AUTONOMOUS WEED DETECTION & TREATMENT ROBOT

MECHANICAL ENGINEERING DEPARTMENT

PUNJAB ENGINEERING COLLEGE

CAPSTONE PROJECT

SUPERVISED BY:
DR. CHANDER KANT SUSHEEL

SUBMITTED BY:
GAUTAM SHARMA 15107059
AKUL MAHAJAN 15107040
SHIVAM SEHGAL 15107064
MAYANK KAURA 15107055

I. Declaration

We, (Gautam Sharma, Akul Mahajan, Mayank Kaura, Shivam Sehgal), declare that this report titled, 'Autonomous weed removal robot' and the work presented in it are our own. We confirm that:

- This work was done wholly or mainly while in candidature for a degree at this University.
- Where any part of this report has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where we have consulted the published work of others, this is always clearly attributed.
- Where we have quoted from the work of others, the source is always given. With the exception of such quotations, this report entirely our own work.
- We have acknowledged all main sources of help.
- Where the reportis based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signed:

Gautam Sharma ______________________________

Akul Mahajan ______________________________

Shivam Sehgal ______________________________

Mayank Kaura ______________________________

Supervisor Incharge:

____

Dr. Chander Kant Susheel
Assistant Professor,
Mechanical Engineering Department
Date: 7th May'19

Contents

List of Figures

II. Abstract

In this work we demonstrate a deep learning strategy using ACF(aggregate channel feature) framework to identify plant species like weeds and develop novel mechanism to destroy the same. A real time intelligent robotic system was developed to identify and kill the weeds growing in close proximity with the plants. A framework that uses least computing power is developed. The advantages of deep learning over conventional image analysis and processing methods are discussed. A solenoid valve connected to a hot water sprayer is used kill the weeds. A few systems have been developed worldwide to destroy the weeds autonomously, but are either complex or extremely expensive to replicate or buy. This research paper aims to make a system that is relatively inexpensive but more robust than its predecessors. This work demonstrates how precision agriculture can be deployed with minimalist hardware expenditure.

III. Introduction

Last decade has seen a plethora of research work in the field of machine learning in agriculture. With the the food demand increasing day by day, farmers have to come up with ways to increase their yield. Normally, yield is proportional to the land being cultivated but the aim of this paper is to establish novel approach to increase the yield by detecting and destroying the weeds growing alongside the crops that compete with the plants for essential nutrients and in that process end up destroying or in most cases killing it. Weed is the number one impediment to high yield.

Weeds are ubiquitous to most crops. Most agricultural soils contain millions of weed seed per hectare, and if left unmanaged, weeds greatly reduce crop yields by competing with the crop for nutrients, light, and water. Unlike most other agricultural pests, weeds are present every year in every field and require some degree of management for optimum crop yields and profitability. Weeds comprise the first stage of plant succession following soil disturbance and removal of native vegetation. From the time man first started manipulating crop plants to grow in designated areas rather than gathering food from nature, controlling competing vegetation became a primary task. Planting crops in rows facilitated cultivation and weeding options. Row spacing was largely based on the width of the particular animal or machine that would be used to cultivate the crop.

Crop losses due to weeds vary by crop, weed species, location, and farming system (Bridges 1992; Swinton et al. 1994). Weeds can directly reduce crop yields, reduce crop quality, and increase harvest costs. Weeds not only compete for nutrients, light, and water but can also harbor pests (nematodes, insects, pathogens) of the crop reducing potential yields and quality further $(Boydstonetal.2008)$. Weeds can also reduce the value of the harvested crop such as lowering protein levels in grain and decreasing fruit or seed size. The presence of weeds in the harvested crop may also lower the value of the crop. Jointed goat grass (Aegilops cylindrica) in wheat (Triticum aestivum) seed, puncture vine (Tribulus terrestris) burs and nightshade (Solanum sp.) berries in green peas (Pisum sativum), nightshade stains on beans (Phaseolus vulgaris), and horseweed (Conyza canadensis) oil distilled with peppermint (Mentha piperita) oil are examples of weeds contaminating and lowering the value of the harvested crop. A Canadian survey of crop losses due to weeds in 58 commodities reported average annual losses of 984 million due to weeds (Swanton et al. 1993). Lentil (Lens culinaris) and cranberry (Oxycoccus sp.) crops had the greatest percent yield loss due to weeds , whereas the major crops of corn (Zea mays), soybean (Glycine max), hay, wheat, potato(Solanum tuberosum), canola (Brassica napus), and barley (Hordeum vulgare) had the greatest monetary value losses.

Most fields are infested with multiple weed species which interact resulting in a combined effect on the crop. Crops vary in their ability to compete and tolerate weeds. Soybean yield was reduced more by weeds than corn yields in previous stud- ies (Swinton et al. 1994). Onions (Allium cepa) lack a competitive crop canopy to shade weeds and are susceptible to nearly total crop loss due to uncontrolled weeds ($Williamsetal.$2007).

IV. Literature review

A lot of research has been done in finding the most novel method to remove weeds. $VanderWeide$[1] Found various methods of mechanical weeding such as torsion weeder, finger weeders and pneumatic weeder. It discusses various technical limitations and challenges to mechanical weeding like its efficiency. Other novel algorithms in computer vision were discussed in [2]. Featured are extracted and interpolated and a classifier is trained. It is one step ahead from normal image segmentation methods for image analysis. It introduces manipulative algorithms that achieve an accuracy of 91.4%.

$FritsKandSamsom$[3] discusses a robot made to detect and destroy grassland weeds. For image detection it uses $FastFourierTransform$ followed by applying threshold to each image. The robot consists of a GPS, camera and a hydraulic motor for the weeder. The wheels of the robot consists of rotary encoders controlled by PID control law. Every sensor is connected to a central PC. It detects 93% of weeds and 70% of the weeds were destroyed. Deepa[4] discusses an image segmentation algorithm for edge detection. MATLAB is used to process the image by segmenting the colors from one another. The weeds are differentiated by the crops by comparing the frequency of occurrence of edges. $SuHninandKhaing$[5] makes use of area thresholding methods to segment weeds from the crops. It uses the following algorithm to differentiate .

$WonSukandSlaughter$[6] talks about robotic weed control for tomatoes. It first binarises the image and then extracts features like area, major axis, centroid, elongation, curvature etc. The image processing algorithm takes a total of 0.344 seconds to identify 10 tomatoes using only features of elongation and compactness. To save time the algorithm only checked the center and the four corner points of each spray cell.
$I = weed, area < T$
$I = crop, area > T$
In this method the darker images caused a lot of problems. Also the system failed miserably when the weeds and the crops overlapped.

V. Pest problem

In both early and modern agriculture, weeds clearly rank as the primary pest problem. Today, weeds plague even the most advanced and progressive farming operations regardless of their management approach, whether organic, conventional, or sustainable. Holm and Johnson (2009) state that ?throughout the history of agri- culture, more time, energy and money have been devoted to weed control than to any other agricultural activity.? In the USA, the vast majority of crop acres are treated with herbicides $(GianessiandReigner2007)$ accounting for about two-thirds of the pesticide expenditures for US farmers in the late 1990s (Donaldson et al. 2002). Today, the development of herbicide-resistant weeds is the major concern for farmers relying on chemical weed control, while in organic production systems, the cost and effectiveness of hand removal of weeds is a concern due to expenses, labor availability, and, in large-scale systems, the social acceptability of employing large numbers of migrant labor. Farmers are increasingly facing environment and economic consequences of emerging weed management challenges, restrictions on the availability and effectiveness of chemicals, changing government policies, and dynamic markets that can reward or punish depending on how weeds are managed.

There is no immunity to weeds and the problems they cause, whether for a large farmer or a typical home gardener. Without continued and focused management and control efforts, a low or an apparent nonexistent weed population can very quickly get out of hand with direct (e.g., lower yields) and lasting (e.g., soil weed seed bank) effects. Because weed impacts are significant and have been passed on through countless generations, there is a continually evolving array of the types and numbers of different approaches for controlling weeds. In commercial cropping systems these options are vast and include the categories of mechanical, chemical, biological, and cultural control.

VI. Traditional practices in weed control

Prior to the development of herbicides, weeds were largely a management challenge that was addressed with planning and the use of high amounts of disturbance. Crop rotation was important, and whatever new ground was available was used once the old location had become too infested with weeds. The movement between and to new land parcels was, in itself, a type of rotation, although not what is typically practiced today. Early day cropping systems relied on routine disturbances to reduce weed pressure.

The use of cultivation was important for disrupting weed growth and could be applied in the simplest of forms. Unfortunately, early day cultivation could not be applied selectively, except in rows, and bare soil, which resulted in high amounts of erosion, was common in many fields. In the Midwest, the Dust Bowl of the early 1900s was caused by excessive tillage, as the prairie sod grasses were eliminated in favor of annual cropping systems. When $Lowdermilk(1939)$ wrote his report on the demise of ancient civilizations due to excessive erosion, the cultivation of weeds in irrigated cropping systems was identified as a likely culprit. As noted earlier, weeds are timeless, and as we have to relearn again and again, the various forms of disturbance used to manage weeds may have significant consequences that ripple across both time and space.

With the invention of 2,4-D in the 1940s, weed control changed dramatically. The agricultural chemical revolution (i.e., the substitution of inorganic fertilizers and manufactured chemicals to replace manure, humus, and various forms of pest control) following WWII gave growers the ability to selectively manage weeds in cropping systems with chemicals designed to kill on contact or through movement within the plant. Later, new herbicides were developed that provided total, selective, or partial control of weeds, which gave growers great flexibility in managing weeds in their crops. These innovations also brought about an important change in the indigenous knowledge associated with weed management. Prior to the introduction of these chemicals, growers had to accrue a system of knowledge on multiple dimensions of weed control: what to do, when and how to do it, and what observations are needed to guide decisions. The increased ease associated with dependence on chemical control also meant less knowledge was required for managing cropping systems. Knowledge of weed ecology became less important, and a grower could focus on other important management aspects, including fertility, marketing, or crop selection.

Currently, the most relied upon techniques for controlling weeds in conventional cropping systems are the use of cultivation and herbicides. The invention of herbicide- resistant (HR) crops has allowed for a quick application of a single herbicide sprayed over the entire field to control weeds without harming the crop. The simplicity of this system has actually led to the emergence of HR weeds. The use of a single herbicide that is applied repeatedly in one season at high rates on mature weeds is a recipe for resistance, which occurs when an individual plant or population responds to intense selection pressure. In addition, growing the same crop each year and using the same weed management program only exacerbates the problem. Add these incorrect management strategies together across large acreages and only time is needed for HR weeds to start appearing in grower fields, which they now have. Today HR weeds are a very significant problem, one that keeps increasing in size and scope, as we continue to fail in understanding that any new technology is a double-edged sword? there are many benefits, but mismanagement can lead to major problems.

In organic and some conventional cropping systems, the use of cultivation remains a heavily relied upon management tool for controlling weeds. The ability to systematically move through a field and physically disturb weeds has been one of the most relied upon control tools for centuries because there is no guess work and virtually all of the risk is eliminated. Large-scale operations use this tool because equipment manufacturers have created a wide range of implements appropriate for these operations. While the same range of equipment may not be available to small-scale growers, they have a greater capacity to respond to smaller or sudden changes than larger growers because they have an intimate relationship with their crops and fields. This type of knowledge or familiarity with the dynamics of weed ecology is extremely difficult at large scales, and since HR weeds are an increasing problem, scientists are looking to other forms of innovation to address this situation.

VII. Cost

All forms of modern-day weed control have costs associated with them. Some accrue to the grower, others to workers who may be exposed to chemicals, and still others to environment and society on the whole. Yet the lack of weed control diminishes yields and profits, thus resulting in an ongoing balance by growers to limit risk by falling somewhere between an insurance level and minimal level of control that will minimize the impact of weeds. In conventional systems, the exposure to chemicals by those who have to make the applications is a safety risk that is costly in terms of health and finances. Although some cases are suspect, there are links between health problems and the application of pesticides in crop production systems. In addition, the locations where chemicals are manufactured are ?no shining stars? of environmental excellence either, but the same could be said for fertilizer manufacturers and their various distribution points.

Not only are applicators and manufacturers vulnerable to the ramifications of handling toxic chemicals, but the environment itself suffers from any level of chemical application. Weeds suffer, which is desirable from a production stand- point, but it is debatable, often on a site-specific basis, as to whether yield benefits justify potential harm to humans and surrounding ecosystems. Non-HR crops suffer from misapplications and even HR crops have been debated as to whether they are completely suitable for the environment. Off-target movement (e.g., drift, runoff) of chemicals has numerous effects on animals, insects, birds, and fish, although all chemicals face rigorous testing mandated by EPA (in the USA) prior to commercial sales. Nevertheless, this testing does not prevent an off-label application made by mistake or in the wrong circumstance. The debate surrounding the accounting for benefits and costs is not new and has been with us with the emergence of each new form of weed management. While Rachel Carlson may have been a lone voice when she issued the warning associated with the use of chemicals in her book Silent Spring, today there are hundreds of books and reports on how we have allowed HR weeds to become a major agricultural issue $(Beckie2006; Beckieetal.2006; BeckieandTardif2012; Bhowmik2010)$.

In organic systems, similar costs to the environment can occur if an over-reliance on cultivation is used. The continued disturbance of the soil leads to excessive erosion by means of both wind and water. Since weed control can be more difficult in these systems, it could be argued that excessive weeds that are left uncontrolled are also polluting the environment. Probably, this is one of the main reasons why there are so few large-scale commercial organic farm operations. For those companies that are successfully producing organic crops, one of their biggest inputs is manual labor, a significant economic cost to the grower, and one that challenges the notion of a sustainable system due to these social dynamics.

The costs for weed control, other than to the environment and applicator, can range from minimal to financially devastating. In many countries, manual labor is used to control weeds because it is cheap and plentiful. Most often, in these situations, other challenges exist that relate to growing, processing, or delivery of crops to market. In locations where labor is not widely available, costs are reduced by using chemical weed control because it is relatively cheap and easy to use.

Increasingly, the environmental costs of weed control are being evaluated, not just by scientists but by the public, along with the financial costs that can escalate for companies and growers trying to expand their market in the organic area.

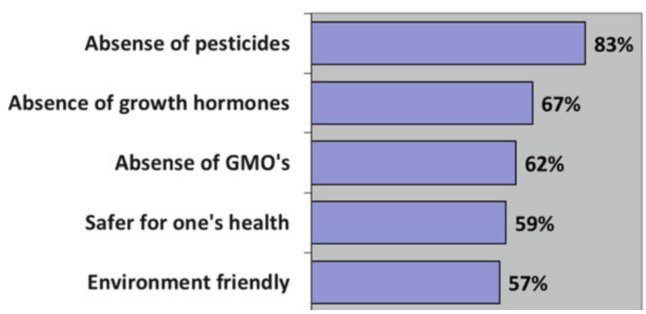

Figure 1: *A Top five US consumer properties associated with organic*

VIII. Herbicide resistant crops

Major acreage crops such as field corn, soybeans, wheat, and cotton drive most of the development of new herbicides as the high development, registration, and regulatory costs can be more readily recuperated with the large sales volume. More recently, seed companies have developed herbicide-resistant traits for many of the major acreage crops. Grower adoption of genetically modified crops with resistance to glyphosate has occurred rapidly in corn, soybeans, cotton, canola, sugar beets, and alfalfa (Medicago sativa). The broad spectrum of weed control, low cost, ease of use, and reduction in cultivation when using this technology has resulted in the most rapidly adopted technology in the history of agriculture ($Dilletal.$2008).

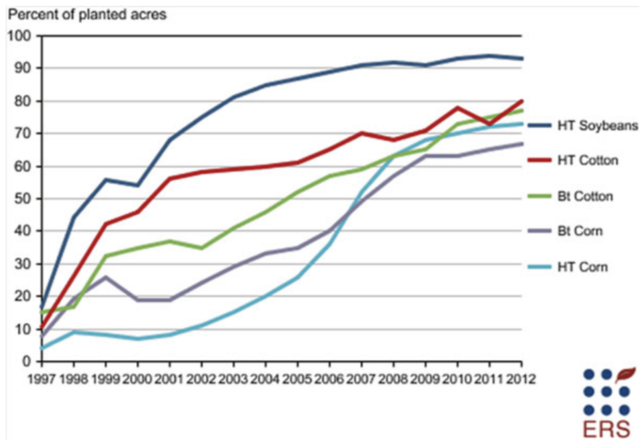

Figure 2: *Adoption of genetically engineered crops in the US*

In some cases, the herbicides used in herbicide-resistant crops are more convenient to use, less toxic to mammals, and less persistent in the environment (Cerdeira and Duke 2006). Initially, glyphosate was extremely effective in controlling weeds in glyphosate-resistant crops, and many growers relied exclusively on glyphosate to manage weeds. Due to the intense selection pressure placed on weed populations with the widespread use of glyphosate, weed resistance to glyphosate has become more prevalent. Weed management programs cannot rely on single tactics, whether a herbicide or other form of weed control, or weeds will ultimately adapt and survive in large numbers. Weed resistance to glyphosate has forced many growers to rotate to or tank mix with herbicides having a different mode of action. Combining herbicides, cultural practices, and mechanical tactics provides the greatest protection from herbicide-resistant weeds and is part of an integrated weed management program. Most high-value fruit and vegetable crops are grown on fewer hectares and have not had the luxury of new herbicide development due to the lower market potential and higher risk of crop injury. As a result, herbicide development for these crops usually consists of adapting and registering herbicides that were developed for one of the major field crops. This often results in fewer and older herbicides labeled on these higher-value crops and sometimes no herbicides available for control of certain problem weeds. Consumers have also voiced concern about the safety of genetically modified crops to humans and the environment. This, coupled with the lower profit incentive due to lower acreage, few seed companies have developed herbicide-resistant fruit and vegetable crops. As a result, many specialty fruit and vegetable growers rely more heavily on tillage, cultivation, mulching, and hand weeding to manage weeds.

Risks associated with herbicide-resistant crops include marketing problems with grain contamination, segregation and introgression of herbicide-resistant traits, marketplace acceptance, and an increased reliance on herbicides for weed control. The evolution of glyphosate-resistant Palmer amaranth (Amaranthus palmeri), common water hemp (Amaranthus tuberculatus), creeping bent grass (Agrostis stolonifera), horseweed (Conyza canadensis), rigid ryegrass (Lolium rigidum), and goose grass (Eleusine indica) is directly attributable to the adoption of glyphosate- resistant crops and the concomitant use of glyphosate as the primary herbicide for weed management (Green and Owen 2011; Owen and Zelaya 2005).

IX. Automation and Computer Science

The advances discussed above in the electronic and electromechanical fields have been greatly facilitated by advances in electronic hardware. However, there have also been software advances. Some of them are discussed above. In addition, there has been a general increase in programming reliability and performance, improving automation performance.

i. Control theory

Control theory continues its development to improve the dynamic performance of systems to which it is applied appropriately. Classical control theory using the frequency domain and Laplace transform analysis is now well understood. Systems can be designed for good steady-state and transient response and yet have stability. This results in faster performance. Modern control theory continues to gain popularity relative to classical control. Modern control describes the system in the time domain with a set of first-order ordinary differential equations, usually expressed in matrix form. It is often better at handling controller synthesis and multivariate applications, although it is less intuitive to many controls designers and users. Pole placement techniques can be used to get desired system responses.

A wide range of new techniques, such as fuzzy control, neural networks, and genetic algorithms, have been developed. These biologically inspired nonlinear techniques can often improve performance or robustness if they are configured properly.

Although they generally do not have strong mathematical provability, they can exhibit adequate behavior in practice. A very general and widespread trend in automation is the tendency for the human to no longer be the direct controller. Direct control is increasingly relegated to auto- mated systems with the humans moving to higher, more abstract levels. The human is the supervisor, not part of the actuation system.

ii. Secondary control

If a hydraulic or pneumatic mechanism is to be actuated, there must be some way of causing the mechanism to move or not move according to some desired path as a function of time. This control is usually traditionally achieved by having a valve to modulate the flow of oil (hydraulics) or air (pneumatics) to the cylinder or motor which is performing the actuation. (This is similar to how an electromechanical actuator will have some electronic or electrical components to control the current and voltage to it.) This valving tends to produce systems which respond quickly and have accurate controllability. However, there are often substantial pressure, and hence energy, losses in regulating or throttling the flow through the valve.

Consequently, there has been an increasing interest in secondary control and related techniques. Instead of directly controlling the actuator, the control is more remote. For example, instead of using a valve to control a hydraulic cylinder, the pump providing the hydraulic oil itself is controlled. There is a much higher effi- ciency in the system since excess power is not generated and dissipated. However, since the control is further from the actuator, there is often difficulty getting fast and accurate control. In addition, more power sources may be required when there are multiple actuators, as shown by examples of secondary control of excavators. However, recent progress now makes secondary control feasible in an increasing number of cases.

There has also been progress in the regenerative capturing of energy during deceleration. Instead of dissipating energy into heat through friction, restricting flow, or resistance heating, energy is stored for later productive use. One example is the use of regenerative braking in hybrid automobiles. Similar concepts are possible in other systems through the use of accumulators, batteries, ultracapacitors, and other energy storage devices.

iii. Formation control

The control of multiple autonomous machines has been an area of significant study and development. This formation control allows many separate machines to be con- trolled and to perform a task which would be impossible for a single small machine to perform, or to perform with acceptable accuracy or productivity. An implication of the ability to control formations is that smaller, multiple machines may replace large machines without requiring multiple human operators. These machines can be smaller, and perhaps be more efficient, have lower environmental impacts, and be less hazardous. In addition, the natural redundancy of multiple machines may increase system reliability.

iv. Human Machine Interaction

HMI, whether representing human-machine interaction or human-machine inter- face, is becoming more important as there are more machines to interact with. And the HMI is happening at higher levels of abstraction. Presentation of information to the human should utilize the improved human factors knowledge developed through the utilization of psychological and ergonomic research.

The best methods for human interface design are changing rapidly as different generations of humans are maturing and the knowledge and habits from their different experiences change. Visual, sound, and kinematic outputs and inputs should be designed to maximize robust performance. Display and control stereotypes continue to evolve.

v. Computer Science

As computational capabilities greatly increase in both hardware and software, the importance of computational efficiency relatively decreases. Computer science is moving away from electrical engineering and becoming more concerned with human issues. Although the vast databases and networking demand efficiencies, the emphasis is now on higher levels of abstraction and human interfaces. As computer programs become more complex, the substantial shift from procedural programming to object-oriented programming continues. This is seen by the widespread use of languages such as C++ and Java and by the use of interactive software environments such as MATLAB or LabVIEW. As more computer programs, packages, and tools have been developed, programming increasingly involves reusing existing code or constructs. The software engineering management of computer programming and how programs are written has also changed. A process called scrum is now often used for the actual writing of software. Scrum is a holistic product development strategy in which the development team works as a unit to reach a common goal rather than an individualized sequential approach. The team works in short time-limited sprints in which portions of the system are created. The process emphasizes self-organizing co-located teams with good verbal communication among themselves.

X. Autonomous Vehicles

One of the most exciting areas of mechanical engineering research has been the development of autonomous vehicles. There have been many research and development projects in land, sea surface, underwater, and airborne environments. Most of the autonomous vehicle work has been done with ground vehicles, including some substantial efforts with agricultural vehicles. The most-publicized activities, involving hundreds of independent efforts, were the DARPA Grand Challenge (in 2004 and 2005) and Urban Challenge (in 2007) prize contests sponsored by the US Department of Defence. These robotic development contests significantly advanced the state of the art and created a large pool of robotics experts by challenging groups from universities and the private sector to develop vehicles which could successfully travel and perform tasks. The successful autonomous vehicles demonstrated the importance of path planning, sensing, and robust automatic behaviors. Many technologies and techniques were substantially further developed. Perhaps agricultural autonomous vehicles can be classified into categories of input-output, transport, and self-contained. Many aspects of agricultural production can be considered a materials handling problem. In that manner, there is a big logistics problem in getting materials (such as seeds and fertilizers) to the fields and harvested crops from the fields. The actual input (planting or transplanting) and output (harvesting) operations within the field are crucial, complex operations. They will perhaps be the last operations to be autonomous. However, given the complexity, they tend to already have automated functions on the machines. On the other hand, transporting the materials to and from the field might soon utilize autonomous vehicles if the interface with the input-output vehicles continues to improve. Examples of self-contained vehicles are those which perform scouting, tillage, weeding, or spraying. They function by themselves and the technology is rapidly developing. Similar advances have been made in small aerial vehicles often called UAVs or drones. Small airplanes, helicopters, multicopters, blimps, and other flying vehicles have become more widely researched and used. Advances in sensing and controls have made them easier to use and more robust. They have great potential in agriculture. Payloads are limited, but the overhead perspective is useful, especially for sensing, scouting, and management tasks. Vehicles with four or eight rotors are easier to control than traditional helicopters with only one lift rotor. The problem of short aerial persistence is being alleviated by the development of autonomous refueling or battery recharging stations.

XI. Methods and Mechanism

The mechanism consists of following parts. A rod over which the linear bearing slides, a platform over with the nozzles are mounted and a stepper motor with belt and pulley. The linear bearing slides over the rod, on the linear bearing the platform is mounted with helps of clamps and the belt is press fitted with clamps, so as when the stepper moves the pulley the belt moves the clamp hence the whole platform with it.

The mechanism is divided in two parts the x axis and the y axis. The x axis position is controlled with stepper motor which gives the mechanism a higher resolution in x axis.The stepper motor is controlled through Arduino using MATLAB. The y axis is stationary as such 4 set of 2 nozzles are placed equidistant to each other. These nozzles are operated with help of 4 pumps which are controlled using a really controlled by Arduino which is also controlled by MATLAB.

MATLAB first takes in information form camera finds the weeds and gets the x and the y coordinates of the weed. The is commands the stepper to mover a particular number of steps to reach the x coordinate. Once this is done it activates a particular nozzle according to the y coordinate hence spraying the weed. It continues to do so until all the weeds are sprayed in one region which is $40 cm by 45 cm$.

XII. Construction

The bot is made up of wooden frame and is driven by 2, 12 volts geared Grade A DC motors which have a base rpm of 18000 and the reduced rpm of 100. It consists of a 8 megapixel HD Logitech webcam that will detect the images of the weed from the field and give its inputs to the MATLAB programme that will be running simultaneously in Apple Mac book Pro .

We are using Nylon base tyres for the rear and a high traction tires for the front that are connected to the dc motors. Dc motors are mounted to the bot with the help of custom made 3D printed clamps. For the herbicide spraying mechanism we fabricated a wooden platform at a height of about 40cm from the ground that consists of a stepper motor and a pulley belt system for the movement of the spraying nozzles in a plane.

There are a total of 8 nozzles that are mounted on a piece of wood which is further connected to linear bearing on one side with the help of 4 hose clamps. we have mounted two stock coolant tanks of Maruti 800 along the width of the bot with the help of a wooden member. A total of 4, 9v pumps are being used 2 in a single tank. The pipes from these four pumps are connected to the 8 spraying nozzles using a T joint.

The coolant tanks are purposely mounted at a height below the level of the nozzles so that the head of water at the beginning of the tanks always remains lesser than the head at the beginning of nozzles to avoid dripping of herbicide from the nozzles when not needed. We are using a 4 relay board for operating the water pumps which is mounted on the top of the bot to the nylon board.

- Jhonson motor : The bot is having a front wheel drive. We are using 2 Jhonson 12V motors (grade-A) of 100rpm.The base rpm of the motors is 18000 which reduces to 100 by fulfilling our torque requirement to drive the bot.The motors are controlled by IR remote with the help of H-Bridge driver connected to arduino UNO.
- Chassis: The chassis frame is wooden fabricated. The frame consists of a 6mm nylon sheet on which the camera ,arduino UNO, batteries ,H-Bridge driver are mounted. Four vertical wooden members are mounted to the nylon sheet with the help of four Lclamps to form a basic structure of the bot. All wheels are attached to these wooden members with the help of brackets and nuts and bolts.Two horizontal wooden members are mounted to the legs of the bot to increase its rigidity.
- Nozzle Assembly: 8 nozzles are embedded in a wooden plyboard which is attached to linear bearing on both the ends with the help of hose clamps. Plastic pipes are attached to these nozzles on one end and the other end is attached to water tanks which will transfer the hot water to the nozzles and spray them on the weeds with the help of water pump.
- Stepper Motor: We are using NEMA 17 stepper motor that produces a torque of 1.6 kg cm. A stepper motor is an electromechanical device it converts electrical power into mechanical power. Also it is a brushless, synchronous electric motor that can divide a full rotation into an expansive number of steps. The motor?s position can be controlled accurately without any feedback mechanism, as long as the motor is carefully sized to the application. Stepper motors are similar to switched reluctance motors .The stepper motor uses the theory of

Figure 3: *Johnson motor*

Figure 4: *Chassis*

operation for magnets to make the motor shaft turn a precise distance when a pulse of electricity is provided. The stator has eight poles, and the rotor has six poles. The rotor will require 24 pulses of electricity to move the 24 steps to make one complete revolution. Another way to say this is that the rotor will move precisely 15ř for each pulse of electricity that the motor receives.

Figure 5: *Nozzle assembly*

Figure 6: *Stepper motor*

- Stepper motor assembly: Stepper motor is attached to a ply board which is mounted to the vertical wooden members. We are using pulley-belt arrangement to move the nozzle assembly in the y-axis.A pulley is mounted on the shaft of the stepper motor on one end and a shaft is attached to a wooden structure on the end to mount the other pulley of the mechanism. The pulleys are connected with each other with a rubber belt and the belt is attached to the linear bearings which slide on two horizontal members with the help of two hose clamps. Both the pulleys have teeth on it which are of the same pitch as the one of the belt.
- Water Tank: The water tanks are OEM parts taken out from the Maruti Suzuki 800.Two tanks are attached to the horizontal members.Each tank consists of two 9v motor pumps that will pump the water to the nozzles.
- Camera : We are using a Logitech 3.2 megapixel HD webcam to detect the weed in the farming field and distinguishing between weeds and crops.The webcam is mounted on the nylon sheet with the help of aluminium tape.The webcam takes a snapshot which acts as an input to MATLAB and it detects weed from the image and further commands the stepper

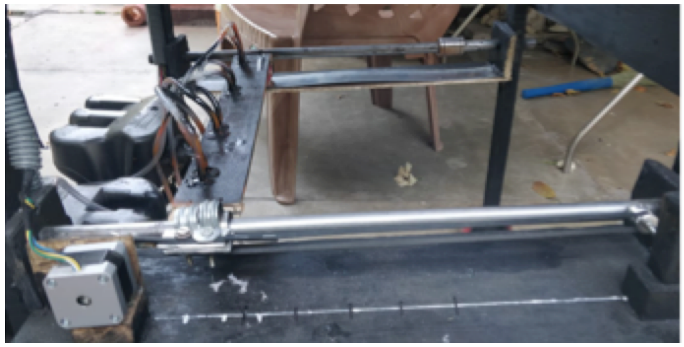

Figure 7: *Stepper motor assembly*

Figure 8: *Water tank*

motor to move the nozzle assembly.

- Apple macbook pro: This is the brain of our bot all the programmes are run in this laptop.MATLAB function is processed by the laptop and both the arduinos are also coded in the laptop and controlled by it. The weight of this laptop is quite less which helped us to reduce the overall weight of the bot.
- Arduino UNO : The microcontroller we are using is arduino UNO which is responsible for giving inputs to stepper motor, jhonson motor and the water pumps fiited inside the water tanks. Arduino Uno is a micro controller board based on the AT mega 328P (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the micro controller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.. You can tinker with your UNO without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again."Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino,

Figure 9: *Camera*

Figure 10: *Macbook*

now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform; for an extensive list of current, past or outdated boards see the Arduino index of boards.

- Battery : This is the powerhouse of our bot.We are using a 12V lead acid battery to power all the motors used and the arduinos and the motor driver.

XIII. Problems faced

1. Calibration of the stepper motor : We needed to calculate the number of steps that we need to give as an input to the stepper motor to move the nozzle assembly in the y direction.The problem we were facing was the pixels that we were getting as an output from the snapshot did not vary linearly with the distance in x that is as we were going further the output from the webcam to the stepper motor was reducing the nozzle assembly used to stop before the weed it detected.To solve it our team decided to lay a chart paper beneath the bot and divide segments of 5cm each and write the function for converting pixels to stepper motor steps for each segment.We calculated that for every 50 steps the nozzle assembly moved 4 cm and the

Figure 11: *Macbook*

Figure 12: *Macbook*

we defined a separate function for every 5 cms in y axis.

2. Calibration of the nozzle assembly : As we were using 4 water pumps connected to 8 nozzles and operated using relay and Arduino UNO, we needed to calibrate that which pump should operate when our system has detected a weed.We divided the x axis in 4 segments because we were using 4 pumps and for each segment we coded the respective pump to operate when weed will be under that segment.

3. Manufacturing chassis First we connected 4 vertical wooden members to the stepper motor assembly but the structure was not rigid enough to carry the weight of the bot so we decided to fix two horizontal wooden members between the legs of the bot to increase its rigidity. Earlier we were using only one nut and bolt to connect these horizontal members to the vertical members to cut the weight of the bot but it resulted in play between the parts so we decided to use two pair of nuts and bolts diagonally to connect all the members of the chassis.

4. Problem with the stepper motor assembly :Initially we were using linear bearing on both

the sides of the assembly sliding over 2 rods.But the torque of our stepper motor was not enough to overcome the resistance offered by both the bearings so we disconnected one side of the nozzle assembly from the bearing and attached an aluminium sheet on the ply board and a wooden block with the nozzle assembly that can slide over the metal surface reducing the overall friction and weight to be carried by stepper motor.

XIV. Calibration

A chart paper was used to calibrate the robot. The chart paper was divided in 7 segments each with a width of 5cm.The chart paper was kept directly under the robot. the First segment was kept right under the initial position of the nozzles. The coordinates of the lines were found out using the image acquisition tools in terms of pixels . The y coordinate was found out for each of the segment.

- 359
- 447
- 536
- 624
- 712
- 795
- 881

The by measurement it was found out that with every 63 steps of the stepper motor the the nozzle assembly moved by 5cm. The area was divided in the 7 segments as follows:

- 0-359
- 359-447
- 446-536
- 536-624
- 624-712
- 712-795
- 795-881

For every segment the number of steps were defined using the formula given below; d=number of steps
s= segment number

$d = 30 + 63 * (s)$ The y coordinate obtained by the matlab on identification was the top left corner of the box as shown in the figure. To get the centre coordinate of the box we did the following transformation to get the result. $y = y + ((heigthofbox)/2))$

XV. Current status

The main purpose of the current prototype is to make a farm free of unwanted weeds with least human intervention and reduce the use of pesticides by automatically identifying ,locating and then spraying hot water on them. The bot is capable of distinguishing weed from the plant and correctly pin point its location in real time. With the help of 8 nozzles it throws high pressure hot water on the exact location of weed.

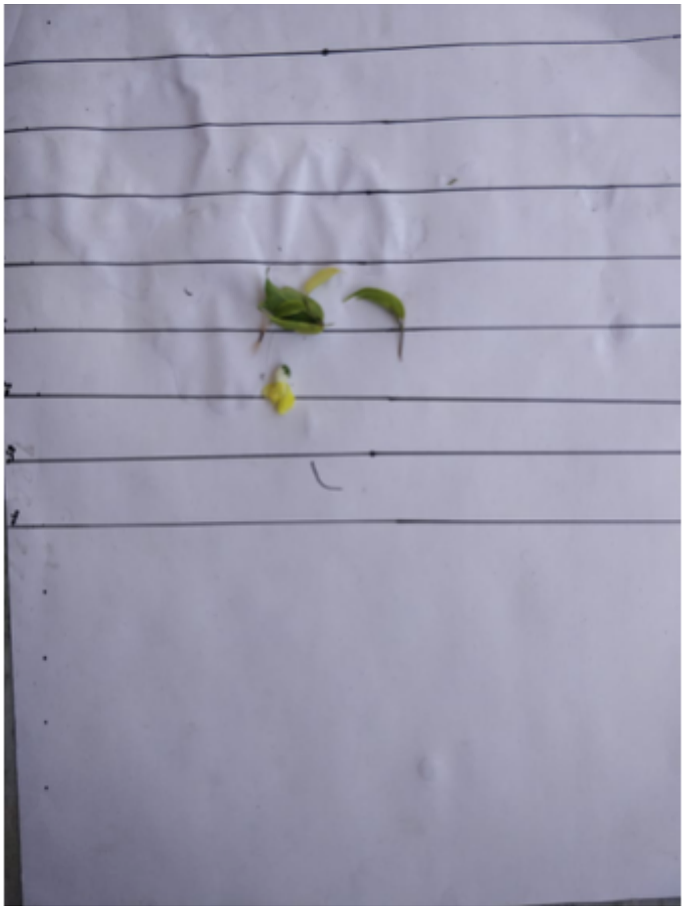

Figure 13: *Chart paper calibration*

XVI. Cost effectiveness

1)Weeding Done By Manual Process:

- Amount paid to the labour for one day = Rs. 250 per labour
- Total number of labour required in general to weed the 1 acre = 6
- Total amount paid to the labour = 6 x 250 = Rs. 1500 per acre in one day.
- Therefore, total expenditure in one day is = Rs. 1500

2)Cost of pesticide per season: Rs 2310

XVII. Practical utility

1. Accuracy : As the bot focuses just on the pesticide and and does not spray on the complete field this increases the accuracy and effectiveness of the machine and make the field weed free.

2. Cost effective :As no supervision is required there is no need of labor .In addition to that we do not require any pesticide as hot boiling water is used. Hence a lot of money is saved.

Figure 14: *Detected weed*

3. Pest control too: In addition to weed removal hot water also helps in reduction of pests which eat up our crop from time to time

4. Time saving : As the bot is autonomous it saves a lot of time for the farmer which can be better utilized in crop care.

XVIII. Scope

By training Matlab adequately we can also use the robot to nourish our plants. The bot could distinguish between a malnourished pant from a perfectly healthy plant and then provide necessary nutrients to it . This would require to provide data for a plant from its sapling stage until it becomes full mature. It could also identify a pesticide infected plant and provide the required treatment. We can also enhance the ability of our bot to move left- right along with its straight line movement to improve its agility to move in the farm. Apart from that number of Nozzles can be reduced by inculcating one more belt for horizontal motion.

1. Plant nourishment - By training Matlab adequately we can also use the robot to nourish our plants. The bot could distinguish between a malnourished pant from a perfectly healthy plant and then provide necessary nutrients to it . This would require data for a plant from its sapling stage until it becomes fully mature. Matlab then processes the data and instructs the bot further instructions.

2. Feedback to farmer- Regular feedback can be given to farmer about the state of each and every sapling . Any discrepancy from the expected data can be identified and farmer can rectify that too.

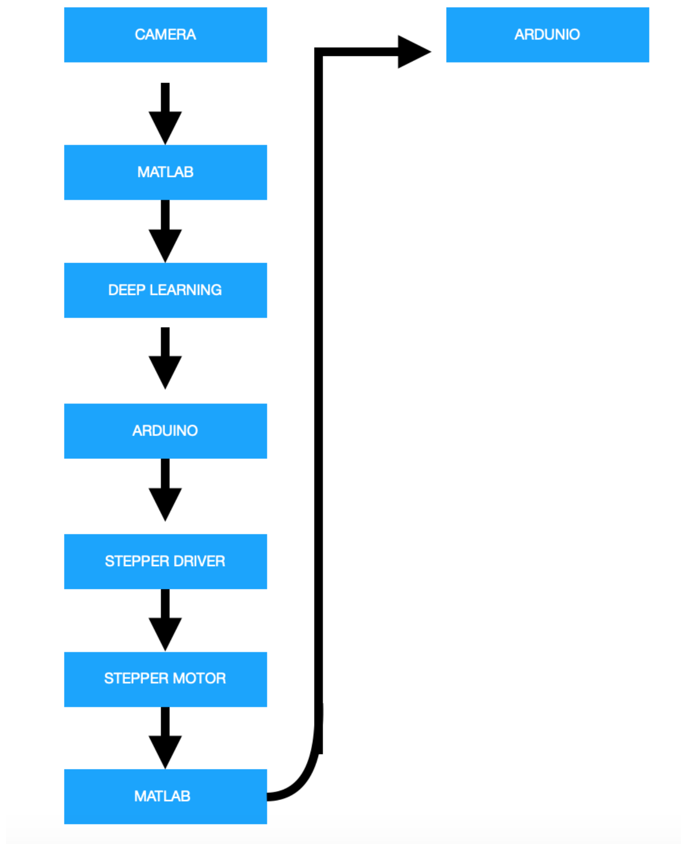

Figure 15: *Flowchart*

3. Pesticide control-It could also identify a pesticide infected plant and provide the required treatment.

4. Improved movability- Agility to move in the farm can be improved by enabling it to move sideways.(i.e. left right movement).Thus the bot can navigate easily throughout the terrain without damaging any crop

5. Improved efficiency- One more belt can be included for right- left motion at nozzle which will also reduce the number of nozzles but still cover more area and improve efficiency.

References

[1] Van der Weide, RY and Bleeker, PO and Achten, VTJM and Lotz, LAP and Fogelberg, Fredrik and Melander, Bo Innovation in mechanical weed control in crop rows *Weed research*, 48:215–224.

[2] Haug, Sebastian and Michaels, Andreas and Biber, Peter and Ostermann, Jörn Plant classification system for crop/weed discrimination without segmentation *IEEE winter conference on applications of computer vision*, 1142–1149.

[3] van Evert, Frits K and Samsom, Joost and Polder, Gerrit and Vijn, Marcel and Dooren, Hendrik-Jan van and Lamaker, Arjan and van der Heijden, Gerie WAM and Kempenaar, Corné and van der Zalm, Ton and Lotz, Lambertus AP A robot to detect and control broad-leaved dock (Rumex obtusifolius L.) in grassland *Journal of Field Robotics*, 28:264–277.

[4] Deepa, S and Hemalatha, R Weed detection using image processing *Int J Res Comput Appl Robot*, 7:29–31.

[5] Hlaing, Su Hnin and Khaing, Aung Soe Weed and crop segmentation and classification using area thresholding *IJRET*, 3:375–382.

[6] Lee, Won Suk and Slaughter, DC and Giles, DK Robotic weed control system for tomatoes *Precision Agriculture*, 1:95–113.