Extension of Botball

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***Abstract*—In today's Botball competition the teams can only use two robots to complete tasks and score points. Both robots are ground based and their parts are limited. This paper shows the possibilities and risks of adding a drone to the parts list.**

***Index Terms*—robot, drone, botball, aerial, competition**

I. Introduction

Every year a new Botball game table with a new task is released [1]. Two robots of each team have to solve these tasks. These bots can be individually built and designed for a specific use case. For these constructions the teams have a limited amount of parts which they can use. Each of these parts has its special purpose. In Botball a run lasts two minutes. The robots are trying to score as many points as possible in this short time interval. The problem of the robots is their limit of speed and inaccuracy. The bots can only accomplish one at a time. With the agility and accuracy of a drone it is possible to counter these problems. Therefore the completion of some tasks could be improved by using a drone. This paper lists the advantages and risks of a drone.

II. Concept

A. Seeding

In Seeding the goal is to collect as many points as possible. There is only one team at each game table at any given time, so their robots will not be disturbed by an opponent robot. Points are collected for every completed task. It does not make any difference how the tasks are solved. The scoring only considers the end situation on the game table.

Currently two robots can be used in Botball. One of them is freely built by the team, the other one is using a vacuum cleaner as its base. In summary every robot is ground based.

An additional drone could be used to simplify many tasks in the competition. This drone could work as an observer to increase the consistency of the robots scoring points.

1) Navigation: First, a drone could make the navigation of the robots a lot more precise. The location of the bots is no longer "unknown". From our experience the bots are very inaccurate while they are driving to a different position. This makes it difficult to get to the same position repeatedly with the same code. Of course the code can be optimized until they achieve this goal, but this concept should decrease the need of hard coding and make the runs less fault-prone. Consequently a robot can be located again if it loses its orientation.

Fig. 1: consumer grade drone (DJI Mini 2) [2]

Also the drone can prevent the robots from crashing into each other and falling off the table. While observing the robots, the drone can inform them about their location and their direction to make sure they are on the correct path and not about to run into a threat. The robot can damage itself, while driving or grabbing against fixed pipes on the game table.

Of course there is the opportunity to mount a camera above the game table and give the teams access to it. But this would not be a new challenge for the teams.

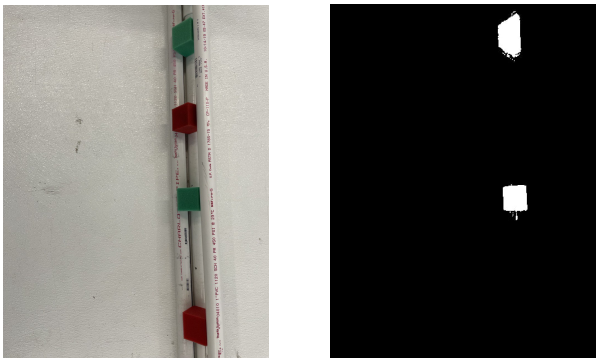
2) Colour Detection: The drone is able to detect colours with its camera. Of course there is a camera, that can be mounted on one of the robots, but the drone has some advantages.

The drone has more agility. Therefore it can travel to different positions faster. So the drone can check the task and then inform the robot, if it is necessary to complete the task. The robot would need a longer time to get to the task and as mentioned before it would be more inaccurate. This can be avoided by using a drone.

For example, there are red and green cubes on this year's game table. The drone can differentiate these two colours from each other, as seen in figure 2.

B. Double Elimination

In Double Elimination two teams compete against each other. The goal is to collect more points than the opponent.



(a) unedited picture (b) OpenCV processed image

Fig. 2: Colour Detection with OpenCV

Each team is allowed to use two robots like in Seeding. It is allowed to sabotage the opponent to make it harder for them to finish their tasks. Of course you can also steal points from your opponent, which can make a great difference.

1) Crash Prevention Concept: We have to consider what happens if two drones fly at the same time. There are two different possibilities to prevent a collision:

One method could be a big plexiglass wall, which would split the airspace. Every drone would then have its own isolated airspace. This will make it impossible for the drones to crash into each other.

Another solution would be flying at two different heights. These heights would be assigned at random. The drones have to fly at the specified height, otherwise the team would get a penalty.

We decided to only use the first method for our evaluation, because with the second variant there remains a possible risk of a collision.

2) Prediction: It is relevant to know what your opponent's strategy is. This advantage can have a big effect on your own strategy and opportunities. With the help of the drone, you are able to locate the opponent's robots, to predict their next steps and to check which tasks they have already completed. For example, there is only one botguy on the table. If the opponent has already grabbed the botguy and brought it on his side, it is unnecessary to try to get it by yourself.

3) Path-planning: In some cases it happens that cubes or other game table pieces are blocking the robots path. These obstacles can cause the robot to lose its path or to get stuck. This would mean that the robot is unable to finish the tasks and is further not able to score any more points. In the worst case this robot also handicaps the second one.

The drone can detect such obstacles and warn the robot. Then it is aware of the danger and can take a different path to get to its destination.

4) Safety: The safety of the bots should be kept in mind. In Double Elimination it sometimes happens that two bots crash into each other, while trying to finish the same task. This crash can damage both bots, leaving them unable to complete other tasks and score points.

With the help of a drone and its camera, it is possible to prevent this kind of accident. Utilizing the information gained by the drone, the robot should be able to navigate around the opponent and avoid a potential crash.

III. Implementation

In order to make it possible for a drone to be a part of the Botball competition, several changes to the game document are necessary. Currently, the game table does not accommodate for the usage of a drone and is inadequate in providing a starting and landing position for the drone. Furthermore, while being in flight, there are not enough visual features for orientation on the game table.

A. ArUco Tag

An ArUco tag is a simplified QR-Code that can be detected by a camera [3] [4]. These ArUco tags always represent an id. This id therefore can then be specified for each relevant object on the game table. The ArUco tags can then be placed onto the objects and the drone can detect the markers attached to the objects. For instance if an ArUco tag is placed on every robot the drone is able to locate the robots and the distance between them. ArUco tags can help the drone to identify objects more easily. The figure 3 shows an example of an ArUco tag.

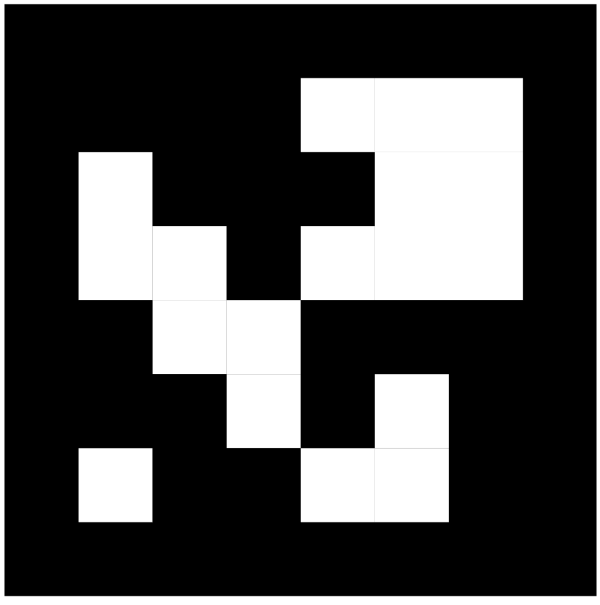


Fig. 3: aruco tag

To improve drones usability in Botball, ArUco tags could be added to the game table and its objects. But not every object has to be marked. It is important to tag areas with ArUco tags, to enable the drone to orientate itself on the gametable.

B. OpenCV

This abbreviation stands for Open Source Computer Vision Library. It provides implementation of algorithms for image processing on a computer. For example, colour detection and ArUco tag detection algorithms are implemented in this library, therefore it is an important requirement in this projects' software [5].

C. Communication

Another important aspect we need to consider, is the communication between the drone and the robots. We achieve this by establishing an wireless connection between the drone and the robots. The drone opens a wireless local area network which the bots can connect to. Over the WiFi protocol all three of them can communicate with each other.

This way of communication has some disadvantages. One of the disadvantages WiFi introduces is the instability of the communication link. Especially in older devices, which use 2.5GHz, only a limited number of channels are available for data transfer. If too many WiFi-devices are transmitting data at the same time, the bandwidth of all connections suffers and the robots might be unable to communicate with each other. If one of the robots loses the connection, there is a routine implemented, which reconnects the bot with the WiFi of the drone. Otherwise the robot should drive into a safe zone, where it cannot disturb the other bot.

D. Risks

The use of a drone also brings some risks with it: For example, the control of the drone has to be guaranteed. Otherwise it can crash into the game table or in the worst case scenario even hurt people.

A crash into the game table would cause a lot of damage to the drone, the game table and its objects and eventually to a robot. Even if no robot has been hit by the crashing drone, the debris could interfere the robots. The bots would lose their orientation and without the drone, are unable to recover from this.

To improve the safety of this new proposed game, teams could be required to implement a "kill switch", which can be triggered manually by a human in case of impending danger. Activating this switch would immediately tell the drone to land and shutdown safely.

This is not the only dangerous situation, that we have to solve. If the programming of the drone is done improperly, it can deliver wrong commands to the robots, causing to stray away from the indented path. Therefore, it has to be guaranteed, that the data coming from the camera of the drone will be processed correctly.

E. Drone Tasks

Of course, there can also be added tasks especially for the drone. One task could be to land in a specified area to score points. This tasks could be made more difficult by detecting a certain color and then land in the associated area. Another one could be to pick up cubes and bring them to their destination area. There are so many opportunities for drone only tasks to be added in Botball.

F. Game Table

In order to make the game table suitable for a new botball game which uses a drone, the table has to be adopted for this purpose. The starting box has to be bigger to fit a starting and landing zone in it.

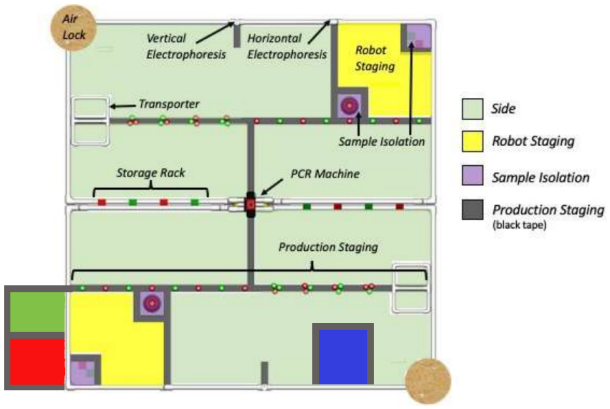


Fig. 4: modified game table

In figure 4 there is an example for a modified game table based on the 2022 game table. The green zone is the starting zone and the red zone is the landing zone. The team will get extra points if the land in the red zone. The blue zone is a possible target for the drone to land in to score points.

IV. Conclusion

As we have shown adding a drone to the parts list, brings a lot of opportunities and risks with it.

A. Time Management

Programming a drone is very time-consuming. It can take hours of programming and testing to start and fly a drone automatically and safely. But even then it can not be guaranteed, that everything will work well. So the time being invested in programming the drone is something that should be considered.

There is a big difference between programming a robot and a drone. The drone has a lot more complexity in it. Starting with the connection to it and the code that has to be executed differs from the robot. A starting and landing zone is needed. It is a bad idea to just turn off the drone, because it can damage the drone. Especially its wings often break easily.

Many of the tasks can also be done without a drone. Until now robots have been driving around the game table without any observer and have successfully completed their tasks.

The amount of time that has to be put into programming another controller should be considered. It may be necessary to give the teams more time for preparation, therefore the game document would have to be released earlier.

B. Costs

The costs of the drone should be considered as well, because drones are not cheap. Adding this part to the parts list would make the botball set even more expensive than it already is. For some teams, this extensions could not be valuable enough to purchase it. This would cause unfair advantages and could make a big difference between teams.

C. Risks

There are risks associated with using a drone, but with the earlier mentioned precautions these risks can be averted.

D. Consistency

The most common problem with the robots is inconsistency. While testing everything works out, but then the program is executed at the tournament and the robots start doing anything except what they were supposed to do. For example, the robots drive in the wrong direction. There is nothing we can do to change this. However, with the help of the drone we are able to inform the robot about its mistake and give it the right commands to get back on its path. This should decrease the amount of bad runs caused by an exception like this.

Sometimes robots tend to crash into each other or into fixed pieces on the game table. In this situation the robots would disassemble themselves. A destroyed robot leaves a lot of work to the team. The construction of a robot occupies much time and while under stress it would even take longer for them to reconstruct it. The drone would prevent the robots from this scenario by warning them about the threat they are running into.

A drone should increase the consistency and efficiency of the robots' runs. The number of accidents and crashes can be reduced, which is something that would definitely be worth considering.

E. Entertainment

Also for the audience it will be a lot more entertaining to watch a drone assisting the Botball robots. A new challenge will make more people interested in the competition. The growing popularity of Botball then will also grow the community around robotics and Botball and this will open new doors for the competition.

F. Overall

Adding a drone to the botball set would revolutionize the whole competition. Of course it brings some risks with it, but it could be the next big step towards the future.

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