Agricultural Robotics
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1. Introduction

We live in a world of polluted unrest; agriculture is a shrinking minority while manufacturing industries crop up like weeds. In all the tumult, we don't realize that we depend heavily on our agriculture industry. In fact, we can't live without it. Every year, hard-working souls arduously plant seeds by hand or with huge machines that crudely maintain the crops while releasing tons of pollutants into the air and water supply. Slowly, but surely, our agriculture industry will be run by huge machines, and our environment will be entirely polluted… These machines cost farmers millions of dollars and that cost is passed on to us, the people that depend on the agriculture industry.

So to solve these problems, scientists are trying to devise robots that can plant, maintain, and harvest crops, allowing a quicker, and hopefully better harvest season without the harsh chemicals that contribute to the collection of greenhouse gases amassed in the air around us. They are also developing robots that can help take care of the animals on a farm.

There will be drastic effects if we don't do anything to the current pollution situation. We need to heed the warnings now so that we may prevent global warming and other calamities. Thus, we must be able and open-minded so we can come up with an efficient solution. This paper will present the history of agricultural robotics, current applications of robots in agriculture and present a unique application of using robots in agriculture.

The purpose of this particular paper is to give a brief history of agriculture, describe the current state of agricultural robotics and see some of the current work being done, because in order to see into our future, we need to peer into our past. This can help us imagine and create some of the innovations of the future.

2. Justification

In several movies such as Star Wars people have their own robots that can milk cattle, water crops, and take care of the animals. Even though we don't expect our robots to save the world, it would be nice to have our robots do the boring, everyday things that no one wants to do like grow our crops and provide food for the world's growing population. In addition it would be nice if robots helped to reduce the pollution and ecological impact that farming causes.

We are going to concentrate our justification of developing and using robots in agriculture on two items:

- **Costs involved in farming** - we believe that using robots in farming can significantly reduce the cost of farming.
- **Ecological impact** - we believe that farming is ecologically damaging and robots can help prevent some of that damage.

Agriculture has been a huge part of our country's resources since the colonial times when 9 out of 10 people in the United States worked on a farm[5]. The productivity of agriculture has tripled since that time, even though less people are farmers [5]. So, why do we want to invest in agriculture? Well according to James Pinkerton, [6]:

Agriculture is the path America took on its way to becoming a great power. In agriculture, the big breakthrough came in 1831, with the invention of the McCormick Reaper. Mass-produced in Chicago, the reaper enabled two men to cut as much grain in a day as a dozen or more men using traditional reaping hooks. As a result, labor was freed up to work in factories, accelerating the Industrial Revolution - and the American Dream.

Yet, it's noteworthy that the reaper and similar productivity enhancing inventions came to the American North, not the South. In slave-holding Dixie, where labor was free - if you don't count flogging and lynching and putting down bloody uprisings as costs - there was little incentive to develop labor-saving technology. The low-tech status quo seemed quite OK to plantation owners.

What he's saying is that the more we invest in farming the faster the work will get done and the less people will have to farm. He also goes on to say that 4/5's of the farming done in America is already done by machines, but these machines cannot think on their own, they require a human operator. And according to Tony Grift, using robotics in agriculture is nothing new and that countries like Japan and the Netherlands have already been using them, but in controlled environments. However, he is trying to get them to work on their own. [6]

Cost

Farming is, surprisingly, a very expensive occupation. You have to buy large tools like tractors, scrapers, and fertilizers. Some of the materials get out of date very fast. Farmers also have to pay labor costs to plant, care for and especially harvest their crops. They also have to buy fertilizers, seeds, and pesticides. So all in all, farming isn't the cheapest occupation. Grift says that he is building machines that are "smaller and smarter" and more cost effective than current machinery. [6]

Grift also asks the question, "Who needs 500 horsepower to go through the field when you might as well put a few robots out there that communicate with each other like an army of ants, working the entire field and collecting data?" Grift's robots cost as little as $150.00 before mass production.[6] They will also replace a lot of the large and expensive tools used today and the robots will be the ones doing the boring, everyday jobs everyone hates. In addition, if robots can harvest the crops, then less labor needs to be hired to bring in the crops, thereby reducing the farmer's cost even more. We believe this cost savings can be passed on to the consumer, making feeding our families even cheaper.

Ecological Impact of Farming

As the march of mechanization and modernization continue in farming the impact of farming is causing an ecological crisis[1]. According to Oxfam America, *"The impact of industrial agriculture on the environment is now widely seen as its most devastating cost to society"* [3]. Fertilizer runoff from farmland can pollute groundwater systems, causing large algae outbreaks. These outbreaks kill millions of fish and upset the ecosystems of the rivers, lakes and streams [2]. In fact, it is estimated that 50%-70% of all nutrients that get into the ground water comes from farm runoff [1]. In addition, many of these chemicals used in farming can get into the air, causing problems for people and possibly contributing to global warming [1]. It is estimated that farming accounts for around 10% of all greenhouse gasses emitted by human activity each year [4].

Pesticides and herbicides used in farming can soak into the groundwater and make this water undrinkable for humans. In fact, an underground water system below a major dairy farm in Southern California has been tested to have pollutants higher than the water coming from the sewage treatment plants [2]. Over 939 million pounds of pesticides are sprayed each year in America and only 10% of that does any good and reaches the plants it was meant for [3].

What We Envision

Clearly, farming is a major undertaking, costing lots of money. In addition, our current farming practices are harming our environment. We envision small, cheap robots that cut down on the need for massive quantities of pesticides and other chemicals. Our idea is to create an army of small "frog" robots that travel through the farm catching insects that prey upon plants in a way that does not need pesticides. The insects would then be used as a natural fertilizer to help the plants grow!

3. History

3.1 The Brief History of the Past:

We believe that the earliest beginnings of what we call farming were in the area of Mesopotamia, originating around the year 9500 B.C. E. Farmers were starting to select individual plants to harvest and grow [13]. Before this they only harvested wild cereals. They used only basic tools, some just chiseled rocks. Soon, farmers started specializing their crops to only a few species per farm. During the middle ages, farmers discovered how to create more intricate tools. Later, the Chinese invented the moldboard plow, which increased efficiency. [13]

Agriculture continued to grow from its small beginnings but did not change much for thousands of years. Farmers planted their fields by hand or with the help of plows or other non robot machines. The beginnings of robot machines really started in the late 1700's with the invention of the cotton gin.

Invented at the beginning of the industrial revolution, the cotton gin allowed for a more efficient cotton harvest. It was created by Eli Whitney in 1793 and got patented the next year [14]. It pushed along the industrial revolution and was a major breakthrough in agriculture. Today, gins are mechanized and controlled by computers and provide an extremely fast harvest.

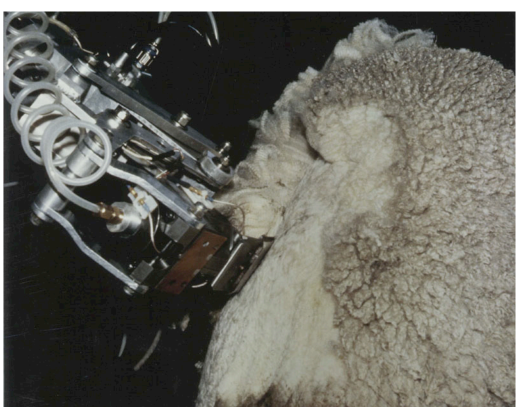
3.2 The Present:

Today farmers harvest their fields with giant combines and other mechanized machines that use lots of gas and manpower and are not very friendly to the environment. They do provide for a quick harvest and are one of the reasons that agricultural productions has become more efficient.

Robotics is one of the fastest growing engineering fields of today's industry. In several years, we might have robots that do our work, re-build themselves, and never require ***us*** to plug them in. Robots have just started to appear in farms in the last 20-25 years. Most of the robots are still in development in universities and other research places and have not made a significant impact on farming ...yet. The future is bright and these experimental robots are paving the way for robot farmers in the near future.

This section will detail a few of the robots currently in use or being invented.

Automated Sheep Sheering:



One of the first automated processes in agriculture to help farmers with tedious tasks was developed at the University of Western Australia in 1979 and is designed to sheer sheep. Sheep sheering is the process of taking the fur or wool of a sheep. This wool is then cleaned and used in the textile industry. The sheep is restrained and many sensors help to position the cutters so the robot does not hurt the sheep. The Oracle sheep sheerer was used as a test model to design its successor, the Sheer Magic Robot.[7]

The image at the left shows the Oracle sheering a sheep. The image was taken from http://www.mech.uwa.edu.au/jpt/shearmagic/autoshear.html

Fruit Picking:

Automated fruit picking robots have been used in Agriculture since the 1980's and were one of the first robots to be used to harvest crops. These robots in fact, led to the development or lines of research today in automated crop harvesting. The robot is able to distinguish between leaves and ripe and unripe fruit through the use of a color camera [8] , like the XBC used in Botball. We plan to use a similar system in our own agricultural robot detailed on our solution page.

Image from: http://www.technovelgy.com/ct/Science-Fiction-News.asp?NewsNum=177

Demeter and Ag-Ants:

Engineers are building a wide variety of 'agbots', including the Demeter automated harvester (see below). This harvester isn't fully robotic, however, because you can still control it manually. It does have a 'cruise control' and 'drone' feature. The first gives control to the harvester for a short period of time, and the latter allows you to remotely control several harvesters at once.[9]

Ag-Ants:

There are several other agbots in production, though. One is the foot – long "ag ant", which you could make a 'colony' of to have a large, co-operative task force. These 'Ag-Ants' work as a "hive" and do the function of huge and expensive pesticide sprayers and harvesters. 'Ag-Ants' actually look like ants as well. They have six robotic legs that allow them to crawl between the rows of crops and have many sensors and controls mounted on top. "Who needs 500 horsepower to go through the field when you might as well put a few robots out there that communicate with each other like an army of ants, working the entire field and collecting data?" says Tony Grift, University of Illinois agricultural engineer [10]. These 'Ag-Ants' are also very inexpensive. They cost $150 to build each one. When asked about how the robots worked and what was the plan for the future, Grift answered, "We're thinking about building 10 or more of these robots and making an ecosystem out of them," Grift said. "If you look at bees, they will go out and find nectar somewhere. Then a bee will go back and share this with the group and the whole group will collect the food. Similarly, one robot might find weed plants. Then it would communicate this location to the other robots and they would attack the plants together as a group--an ecosystem, if you will". Grift also said that someday he would like to see an experimental farm run autonomously by robots[10].

Another robot, this one for roughly $500, has been developed as well. The robot is equipped with two ultrasonic sensors that bounce sound waves off of objects, as well as four of the cheap infrared sensors used in simple motion detection sensors. This one is (so far) simply designed to meander through the rows in a 'drunken sailor' style. It goes in a zigzag pattern, sensing a plant at the end of each 'line' and turning into the next 'line'. [11]

3.3 The Future and Problems to Overcome:

The future of agricultural robots seems to hold small and inexpensive robots that can work efficiently. These robots work together as a team, passing information back and forth and solving problems in a hive type manner. The future looks to hold efficient robots that can spray herbicides and pesticides on to crops in an efficient manner so that pollution is kept to a minimum.

Currently the main problems in agricultural robots are:

1. How can the robots distinguish plants from weeds and other visual problems. A lot of work has been done with computer vision and but it is still not very good. In fact, Wikipedia describes the field this way *"The field of computer vision can be characterized as immature and diverse"* [15]. Scientist still have lots of work to do to get computer vision right. But we think a simple color and motion camera like that used in the XBC can go a long way to giving robot farmers "eyes". This is shown in our solution.
2. Navigation is also a problem. How can robots know exactly where they are? This problem is pretty easy to solve with GPS and in fact Tony Grift imagines robot farmers will use GPS: *"Planting, seedbed preparation, spraying, cultivation are all possible with smaller robots using GPS guidance"* [6].
3. How can they communicate this with others? Tony Grift imagines robots talking to each other and communicating all their information with each other to make farming more efficient. We also implement this in our solution.
4. How do they avoid destroying crops while moving from place to place?

4.0 A Possible Solution

Presenting: "The Medusa"

4.1 Problem Statement:

How can we design a robot that will cut the costs of farming and lessen the impact of farming on the environment? The robot should be small, lightweight, capable of working in a group or swarm type environment. The robot will be able to precisely know its position in the farm, avoiding obstacles and not damaging crops in the process. In addition it will be low Maintenance and be able to charge itself.

4.2 Purpose:

Our robot's purpose will be to keep the plants healthy by keeping them free of insect pests while NOT using environment damaging pesticides. It would also be nice if we could find a way to water the plants while getting rid of the insect pests. We would also like it to be very inexpensive so the farmers won't kill themselves to buy it. Another thing we want it to be is automatic so the farmers won't have to do anything.

4.3 Problems to Solve:

Basic Shape and Design:

Our robot is a tiny tank that has eight arms that go and actually catch the bugs. This is how we made up the name "Medusa." At the end of each of the arms is a camera that can find bugs. This tank has a computer on the inside that does all of the main computing but each arm is also a separate computer networked to the main computer in the tank. The robot will have an antenna on the top so that it can get internet access and communicate with the farmer and other robots in the field. It also has treads that help it go through the uneven part of the farm and over rough surfaces. On on each side of the robot's body is a camera so it can see where it's going. In addition it uses sonar on the front, back, and side in order to keep its distance from obstacles and plants. The Medusa has sprinklers positioned in each arm which spray water on the crops as it passes. Each hole has a nozzle in it, which sprays the water evenly upon the crops.

The Medusa will also have a soil probe. This soil probe will be able to test the dirt the plants are in for moisture and nutrients like nitrogen. If it determines the plant needs water or fertilizer it can give the plant what it needs directly without having to spray over everything.

Navigation and positioning:

To solve the problem of navigation, we have decided to put several cameras on our robot. We will place one camera on each side, to monitor the crops as it is passing by. We will have also have one camera each on the front and the back of the robot. Aside from that, we will place three radio beacons on the edges of the field, so that using it's antenna, it will be able to triangulate its position at any time during it's work. If the farmer wants to change the robot's position, the Medusa will be able to communicate with the farmer through the Internet. The farmer can give commands to the Medusa to tell it to go to other areas of the field and get reports on plant health and bugs killed.

4.4 Bug Identification:

For bug identification, The Medusa will have cameras in each of its eight tentacles. Once it sees something that looks like a bug, it will get up close to it and take several pictures from different angles using its many tentacles. After it gets the picture it will send the picture to the computer which is on the inside of the robot. It will identify the bug as good or bad from a database of bugs kept on the computer. If it is a good bug the Medusa will continue on and look for other bugs. If it's a bad bug, the bug catching system will kick in. The Medusa catches the bugs by using a frog-like tongue. Of course, the tongue is not the actual tongue from the frog, but is very similar. The "snake" is camouflage in color, and it will track the bug that it sees, while the other "snakes" go after the other bugs.

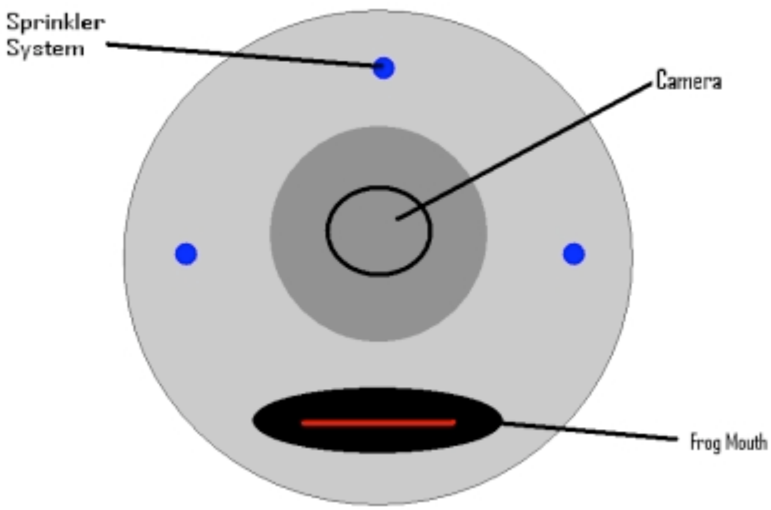
If it determines there is a large scale infestation and cannot get all the bugs itself it can use its on-board communication system to call other robots for help.

4.5 Bug Catching:

To catch a bug, one of the arms will track the bug with a sophisticated computer algorithm and will compute a targeting solution. Then a sticky frog-like tongue will shoot out at the bug and pull it in. After it grabs the bug it will find out if it will be good for fertilizer or for its own energy source. Once the Medusa decides what it will do with the bug, the bug disposal will kick in.

4.6 Bug Disposal:

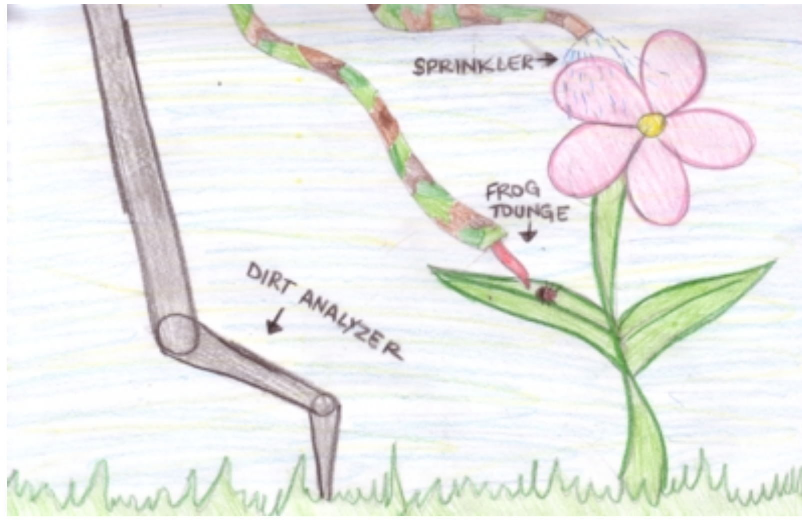
Because the bugs are filled with organic matter, our robot will be self charging during periods of bug infestation. It will smash up the bugs and through a chemical reaction be able to produce power and energy for the robot. If our robot has enough power, it will store the bugs so the farmer could use them for fertilizer. Once the robots container for the bugs that is going to used as fertilizer is full, the robot will make a stop by the farm and drop off the smashed bugs in a specific place and go back to where it was in the fields to continue work.



4.7 Sprinkler System:

The Medusa is equipped with a sprinkler system so that the farmer doesn't have to worry about watering the crops. The Medusa will take care of watering the crops as they patrol the rows of plants for bugs. The Medusa will utilize the sprinkler nozzles on it's arms to water the plants. The robot will implant a sensor in the soil that will observe the moistness of the soil and the fertilizer content. Using its arms it can directly target the plant for water or fertilizer. This will prevent over-watering, and will not waste water.

This picture shows a close-up of 3 arms of the medusa tending to a plant. The sprinkler is spraying a calculated amount of water onto the plant. Meanwhile, the frog tongue is capturing a pest that it saw on a leaf with its cameras. It will later process the bugs into a fuel. Lastly, the dirt analyzer is testing the needs of the soil. If the soil is lacking something, it will take measures to replenish it.



4.8 Cost Analysis

When coming up with the idea of our robot, a challenging problem was figuring out the cost of buying and working robots on a farm. Costs such as fuel and maintenance stumped us since all we could do was offer up an estimate, but we found a website that calculated the cost of buying and running combines on a farm, depending on horsepower (Available at http://www.farmdoc.uiuc.edu/manage/machinery/combine_calculation.asp). We decided that our robots are equal to five horsepower and that they cost about $500 in bulk. So we figured out how many Medusas could replace a combine and we punched in our own numbers. Below is a table with our results:

	Total Yearly Costs	**Total Costs Per Acre**
265 Horsepower Combine	$42,768	$26.73 / acre
53 Medusas	$9,399	$5.89 / acre
305 Horsepower Combine	$47,264	$23.63 / acre
61 Medusas	$11,599	$5.82 / acre
340 Horsepower Combine	$58,386	$22.45 / acre
68 Medusas	$13,003	$5.18 / acre

That shows how much our robot would help. It costs almost a factor of four less per year and our robots are much smaller and more efficient than combines and can do more. They also create their own fuel from the pests they process. So costs for fuel is completely eliminated. This is the perfect, cost friendly, solution. .

4.9 Conclusion:

As you can see, we envision a robot that is environment-friendly, self-fueling, pest exterminating, and cost effective. The robot will eliminate the use of pesticides, and still kill the pests efficiently, which will prevent pesticides to contaminate our foods. It will get rid of the need to fuel it, for it will fuel itself from bugs. It will get rid of the barrier of cost, for it can be built from parts that you are likely to find on the shelf in a store. Therefore, our robot meets the requirements for a very efficient replacement for human labor in agriculture, and will be a very good solution for the problem.

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