Rethinking Automated Farming
An Arm to Fit Them All

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***Abstract*—Agriculture is the basis for human development and survival. It has existed for thousands of years and has been improved over and over again. Today, in the age of technology, rethinking and innovating farming is increasingly popular as well as needed, with many concepts taking advantage of machines and robots to grow crops, feed livestock, or monitor fields to increase productivity and earnings. As we are attending this year's Botball competition many ideas have grown among us on optimizing these concepts and we have come up with our own idea to create the farm of the future.**

***Index Terms*—Robotics, Automation, Agriculture, Modularity, Digitalization, Farming, Harvesting, Tools.**

I. Introduction

Although robots have not been around for a long time, they are rapidly advancing in many different areas. Some of the signs that they have found a place in our daily lives are industrial robots in manufacturing, that speed up output and lower cost for companies, as well as Roombas at home. However, also the farming applications and aspects of robotics have been in development. It is one of the big markets robotics is tackling for improvement next. Automated vertical farming as it can be seen in Japan and self driving combines and tractors help farmers overcome the increasing demand and decreasing willingness to pay for produce.

Automated farms are without a doubt the future of corporate farming and agricultural design. The farmer benefits from in depth monitoring of their farm including aspect such as soil quality and their plants, as well as machines that take care of different tasks.

II. State of The Art

The status quo of farming has changed a lot in the last 100 years. The elaborate milking process has already gone under improvement in the form of robots, making it, in its current state, almost fully automated. Although it does not solve the sustainability problem, it does minimize the area and work required.

The machine scans the cow with lasers, attaches teat cups and milks the cow. After milking, the machine scans the cow's milk and provides information about it to the farmer. The cows quickly get accustomed to this kind of machine, often quicker than the farmer himself. Companies like Texha have taken on the challenge of automating poultry farming as well. Using carefully planned farms, made and organized by the company, robots are used to feed the birds, transport, handle and pack eggs and even manage shed ventilation.

Fig. 1. Automated Milking

A. Open Source FarmBot

FarmBot is an open source home gardening robot created by Rory Aronson, Rick Carlino and Tim Evers, with the aim to create a platform for growing vegetables, available to everyone. The robot's construction is quite simple, yet effective and has great potential due to its low cost. Moving similarly to 3D printer heads, it can accurately distribute seeds and water, as well as monitor soil quality. FarmBot achieves this using a number of attachments:

Fig. 2. FarmBot with its attachments

Fig. 3 The mountable seed injection tool can plant seeds deep into the soil precisely around the grow bed with enough spacing to allow for ideal growth of the plants while limiting the used space.

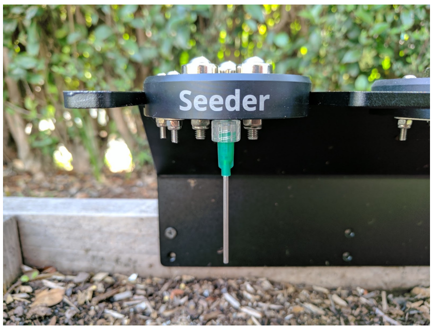

Fig. 3. FarmBot's Seeder

Fig. 4 The soil sensor measures moisture content of the soil by driving its copper measuring tip into the ground.

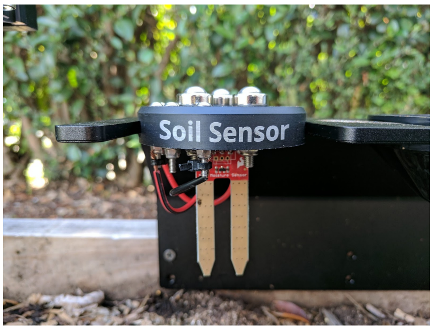

Fig. 4. FarmBot's Soil Sensor

Fig. 5 The Watering attachment allows for precise and gentle watering according to the needs of your plant. FarmBot recognizes the plant via positioning and supplies the amount of water for the configured plant by showering it.

Fig. 5. FarmBot's Watering System

Fig. 6 The weeder tool is used to destroy the fragile roots of young weeds automatically.

Fig. 6. FarmBot's Weeder

All of these tools are stored in the tool bearing located at the top end of the field so they are always ready to be attached.

B. Robotic Fodder - Growing System

As 50 percent of the world's population already resides in urban areas and the current space used for farming equals approximately the continent of South America. A new, more suitable and space efficient way of farming was needed to counteract the increase in space required. The solution: vertical farming. It is unfortunately very labour intensive which most farmers simply cannot afford. To solve this problem, a Californian agricultural tech company came up with the robotic fodder-growing system, which is able to produce daily quantities of fresh food for livestock. It builds on a system that already reduces water consumption and adds the capability to accelerate it by removing the possibility for human error which might slow down production.

III. Our Idea

The concept that that was developed, is a fully automated farming field. In the centre, a terminal is located, with a, in a curling motion, retractable arm attached to it, with the ability to rotate around the outside of the terminal. Rolled out, the arm serves as a rail for the various tools the robot supports and works with.

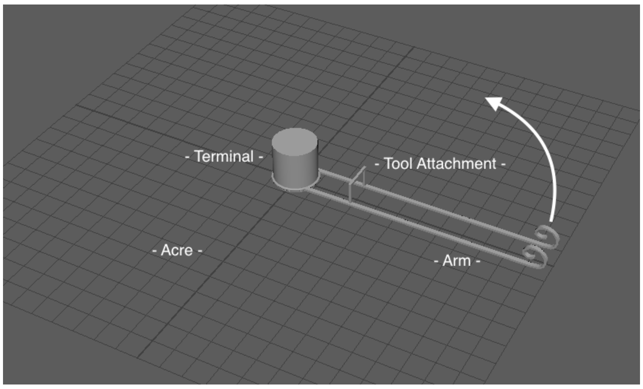

Fig. 7. 3D Model of the terminal holding the arm with the attachment for tools

A. Movement

For movement along the width of the field, the arm is positioned on a second rail system around the terminal. This allows for quick and easy relocation of the retractable arm. When moving across the field, it can be rolled out to reach the desired area.

B. Farming

To harvest the crops, the deployed arm works its way across the acre using the rails attached to the terminal, slowly covering all of the fields area. The tools attached to the arm collect the yield and transfer it, using the conveyor belt alongside the arm, back to the terminal. There it will be stored and wait for further transportation to a depot.

The configuration as well as the tools have to be adjusted for each type of plant that is to be harvested, as it needs to work differently while gathering fruits, like apples because of the differences in plant anatomy. Talking about apples, the tools would need to shake the tree which results in the fruits falling to the ground. Afterwards, these would be collected by an additional module on the arm and the be transported to the local storage.

C. The Field

The farming area plays a big role during the task fulfilment. Its ideal shape is a circle, since the arm has to reach every point from a central location. As the farmers already have existing fields which are often rectangular the tools will have the possibility to expand further at the peak/end of the arm after its full extension, a hexagonal layout is advised in such a scenario with enough clearance space to avoid arm collisions between multiple fields deploying this technology.

D. The Arm

The main tool of this robot is the arm attached to the terminal. Its purpose is the transportation of its attachments and the crops themselves. It should be able to span the radius of the field.

Concerning the conveyor belt two concepts have been developed:

1) As the arm unrolls small pieces of the conveyor belt, which are each able to work individually, simply attach to each other and thus forming a working transportation mechanism.
2) Multiple "grab tools" hold onto the harvested crop and transport it back to the terminal for storage using the rail they are mounted on.

E. Tools

As the main arm itself can not actually fulfil any work on its own. Therefore, tools are provided to help out with the assigned missions. Many tools for different applications are available and general use case tools have already been conceptualized.

1) Measurement Tool - Fig. 8: The automated farmland will have a tool dedicated to gathering information about soil, crops and the climate. The sensor located in the drill measures the electrical conductivity in the soil and calculates how much water is needed and if the crop is ready for harvesting. A group of sensors at the top of the tool is responsible for predicting weather and measuring environmental factors, using a barometer, thermometer, hygrometer and anemometer.

Keeping track of the information gathered by the measurement tool is crucial for optimising the process of farming in the future. The system can learn how to react to certain events such as drought or frost to protect the crops from freezing or drying out by adjusting temperature(if in a greenhouse) and watering times.

Key for Fig. 8:

- 1 - Spinning drill to get the conductivity sensor (- 4 -) into the ground.
- 2 - Motor responsible for spinning the drill and mount for attaching it to the arm.
- 3 - Barometer, thermometer, hygrometer and anemometer for measuring temperature, humidity, and air pressure. Responsible for transmitting gathered information.
- 4 - Conductivity sensors to analyse dryness and nutrition aspects in the ground.

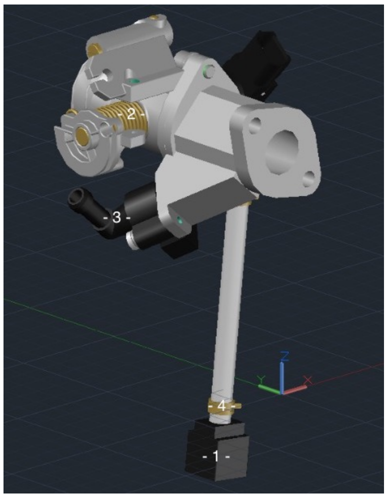

Fig. 8. 3D Model of the measurement tool

2) Cut-down Tool - Fig. 9: This tool consists of a tiny arm with a cutting device attached to it. Its purpose is to cut down and divide the plants into small pieces (with the actual fruit still intact) to make transportation to the terminal possible.This tool will mostly be used for removing unnecessary extrusions of the plant or in connection with the "grabbing tool".

Cutting the plant is achieved by a number of spinning knives at the bottom of the tool. The tunnel allows the fruit to be cut right at the branch and not to get damaged in any way.

Key for Fig. 9:

- 1 - Spinning knives in order to cut down fruits, leaves or branches. Size and sharpness of the knives is to be adapted depending on the task.

- 2 - Tunnel to cut the fruit right where it is connected to the branch.
- 3 - Mount to connect it to the arm. Enables rotation of the knives.

Fig. 9. 3D Model of the cutting tool

3) Grabbing Tool - Fig. 10: As the main arm needs a device which collects and places the crop on the conveyor belt, an additional tool has been developed. The grabbing tool adds the ability to grab and harvest crops, as well as moving them to the conveyor belt.

Key for Fig. 10:

- 1 - Claws that carefully grab the desired object. Number, size and radius of the claws can be adapted depending on the population of the field.
- 2 - Mount that enables rotation and connection of the tool to the arm.

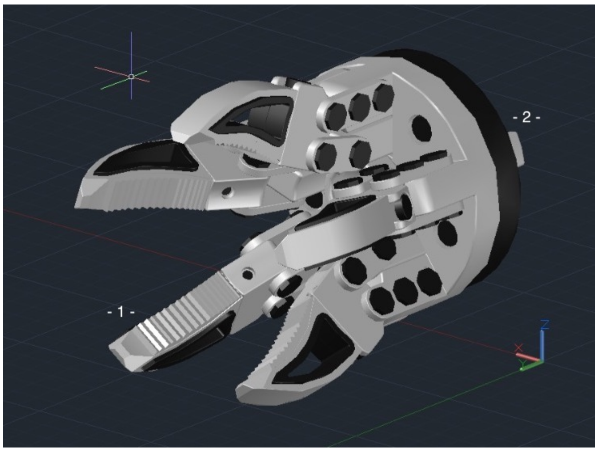

Fig. 10. 3D Model of the grabbing tool

F. Implementation

A terminal represents the central hub for the farming operation. It handles not only storage but also orchestrates the various tools and the main curling arm, therefore managing the farming process. A sufficient storage management system has to be implemented with an efficient way of organising and managing the harvested crops. Keeping track of which crops are stored where and making automated or manual transportation to a storage facility is also needed.

G. Conclusion

Controversy quickly sparks on the topic of superiority of robots in the same branch. The automated farm provides the farmer with many advantages of other products while condensing them into one solution. The farmer is not plagued by the high labour intensity of vertical farms and saves effort and time compared to a traditional farming approach as well. They can focus on the well-being of the farms livestock and therefore enhancing the overall quality of the products. Additionally, the opportunity to not only implement it on fields but combining it with vertical farming has the capability of solving the space problem too. The arm can still operate in a rather narrow area by adjusting the size of the tools and the terminal. Slightly adapting the design from a centralized approach to a one sided approach would allow for the combination to be implemented.

IV. Acknowledgement

With this opportunity, we as Team Curiosity from HTBLVA Spengergasse, want to say thank you for all the overwhelming support we received. In particular Prof. Walter Hammerl and Prof. Harald Zumpf who made our dream of attending Botball 2017 come true.

Not to forget, we also want to thank KIPR that provided us with all the parts for building the robots but also all the organization to make such a great event possible.

Last but definitely not least, we want to give a big thanks to Raiffeisen Bank International, LEAF, Allianz and Hammerwerk Müller und Shne GmbH. All of them supported us wherever possible and without them attending Botball 2017 would have been near to impossible.

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