How robots will revolutionize agriculture

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Farming is getting increasingly more difficult since many of the used pesticides are banned or are too expensive. One solution for this problem are robots. Special weeding-robots can remove the weeds and therefore decrease or completely remove the need for pesticides, but there are many other ideas. In this document, we will present some of these new concepts and talk about farming in general.

Keywords: Robots, agriculture, modern farming

I. Introduction and overview

Every year dozens of students take part in the botball contest, which is an international competition for robotics. The most important aspects for wining are teamwork, mechanical design and also programing. We are certain that we will meet all of the requirements and will do our best to win this competition.

In this paper, we will discuss the pros and cons of robots in agriculture and how they will hopefully influence the environment in a positive way.

Most conventional farming is done by using pesticides and genetically modified plants that grow faster and are more resistant to the very aggressive and toxic pesticides.
A big problem is industrialized agriculture, providing food for little to almost no money. The smaller farmers simply cannot compete anymore, since prices have been rising for years. Big companies like Monsanto have monopolies and sell their specific seeds for as much as possible. An example for this is cotton: With their huge market share in this sector, many farmers cannot even afford to buy the seeds anymore. They have even gone so far, as to modify the seeds so that they cannot multiply themselves. These seeds are called Terminator Seeds and they cause farmers to rebuy seeds every year. While doing that, they, of course, have to remove all the old and "normal" seeds. This puts the company into very bad light and makes one wonder how something like this is even possible [1]. All of the mentioned aspects lead to huge monocultures which have proven to be very bad for the environment, but still, there is almost nothing that the citizens or the government can do. The latest known effect of monoculture on the ecosystems is the mass destruction of our beloved banana fruit. Huge monocultures have always had the problem of being very prone to pests. The reason for that is very simple: the insects feed themselves upon the hosts and therefore multiply rapidly. Since there are little to no enemies for the insects, there is nothing to stop them except for aggressive pesticides. As already said, this is currently leading to the death of the well-known yellow banana. Interestingly, there are dozens of other types of banana, some of which even have a different color like red or blue.

II. Sustainable Agriculture

The meaning of sustainable agriculture is rather self-explanatory: it is farming in sustainable ways based on variable things such as the adjacent ecosystem. So, in a nutshell, it means that it will last over the long term and enhances environmental quality.

As already said, the current way of farming is going into another direction: aggressive and toxic pesticides are destroying not only the plants around the monocultures but rather the whole ecosystem. The problem, however, is comparable to the nuclear power problem. Nobody wants to leave it the way it is at the moment, but we cannot just turn off every nuclear power station. The same applies to agriculture, we cannot just stop producing food the way we are currently doing it. But we definitely have to start working towards the future right now. As you can see in Fig. 1, the population is growing faster than food is being produced.

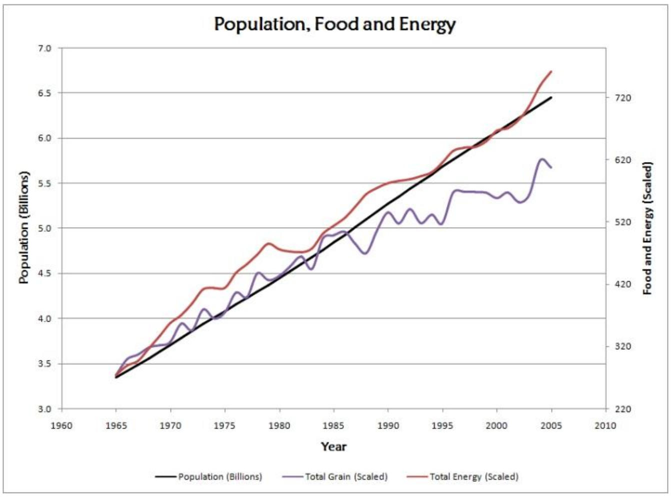

Fig. 1. Food production vs population growth

Currently most of our food is based on previously mentioned monocultures, which, for a fact, cannot all be replaced with conventional farming anymore. The world population is steadily growing and therefore the monocultures are definitely a necessity at the current growth-rate.

The solution for sustainable agriculture are robots. Their abilities range far beyond the simple “removing weeds” or “planting seeds”.

III. Phase I - Planter

Planting is sometimes a very elaborate and inefficient work. There are basically two options: either just throw a few thousand seeds on the floor and hope that maybe ten of them start growing, or dig a trench and then put the seeds in it. Robots can do this in a very efficient way: By permanently observing the size and health of the plants they generate a huge dataset that can be used to determine the best spot for planting. A recent example for this is “Prospero” (Fig. 2), a farmbot that might soon even use swarm behavior algorithms to optimize every inch of a given field [2].

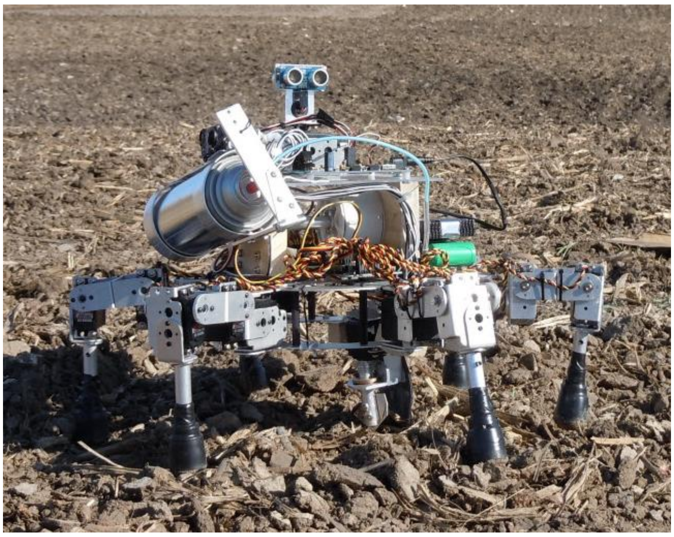

Fig. 2. Prospero farming bot

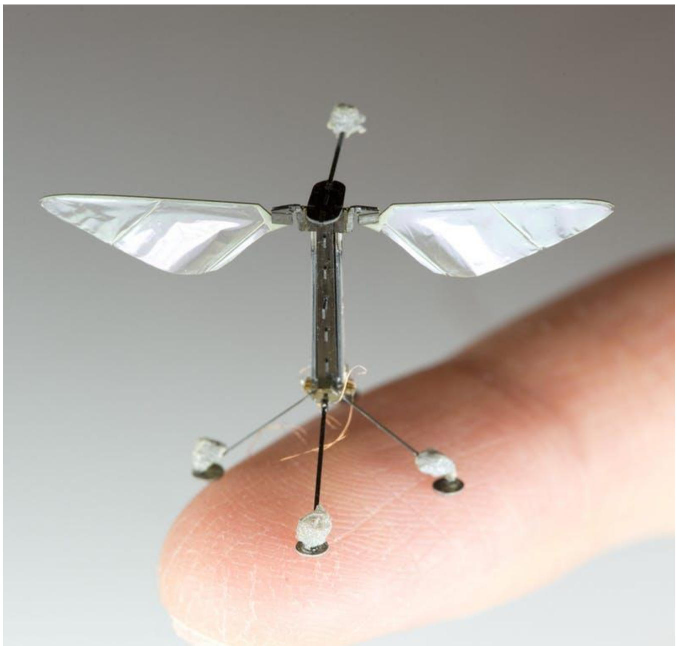

Fig. 3. RoboBee from Harvard University

Another helpful robot is the RoboBee, which can be seen in Fig. 3, from Harvard University. It is an autonomous microrobot that can fly and swim. At its current state, it is only a project of a few researchers, but it might soon help with pollination of plants. The tiny thing weighs less than one-tenth of a gram and is half the size of a paperclip. The motivation of the project was the creation of autonomous micro-aerial vehicles that are capable of self-directed flight and achieving coordinated behavior in large groups [3].

IV. Phase II - Tender

Phase two is probably the most crucial part, since most of the current way of doing this is basically using pesticides. Farming robots can, as stated in IV, permanently observe the plants while they are growing. Meanwhile they can also watch out for insects and weeds. While pesticides are detrimental to the ecosystem and maybe even to our health, robots can reduce the amount of pesticides dramatically, for instance by only spraying areas with huge amounts of weed or by removing the weeds with something like a spade.

Besides the Prospero, drones could also be used to inspect fields. With high-resolution-sensors they could record various data and therefore also reduce water and pesticide usage.

It is important to keep in mind that every crop is different. Grapes are not tomatoes and tomatoes are not corn. Different crops will also require differently measured data. There will not be an ultimate crop solution, instead, farming will be very specific to each sort of crop type.

V. Phase III – Harvester

Harvester robots are already used at many farms. Their basic function is to harvest the fully-grown plants. There are two different systems of these machines: ones that autonomously drive through the fields and collect the fruits and vegetables and those that have to be driven by a person.

The first kind of farming robots are currently mostly “normal” farming machines that have been upgraded to autonomous driving. Although it has to be said that specifically designed autonomous harvesters are currently in development. An example for this are cucumber-harvesters, which have already been developed in 2002. University Wageningen in the Netherlands, did a research project on said machines. With a detection-rate of 95% they had already been able to harvest a big amount of the cucumbers in the greenhouse [4].

The second kind are already wide-spread. A well-known distributor of such machines is Agrobot. The SW6010 (Fig. 4) is an automated strawberry harvesting machine that promises to reduce cost of harvesting by maximizing the efficiency [5].

Fig. 4. Agrobot SW6010

VI. TECHNOLOGICAL ISSUES

Currently one of the biggest problem is the accuracy of GPS. Default GPS-enabled devices have an accuracy of around 5 meters in x- and y-axis. This is by far not enough for accurately planting a previously set field. A workaround is the usage of dual-frequency receivers and augmentation systems. These technologies allow a real-time positioning with an accuracy of a few centimeters up to a few millimeters. These are very expensive and can still be unreliable near high buildings or because of radio interference [6].

Another issue are the high costs and the high service charges for the machines. Since most of the machines are not mass-produced, the machines themselves and spare parts are very expensive. This issue might resolve itself when more companies start producing such machines. If they do not, however, there is little to no hope for a decrease in price.

VII. REQUIREMENTS FOR FARMING ROBOTS

Producing robots that can plant different crops at once is a very difficult task, since, as already stated, every crop is different. Companies will probably have to specialize in specific plant types or even in a specific plant itself to provide functional machines.

The machines should be easy to use and could profit from the internet of things. An example would be a pre-planting drone that monitors the field autonomously and tells the farmer when it is the perfect time for planting. Via an internet connection, this data could be delivered to the farmer’s mobile phone or sent via e-mail.

This is also where the next important aspect comes to attention: autonomous farming should be fully autonomous. Farmers have no intention to study the machine, they want it to be ready by the press of a button. The sophisticated parts of planning and figuring out how to best survey the preset field should be done by the machine.

Permanent status updates are also very welcome, always knowing how the field and the crops are doing, is very helpful. Adding photos or videos of the field would also be a good idea to reassure the farmer that everything is going as planned, or help him spot upcoming problems more quickly.

Another very interesting question is: What are the machines actually looking for? It might take some time to find the right set of data from the huge data cloud. NDVI, Normalized Difference Vegetation Index, is one of many ways to determine the health of a crop. Basically, healthy plants hardly reflect any red light (600-700nm), but therefore reflect infrared light (700-1300nm) very well. Damaged plants also reflect red light and can therefore be easily recognized [7].

Fig. 5. Multicopter from 3D Robotics, mainly used for ripeness analysis

This multicopter (Fig. 5) is an example for the data analysis mentioned. It was built by 3D Robotics and can perform rapid on-the-spot analysis of ripeness.

VIII. EXAMPLES FOR FARMING ROBOTS

Fig. 6. Agribotix Hornet Drone

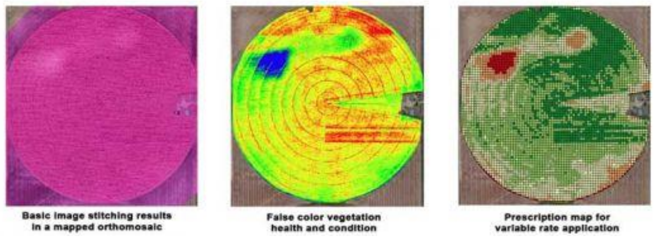

Fig. 7. Example result of an inspection flight

The first example is the Agribotix Hornet Drone, which can be seen in Fig. 6. Its main function is surveillance of the field by generating a previously mentioned NDVI-image of the area. This information enables the farmer to use fertilizer and pesticides more effectively. With a rental price of around 8.000$ per year it is meant to be used on bigger farms.

Fig. 8. ecoRobotix

This machine (Fig. 8) is something very unique: solar powered, it has two robotic arms that inject small doses of herbicides where it is necessary. Advanced weeds recognition algorithms detect the weeds via the camera and then efficiently only put the herbicides at exactly those places. The machine is made by a company called ecoRobotix and will soon be available for about 15.000$.

Fig. 9. Combo-robot that is only available for research

The last example is a combo-robot (Fig. 9), capable of harvesting, moving and hauling asparagus. It features a laser scanner that can identify stalks and then cuts the stalks below the ground with a cutter. Another example is the special treatment of soil where cows urinate, which it can also detect. It is sold to academic institutions and research organization for 12.000$ up to 100.000$ depending on the configuration [8].

IX. Conclusion

To sum it all up, farming robots are the future. Technology has been advancing very quickly for the last few years and will soon make another leap towards revolutionizing agriculture. Some steps have already been made, like the robots mentioned in IX. There is much hope for cheaper and smaller solutions that could be used by everybody. Swarm intelligence might also play a big role in future agriculture, since combining it with big data and analysis of big data could bring up yet unknown patterns of pollution, pesticides and more.

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