above. Allowing similar robotic arms to be easily programmable and dynamic (collaborative robots).

1.3.1. RESEARCH OBJECTIVES

- Research on Servos motors:
    - Servos continuous motors
    - Servos regular motors
- Research on microcontrollers:
    - Arduino Uno R3
    - Pulse Wave Modulation
- Research on suitable structural dimensioning, length of links and types of joints of robotic arms.
- Research on how to conduct Finite Element Analysis (FEA) on links in order to find the stress distribution in the arm for different loading scenarios.
- Research on how to performing an FEA in the robot design process to obtaining the optimum link dimensions.

1.3.2. SYSTEM DEVELOPMENT OBJECTIVES

- Develop & design the procedure that will be used by Kenobi to:
    - Pick an object.
    - Move an object
    - Place it in another location.
- Test developed procedures

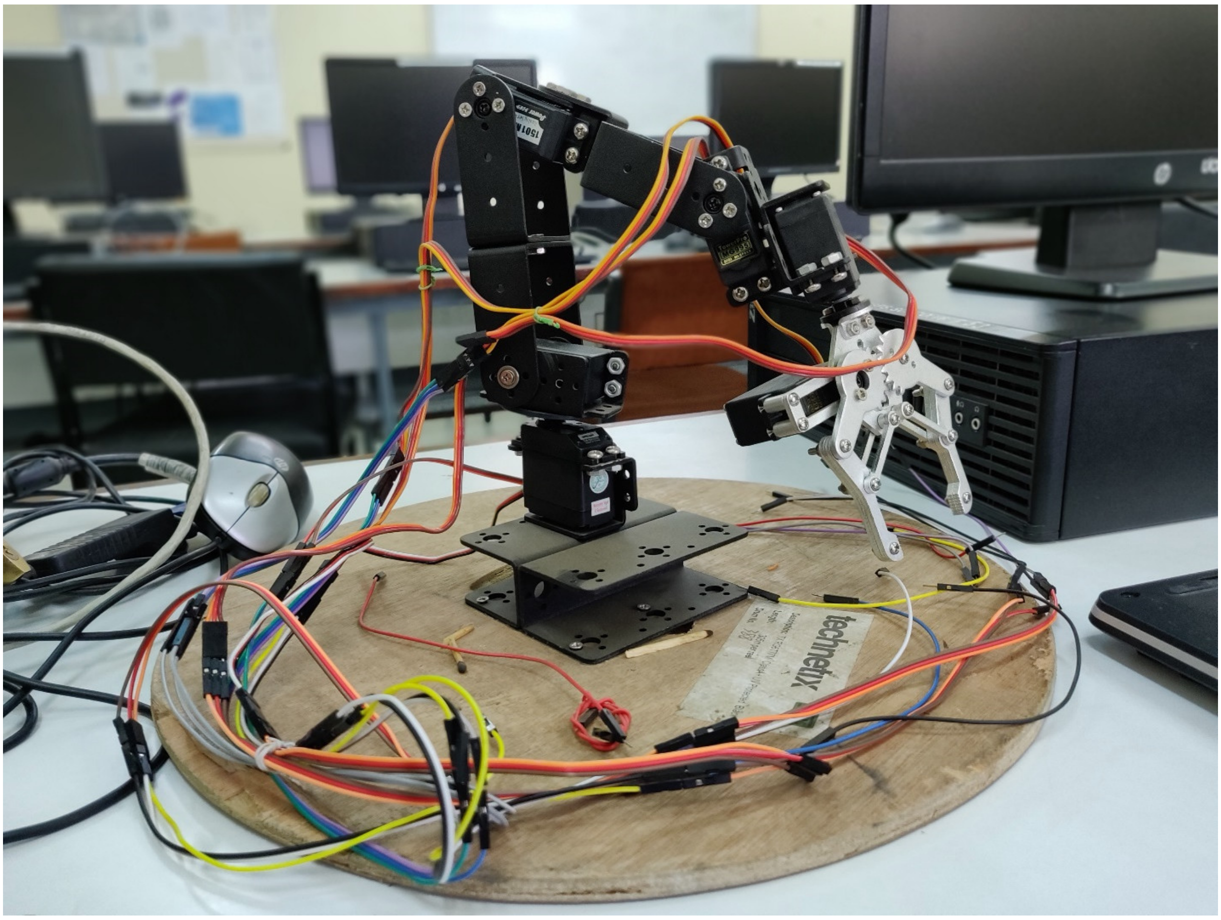


Figure 1: Kenobi (Robotic Arm)

1.4. PROJECT SCOPE

The project will cover development & design a procedure that will be used by Kenobi to pick an object, move it and place it in another location.

1.5. PROJECT JUSTIFICATION

It is evident from the previous discussions that one of the factors an economy requires to grow is industrialization. Industrialization is brought about by setting up manufacturing and processing plants that produce competitive products that can be sold in a global market. These products not only have to be of good quality, but also relatively cheap. Therefore, the manufacturing companies in play need to find suitable ways of achieving high volumes of quality products. Considering economies of scale, robotics can play a vital role in helping both large manufacturing companies and SEM businesses achieve this.

Why use industrial/collaborative robots? (Smith, 2017)

- Mass adoption may attract skilled labor to fields such as agriculture, manufacturing, construction and various informal sectors (Corporate Author (Kenya Engineer), 2014).
- Much faster and more accurate than a human, even with high payload.
- Fully automated production lines can handle applications that are not conducive to humans, removing operators from unsafe or unclean environments.
- Can be programmed. Programming is intuitive and powerful and can allow extensive integration options.
- Can be implemented in collaborative applications with appropriate risk assessment.
- Returns on investment is defined and usually between 12 to 18 months.
- Suitable for short low volume processes that are repetitive and require many iterations (using cobots)

An article from the International Journal of Innovations, Business and Management journal shows a study conducted on fifty listed companies in Kenya and had the findings below:

Statements on Industrial Robots	**Mean**	**Std. Deviation**
There is a great extent use of artificial intelligence in your firm operation	1.8415	1.01190
There is a great extent use of industrial robots in your firm operation	2.2805	1.17877
There is a great extent use of Tele-operated robots	1.6341	0.82420
There is a great extent use of cognitive robots	1.6463	0.90774
There is a great extent use of hybrid forms of tele-operated and programmed robots	1.4444	0.86603

Table 1: Influence of Industrial Robots on Firm Competitiveness

The regression results established a negative and insignificant relationship between competitiveness of listed manufacturing firms and Industrial Robots as shown by $\beta = -0.170$ and $p = 0.098 > 0.05$. The insignificant relationship between industrial robots and competitiveness of listed manufacturing firms may be as a result of low application of industrial robots. According to the article, the CEOs of manufacturing firms and industrialization directorates were also asked on the extent of use of robots in the manufacturing firms; and some indicated that robots were not available in their firms while others revealed that they had not experienced robots in their firms' operations. These results show limited application and use of industrial robots in Kenyan manufacturing firms. Additionally, the article also stated that the respondents further indicated that use of industrial robots enhanced competitiveness of manufacturing firm (Magachi, et al., 2017).

CHAPTER 2: LITERATURE REVIEW

2.1. INDUSTRIAL ROBOTS

Industrial robots are considered as the principal of productive, high quality and low-cost manufacturing. Newly emerging manufacturing processes such as laser-based processes and precision assembly increasingly depend on robot technology. A robot should meet the requirements in the widest possible range of potential applications when it is going to be produced in large quantities. Since this is hardly practical, different classes of robot designs with respect to number of degrees of freedom (DOF), workspace volume, and payload capacity have emerged for separate applications such as welding, painting, assembly and so forth (Buccella, 2017).

Nowadays, industrial robots are mainly designed according to the requirements in large volume manufacturing operations such as automotive and electronics industries. Some typical applications of industrial robots are as follows:

2.1.1. WELDING

Welding is one of the most important joining manufacturing processes. As small imperfections would lead to serious damages, manual welding requires highly skilled workers. Robots are ideal for welding process because of specifications such as: high repeatability and accuracy and high speed. Figure 2 shows the welding station in the production line of an automobile manufacturing company.

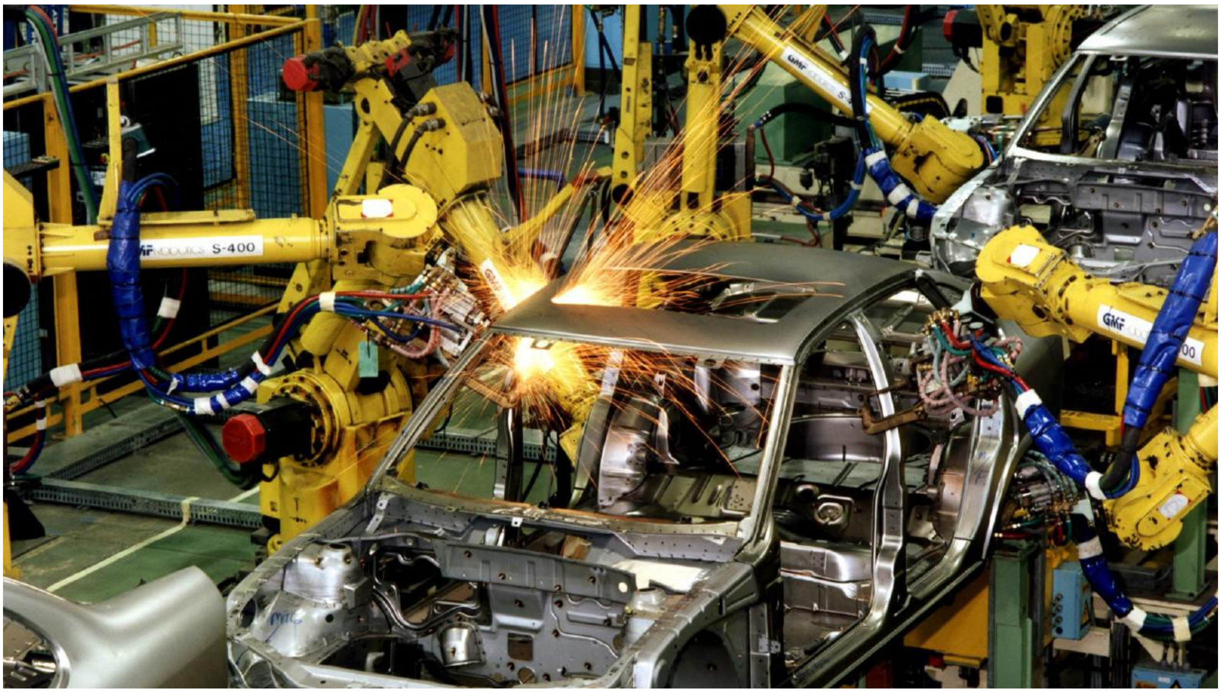


Figure 2: Robots welding a car's chassis

2.1.2. CAR BODY ASSEMBLY

The benefits of robot application in car body assembly became apparent very early in the robot history. Robots are useful in handling and positioning of metal sheets, car components, body frames and everything which is hazardous or physically difficult for workers. Figure 3 shows robots which are assembling the body a car in a car assembly line.

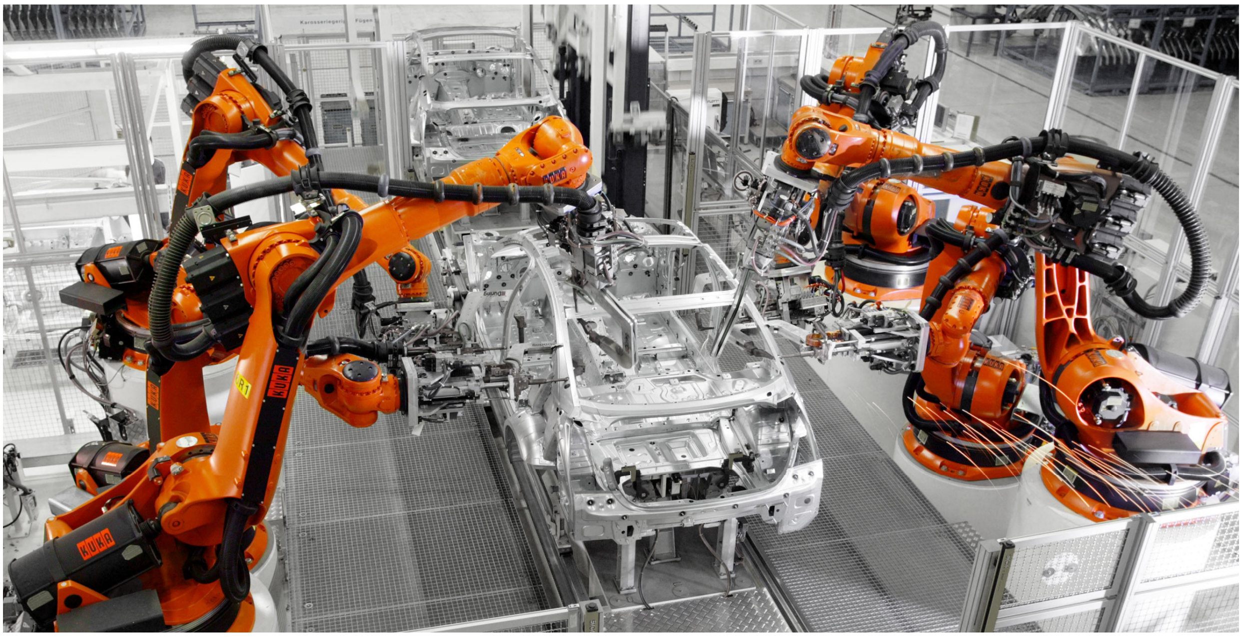


Figure 3: Assembly robots

2.1.3. PAINTING

Painting environments are usually hazardous and harmful for humans. In 1969, a Norwegian company developed the first spray painting robots for automotive industry (Corporate Author, 1995). Hollow wrists are used in painting robots to embody the gas and paint hoses and also increase the agility of the robot. Painting robots, Figure 4, mimic the movements of the painting workers around the object.

Figure 4: Paint robot

2.1.4. HUMAN-ROBOT INTERACTION FOR HANDLING TASKS

An example of this application is in car drive train assembly, Figure 5, where the robot grasps the heavy gear box and balances it softly so that the worker can accurately insert it into the housing. Obviously, the human robot cooperation must follow certain safety standards as the human's and robot's workspace overlap. ISO 10218-1:2006 standards specify the requirements for safe and protective environments.

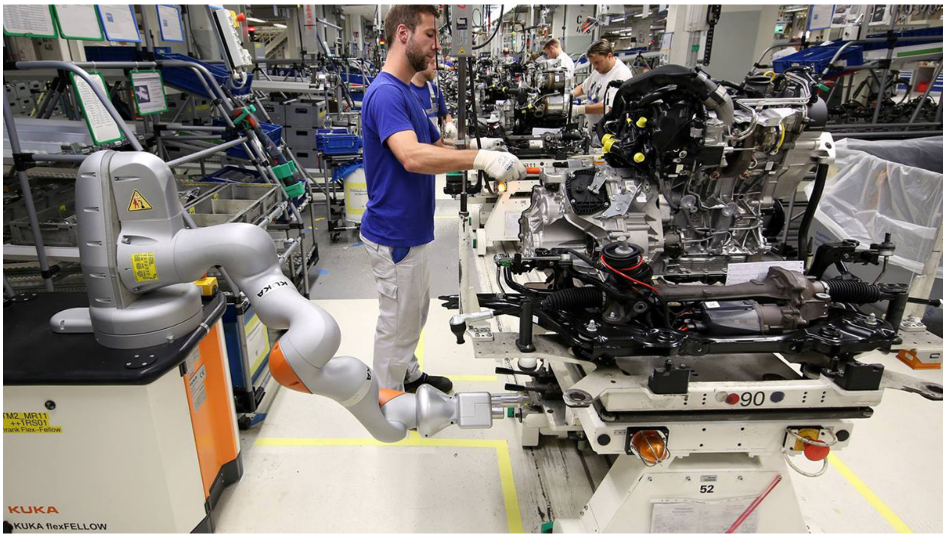


Figure 5: Human-Robot interaction

In addition to the wide range of applicability of industrial robots in automotive industries, they are also successfully utilized in other applications such as metal and chemical productions, electronics and food industry. Recently, the robots are also utilized in nonindustrial applications such as agriculture, cleaning, underwater and space explorations and medical applications. Some nonindustrial applications include:

2.1.5. FIELD INSPECTION ROBOT

A field inspection robot does the laborious monitoring tasks that human researchers used to do, a time-sucking process that made a lot of projects impossible to approve. It travels up and down the plantation rows, taking micro-scale pictures and further readings with instruments like a “stem penetrometer,” which is used to stab and test the health of stems. Advanced computer vision algorithms then interpret the images, gauging both the overall level of growth in the field and the specific impact of different crosses, as seen in the number, size, and even growth angle of a particular plant’s set of leaves.

Figure 6: Field inspection robot

2.2. COLLABORATIVE ROBOTS (Emerson, 2019)

Robotics occupies an odd place in contemporary popular culture, as this technology is regarded with a curious mixture of eager anticipation and narrow-eyed dread. We all expect robots, and automation technology in general, to assume increasing importance in our society—but what is the endgame of all this advancement? The advent of collaborative robots –"cobots" – may serve as an indication that future developments in robotic technology will be a net benefit to our society.

As the name implies, collaborative robots are designed to operate in cooperation with another agent—a human being. This sets cobots apart from traditional robots that function autonomously.

Cobots are not associated with a particular design; one common type, though hardly the only variety, is an articulated arm attached to a base. Cobots do, however, tend to share certain characteristics. Because they are intended to complement human activity, these machines are engineered for safety. Therefore, they typically cannot generate enough torque to cause injury if they come into contact with human personnel, or they are equipped with force-limiting features that enable them to shut down instantly if they encounter a foreign object.

They often have motion-detection sensors that stop their activities if any contact is made. Therefore, these robots can literally work side by side with people without posing a significant health hazard or requiring the use of safety cages. They also tend to be lightweight and mobile, which means that they can be easily shifted to another area of a facility when necessary.

Some specific sectors of industry where cobots are currently in use include:

2.2.1. MANUFACTURING

Cobots have already made inroads on the assembly line, performing a variety of simple tasks with minimal human intervention. These machines can be used, for instance, for quality control purposes, such as detecting the presence of defective or non-standard products and removing them from the line. They can also test circuit boards, load pallets, apply paint, and affix or tighten small objects.

Cobots are able to manage simple tasks that might cause repetitive stress injuries in human personnel, and they can operate well in temperatures that would be uncomfortable or intolerable to people. They can manipulate materials that may be unsafe for human handling.

Bear in mind, however, that a single cobot is unlikely to perform all of these functions; the foregoing is just a sample of the range that this technology has to offer. Cobots can't do everything—as we have pointed out, their job is to help human beings do their jobs.

2.2.2. HEALTHCARE

The notion of collaborative robots in the healthcare sector makes a lot of sense when you consider that this field is all about collaboration—people getting the medical assistance they need from individuals specifically qualified for this purpose. Cobots can be used to help with simple maintenance and upkeep tasks, like setting up or putting away beds, in order to take some of the burden off busy nursing aides.

Figure 7: Cobot used in health

They can even assist in therapy sessions with developmentally-disabled children, who can benefit from simple interactions with these portable machines, which provide a measure of the stimulation and companionship that small domestic animals can.

Figure 8: Cobot helping children with autism learn

Cobots provide invaluable help in the operating room as well. Machines of this nature aren't susceptible to muscle fatigue or involuntary tremors, so they're well suited to surgeries that demand enormous precision. When guided by an experienced physician, cobots can execute virtually error-free procedures.

Cobots also work wonders in biomedical applications that demand sterile environments—for instance, the preparation of vaccines. It goes without saying that biomedical materials of this nature must be handled with enormous care. Accidental contamination requires only a moment's inattention.

That's why these materials are often handled in cleanrooms—controlled areas where contaminants are strictly regulated. These areas can be compromised very easily, which is why human personnel typically must pass through a shower room prior to entering them, and must be barred from the area altogether if they display any signs of sickness. Cobots are much less likely to contaminate these environments, which makes them ideal for use in these kinds of applications.

2.2.3. LAW ENFORCEMENT

Collaborative robots in the law enforcement field provide an especially vivid example of the usefulness of this technology. We're talking about bomb disposal. You may have already seen this procedure dramatized in a movie: A tiny mobile robot under remote control guidance ventures into a building, locates an active bomb, and then attempts to remove it from the immediate area.

Cobots can also be utilized to obtain video or photographic evidence from environments that are judged to be too perilous for human personnel. Occasionally they're used to help negotiations during hostage situations by opening a line of communication between the parties involved.

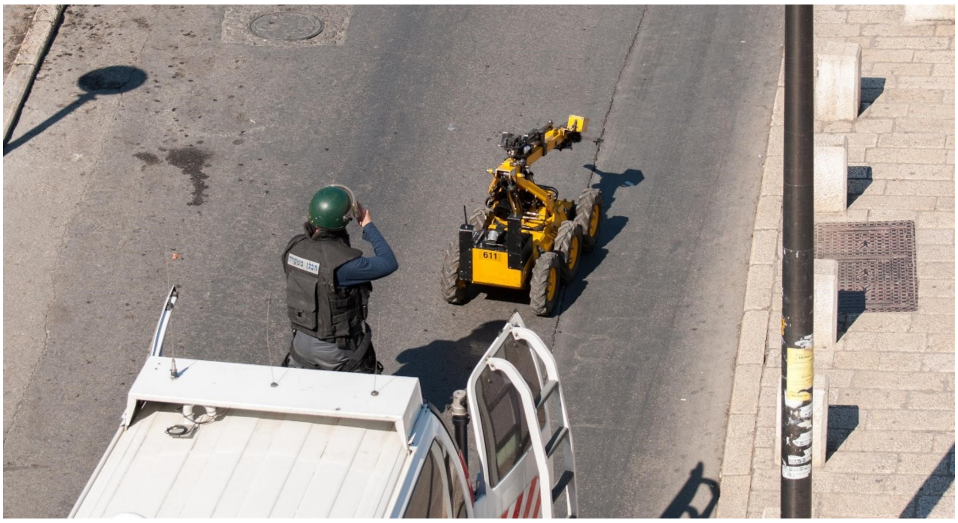


Figure 9: Cobots in law enforcement

2.2.4. CONSTRUCTION

The construction field can be harsh on human bodies. Workers are routinely subject to a number of dangers, from heavy mobile objects to simple wear and tear from repetitive tasks. Fortunately, cobots have already shown that they can take over some of the busywork involved with construction tasks. For instance, cobot welders are in use in some facilities, where they are called upon for welding tasks that require precision accuracy, like preparing support beams for new buildings.

Additional applications for which cobots are used include laying bricks and pouring cement—tasks that human beings tend to find tedious at best and hazardous at worst. In the construction industry, cobots reduce expenses, speed up assembly processes, and lower the risk of personal injury.

2.2.5. AGRICULTURE

For anyone who is involved with the agricultural industry, the business of harvesting crops occupies a lot of time and energy, whether you're talking about physically picking them from the field or providing some type of support service for this task. Robotic technology can save an enormous amount of resources by automating this process to a large extent.

What about delicate crops that require careful handling? How do you keep robots from damaging them? This is an issue that so far has limited the usefulness of robots in the agricultural sector but, in recent years, technology—particularly the force-limiting capabilities of cobots—has begun to crack this problem.

With cobots, fragile crops can be harvested at speeds that would be unthinkable in an agricultural operation that relies solely on human hands. This has the potential of substantially reducing the labor expenses involved in harvesting—savings that could be passed on to the consumer.

Figure 10: Cobot picking and examining produce

2.3. OVERVIEW OF ROBOT STRUCTURE

The mechanical structure or mechanism of the robot which is its moving skeleton is comprised of beams, links, castings, shafts, slides and bearings. Actuators are the components that cause the motion of links and can be motors, hydraulic or pneumatic pistons, or other elements. In the following section, various mechanism and actuator designs that transform the computer signals into different physical movements would be presented (Reddy, 2016).

Under the assumption that the robot would find a larger market if they have general motion capabilities, the early robots were designed to perform a wide variety of tasks. But this proved to be expensive, both cost and performance wise. Therefore, robots are now designed for specific set of tasks. The focus in the design process is on the number of joints, size and payload capacity and the size and configuration of the robot skeleton is determined by the task requirements such as reach, workspace and reorientation ability. Choice of geometry, material, sensors and cables routing, depends on topology of the robot structure and the actuator system which depends on the required level of robot flexibility in performing intended tasks (Reddy, 2016).

Generally, a robot is characterized by its work envelope and load capacity.

2.3.1. WORK ENVELOPE

The work envelope encloses the robot workspace and is the space where the robot can operate in. The workspace defines the positions and orientations that a robot can achieve to perform a task and also includes the volume of the space that the robot occupies as it moves. Envelop is defined by the joint type and length and movement range of the links which are connected with the joint. A primary consideration in the design of robot structures is the physical size of the work envelope and robot loads within this envelop. Figure 7 illustrates the working envelope of the robot.

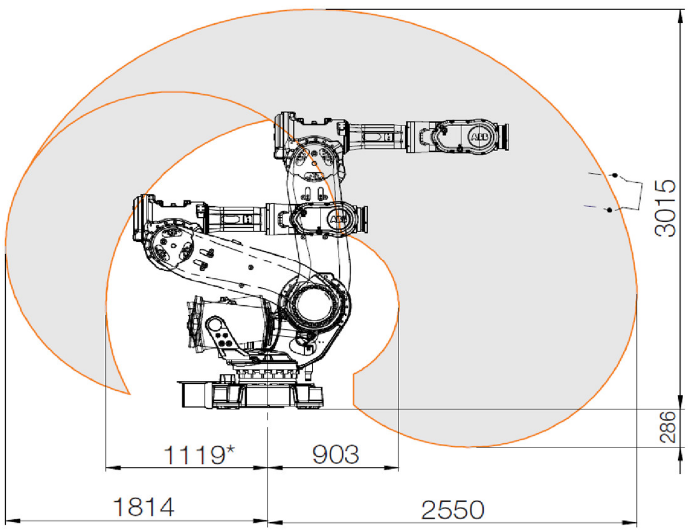


Figure 11: Kenobi's work envelope

2.3.2. KINEMATIC SKELETON

The shape and size of manipulators are selected based on the requirements in the workspace, precision of movement, speed and manufacturing issues. The simplest transform and control equations belong to Cartesian manipulators. Due to the existence of a prismatic joint in Cartesian manipulators, motion planning and computation is relatively straightforward. On the other hand, the manipulators using revolute joints are harder to control but for a given working volume, their structure is more compact and also more efficient. Specific kinematic, structural or performance requirements are important in the choice of the manipulators e.g. for a very accurate vertical straight motion a simple prismatic vertical axis would be more favorable than two or three revolute joints requiring coordinated control.

To have access to any arbitrary location in the workspace and place the end effector or the tool of the manipulator at that location, six degrees of freedom (DOF) are the minimum required. In case of simple or predefined tasks, since certain axis motions can be eliminated fewer DOFs can be used.

In Some application such as cases where mobility or obstacle avoidance is necessary, more than six DOFs are required. In general, increasing the DOF would increase the cycle time and decrease the load capacity and accuracy of the robot for a given manipulator and drive system.

2.4. KINEMATICS AND KINETICS

The properties of the robot can be categorized into:

- The properties depending on the geometry of the mechanical structure - kinematics.
- The properties depending on the forces acting on the system - kinetics.

According to the principle of virtual work, the difference between the work performed by the forces acting on the robot, and the change in the energy of the moving robot does not vary in small increments of robot's trajectory. In other words, according to (Greenwood, 1977) and (Moon, 1998) the variations in work and energy must be the same in all virtual displacements. Although there are often losses due to friction and material strain, it can be assumed that the change in the energy level is small since the robots are designed to minimize the energy losses. This implies that the work input of the actuators is nearly equal to the work output.

Considering this relation over a small period of time, the time rate of input work or power is almost equal to the output power. Therefore:

$$P = F \times V \quad \& \quad P_{in} = P_{out} \Rightarrow \frac{F_{in}}{F_{out}} = \frac{V_{out}}{V_{in}}$$

2.3.1 ROBOT TOPOLOGY

A series of links connected through joints forming a serial chain, determine the skeleton of a robot. The robot skeleton has mainly two types:

- Serial: A single serial chain, Figure 8.
- Parallel: A set of serial chains supporting a single end effector, Figure 9.

The end effector is the part interacting with the environment and the robot skeleton defines its position and orientation. As mentioned before, six DOFs corresponding to six joints in the structure provide full control over the end effector. In parallel robots there are more than six joints and actuators are applied to these joints in various ways to control the movement of the end effector.

Serial robots can be configured in way that they act as a single parallel robot e.g. hands of a human robot Figure 12.

Figure 12: Serial robot

Figure 13: Parallel robot

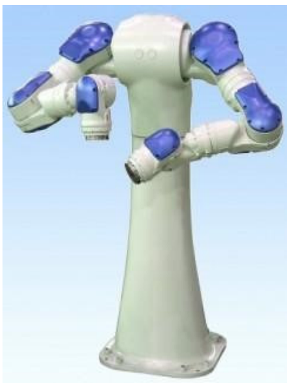


Figure 14: Serial robots working in parallel as hands

2.3.2 SERIAL ROBOTS

Serial robots are the most common industrial robots. A serial robot is constructed by a series of links and joints which connect the base of the structure to the end effector. Separate translations and orientations of structure are usually achieved by the links and joints of the robot. Normally, the first three links are utilized to position a reference point (wrist center) in space and the last three form the wrist which orients the end effector around the wrist center, forming a six DOF robot. However, the most popular activity of the serial robots in industries is pick and place tasks and only four DOFs is required for such operations. Thus, Selective Compliant Articulated Robot Arm (SCARA) robots with four DOFs are manufactured for this purpose, Figure 15.

Figure 15: SCARA robot.

Reachable workspace of a robot is defined as the space volume in which the wrist center is placed. Normally, the robots are designed in a way that the workspace is symmetric.

The main advantage of serial robots is their large workspace compared to the robot volume. On the other hand, low stiffness, accumulated and amplified errors from link to link and carrying the weight of most of the actuators which limits the speed and performance can be mentioned as their main disadvantageous.

2.3.3 PARALLEL ROBOTS

In a parallel robot, two or more serial robots support an end effector. Each of the supporting chains can have up to 6 DOFs; however, generally only six joints are actuated in the entire system at a time. It should be noted that however the serial chains act together, it is not implied that they are aligned as parallel lines and the word parallel is used only in a topological sense (not geometrical).

In parallel robots, the serial chains are usually shorter than serial robots thus making the robot structure more rigid against unwanted disturbances. Another advantageous of the parallel robots is that heavy actuators can be mounted on a single base platform therefore reducing the weight of moving arms and increasing the speed. Also, centralization of mass decreases the robot's moment of inertia which is an advantage for mobile applications such as walking robots.

The workspace of a parallel robot is the intersection of workspaces of its supporting serial chains. The workspace is usually larger in the vicinity of the center of reachable workspace and shrinks as the reference point moves toward the edges.

Parallel robots are mainly utilized in applications such as flight and automobile simulators. Stewart platform and Delta robot shown in Figure 16 and Figure 17 are examples of popular parallel robots.

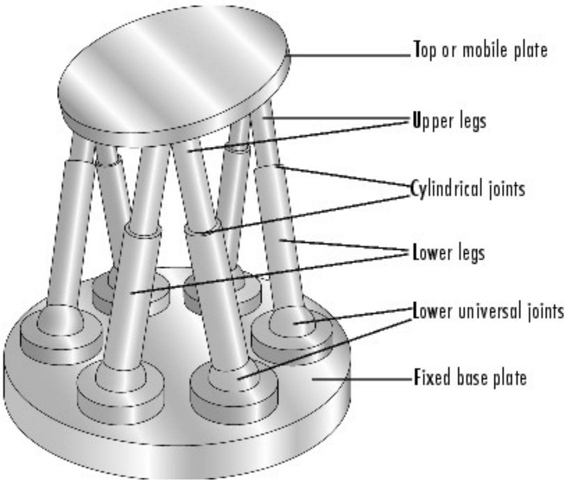


Figure 16: Stewart platform

Figure 17: Delta robot

2.5. SIMILAR SYSTEMS AND RESEARCH WORK ON ROBOTICS IN KENYA AND THE REST OF THE WORLD

2.5.1. FARMING ROBOT (Abuga, 2015)

An engineering finalist at Egerton University designed a farming robot which helps farmers in sorting their produce based on weight, color and size.

Anthony Maina is advocating for the use of machine such as robots in farms saying they improve on efficiency by reducing on the cost of labor. The robot that Maina developed is fitted with a camera that is able to sense the color of a product and place it in the right space. Through computer programs the robot is also able to detect the weight of the same products and sort them.

Maina says he was inspired to develop the robot after he saw the struggle that workers at a firm, he was attached in were going through.

“The workers were required to sort out chicken based on weight. After working for a few hours, most of them would get tired,”

he says of the workers at the firm based in Nyeri. This scenario he feels reduced their efficiency and consequently led to losses at the firm.

2.5.2. MILKING ROBOTS OF KOTUTS FARM (Corporate Author (SmartFarmerKenya), 2018)

Mr. Kirui, Kotuts farm veterinary doctor, says that the milking robots take about 2 hours to milk all the 159 dairy cows in the farm.

“We use the milking robot to manage the dairy section. This is a cow management system from Israel which uses electronic tags fastened around the cow’s neck and synchronized to a computer software system to collect data. The collar records lots of information about the cow and gives regular updates in the form of an email. Data such as heat periods, fertility, milk production, health, breeding, physical activity of the cow, feeding is captured and I use this information to analyze exactly what condition the cow is in. The milking robot has made many of the processes easy and we are able to manage our herd of 500 animals with a limited staff of about 10.” He said.

The system has a main door which is opened using a lever and the cows stream in positioning themselves in the compartmentalized milking pens. The side bars slide closed as each cow enters effectively locking it inside. “Our system is such that it needs to be aided by two workers. The first worker washes the teats with a disinfectant while the second wipes them dry. They both then begin attaching the four arms of the milking robot to each teat and the milking process begins,” adds Kirui. A small screen displays the name of the cow in red and accesses all data about the cow including how many liters of milk are expected.

The cow removes robot’s arms using her hind legs. However, should she do this before the required liters are collected, the system flashes a warning and the technician will come and re-attach them till the machine stops flashing indicating that it’s done with the particular cow.

All this takes a maximum of 7-8 minutes. “The robot milks 20 cows at a go and If a cow comes in twice It will not repeat the process. If the cow is recorded as being on antibiotics or having an ailment such as mastitis milking will not take place either, until a bucket specifically for contaminated milk is connected.” Said Kirui.

The robot can also milk three teats and leave a fourth if only one of the teats is infected. “To understand the data, I combine different factors from the robot. For example, low activity and low rumination (feeding) means the cow is sick and I will immediately inspect it and diagnose the problem.” Said the veterinary.

2.5.3. AXIS, NEW ENGLAND (Emerson, 2019)

Axis New England provides cobots that help workers—they do not replace human personnel. They do this by guiding and correcting human activities in the workplace, and/or by taking over simple functions so workers can occupy themselves with other tasks. Many cobots "learn" their tasks through hand-guiding technology, where a human operator literally leads them through a given process step by step, which the machine is then able to repeat under its own power.

Axis deals in manufacture and installation of collaborative robots in factories that require automation. They also offer complementary seminars where their automation experts showcase step-by-step guidelines through a real application where the attendance learn about:

i. Pick & place
ii. Stacking and palletizing
iii. Grippers, sensors and tooling
iv. Robotic vision
v. Path following
vi. Safety

Talks on how to program cobots are also given during these complementary seminars.

CHAPTER 3: METHODOLOGY

3.1. DATA COLLECTION

Data for this project will be obtained primarily from online sources that publish and document credible specifications of Servos Motors. Majorly from Arduino Development Cookbook (Amariei, 2015) and ezrobot (Sures, 2017). Additional data may be obtained from specialists and authentic articles online.

3.2. SYSTEM DEVELOPMENT METHODOLOGY (Corporate Author (DSDM - WikiDot), 2011)

The Dynamic Systems Development Method (DSDM) is an agile project delivery framework, primarily used as a software development method. It is a framework which embodies much of the current knowledge about project management. DSDM is rooted in the software development community, but the convergence of software development, process engineering and hence business development projects has changed the DSDM framework to become a general framework for complex problem-solving tasks. The DSDM framework can be implemented for agile and traditional development processes.

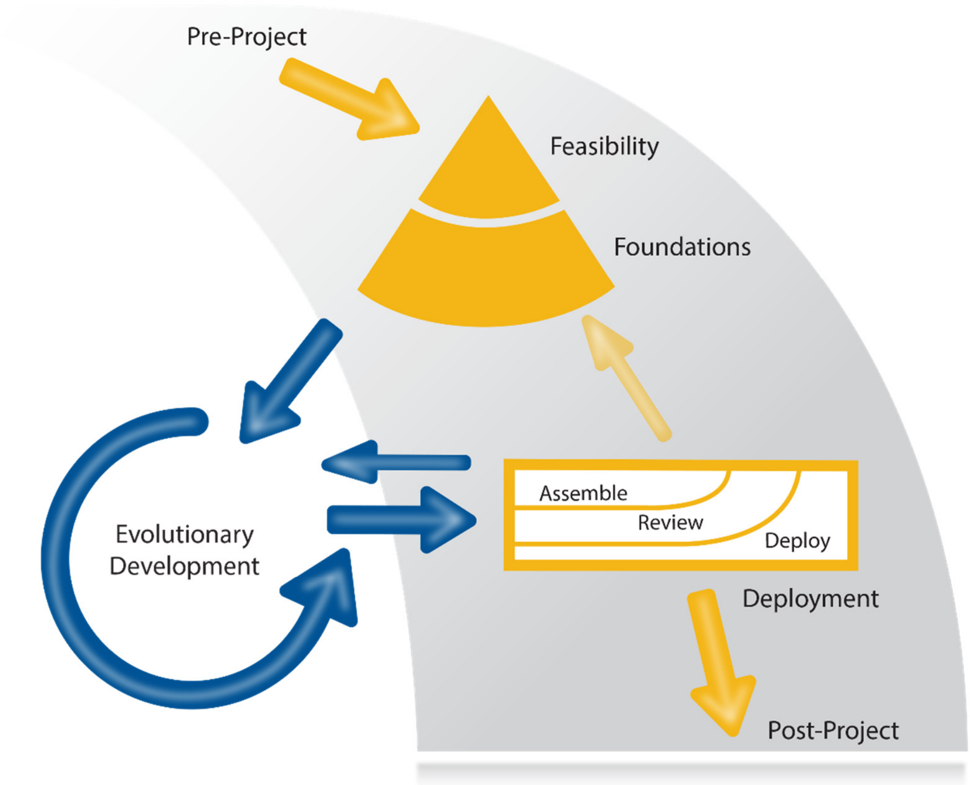


Figure 18: Dynamic Systems Development Method (DSDM)

3.2.1. WHY USE DSDM?

i. Results of development are directly and promptly visible
ii. Since the users are actively involved in the development of the system, they are more likely to embrace it and take it on.
iii. Basic functionality is delivered quickly, with more functionality being delivered at regular intervals.
iv. Eliminates bureaucracy and breaks down the communication barrier between interested parties.
v. Because of constant feedback from the users, the system being developed is more likely to meet the need it was commissioned for.
vi. Early indicators of whether project will work or not, rather than a nasty surprise halfway through the development
vii. System is delivered on time and on budget.
viii. Ability of the users to affect the project's direction.

3.2.2. CORE TECHNIQUES USED IN DSDM

3.2.2.1. TIMEBOXING

Traditional Project Management uses milestones where as DSDM uses timeboxing technique. Is an interval, usually no longer than 2,4 or 6 weeks, where a given set of tasks should be achieved.

A timebox:

i. Can contain several tasks.
ii. At the end need to deliver a product.
iii. Are subject to change since tasks are defined, not what to be delivered.
iv. Can change the tasks during time box iteration which allows for rapid response to business needs.

DSDM drops functionality in flavor of delivering in time.

3.2.2.2. MOSCOWRULES

DSDM projects are concerned to be in time and on budget and users are heavily involved in the development process. So, it is mandatory to keep on watch on what users need the most.

User requirements may change (during the process);

i. Aware of new technical possibilities
ii. User work environment changes

The DSDM techniques to weight the importance of requirements are the MosCow rules. And the rules are as follows,

1. Must have: All features classified in this group must be implemented and if they are not delivered, the system would simply not work

2. Should have: Features of this priority is important to the system but can be omitted if time constraints endanger.
3. Could have: These features enhance the system with functional items which can easily be reassigned to a later timebox.
4. Want to have: These features only serve a limited group of users and are of little value.

3.2.2.3 PROTOTYPING

Evolutionary prototyping in DSDM projects satisfy 2 principles,

i. Frequent Delivery
ii. Incremental development

Implements critical functionality first so can discover difficulties early in the development process and allow having early deliverable to get user feedback.

The necessary feedback-loop is provided by a workshop which is the last important technique in a DSDM project.

1. DSDM differentiates on the following for types of prototypes,
2. Business Prototype: Allow assessment of the evolving system
3. Usability Prototype: Check the user interface
4. Performance Prototype: Ensure solution will deliver performance or handle volume
5. Capability Prototype: Evaluate possible options

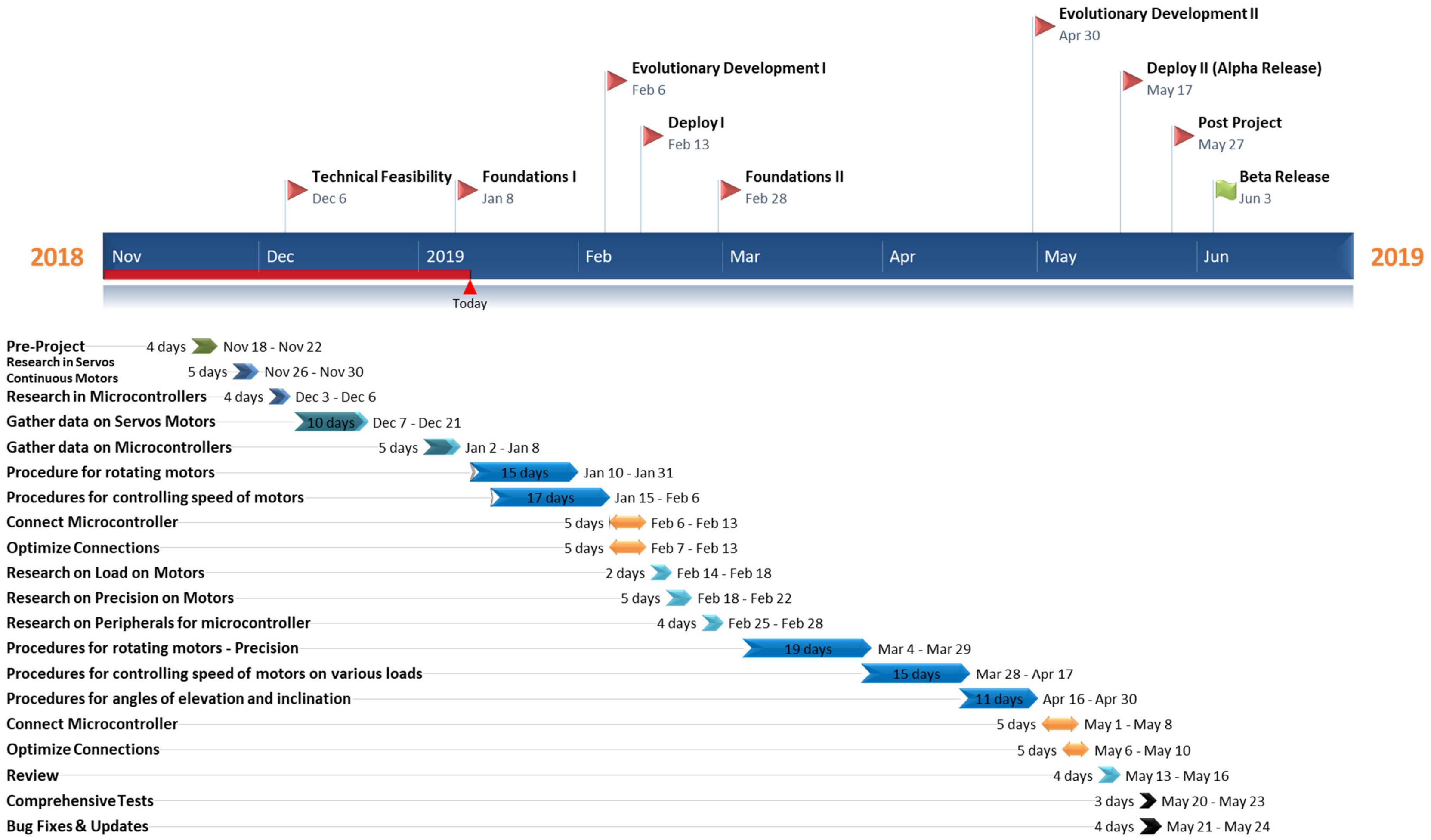
CHAPTER 4: PROJECT PLAN AND MANAGEMENT

4.1. PROJECT ACTIVITY PLAN

Title	Start date	End date	Duration (days)	% Completed
Pre-Project	2018-11-18	2018-11-22	4	100
Research in Servos Continuous Motors	2018-11-26	2018-11-30	5	73
Research in Microcontrollers	2018-12-03	2018-12-06	4	80
Technical Feasibility	2018-12-06	2018-12-06		100
Gather data on Servos Motors	2018-12-07	2018-12-21	10	95
Gather data on Microcontrollers	2019-01-02	2019-01-08	5	80
Foundations I	2019-01-08	2019-01-08		100
Procedure for rotating motors	2019-01-10	2019-01-31	15	5
Procedures for controlling speed of motors	2019-01-15	2019-02-06	17	2
Evolutionary Development I	2019-02-06	2019-02-06		0
Connect Microcontroller	2019-02-06	2019-02-13	5	1
Optimize Connections	2019-02-07	2019-02-13	5	0
Deploy I	2019-02-13	2019-02-13		0
Research on Load on Motors	2019-02-14	2019-02-18	2	0
Research on Precision on Motors	2019-02-18	2019-02-22	5	0
Research on Peripherals for microcontroller	2019-02-25	2019-02-28	4	0
Foundations II	2019-02-28	2019-02-28		0
Procedures for rotating motors - Precision	2019-03-04	2019-03-29	19	0
Procedures for controlling speed of motors on various loads	2019-03-28	2019-04-17	15	0
Procedures for angles of elevation and inclination	2019-04-16	2019-04-30	11	0
Evolutionary Development II	2019-04-30	2019-04-30		0
Connect Microcontroller	2019-05-01	2019-05-08	5	0

Optimize Connections	2019-05-06	2019-05-10	5	0
Review	2019-05-13	2019-05-16	4	0
Deploy II (Alpha Release)	2019-05-17	2019-05-17		0
Comprehensive Tests	2019-05-20	2019-05-23	3	0
Bug Fixes & Updates	2019-05-21	2019-05-24	4	0
Post Project	2019-05-27	2019-05-27		0
Beta Release	2019-06-03	2019-06-03		0

4.2. PROJECT GANTT CHART



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