The Role of Robotics in Space Exploration and Planetary Research

Ioana-Denisa Barbos
Informatics
HTBLuVA
St.Pölten, Austria
ioana-denisa.barbos@htlstp.at

Tiago Lourenço da Silva
Mechanical Engineering
HTBLuVA
St.Pölten, Austria
tiago.lourencodasilva@htlstp.at

Abstract — In this paper, we will discuss the role of robotics in space exploration and planetary research and about its benefits, like reducing costs, but also about its challenges, which includes communication delays, power and reliability issues. The paper also presents the design and construction of our three robots, used in the competition Open-Botball, which were built to collect samples, transport objects and stack cubes.

Keywords — planetary, research, exploration, robotics, explorers, NASA, autonomous

I. Introduction

Space exploration and planetary research have always been areas of great interest for scientists and researchers. However, discovering and studying other planets and celestial bodies is not a particularly easy task, and it requires advanced technology and equipment. The field of robotics has significantly contributed to space exploration and planetary research, providing a wide range of possibilities that would otherwise be impossible with human exploration alone. Since the early days of the space program, robots have been utilized to explore and gather data of planets, moons, asteroids, and other celestial bodies. The advancements in this kind of technology have made it possible for these machines to perform complex tasks and even operate autonomously in harsh and remote environments. This paper will examine the role of robotics in space exploration and planetary research and highlight the benefits and challenges of this technology, but also present the implementation based on this concept in our robots for the competition Open-Botball. [1]

II. Concept and Design

One of the similarities that we have with the planetary robots is sample collection. There are many methods on how you can do it. One of the most obvious ways is to use some kind of hand. Usually, a very simplistic adaptation of one suffices to get the job done. Probably the easiest way is to have one stationary “finger” and one attached to a servo. That way, the movable one can press the sample against the stationary one, resulting in a grabbing motion.

In our case it was good enough to pick up the “samples” on the board. All three of our robots needed some sort of grabbing mechanism, so it was a central part in the development process. Robot 1 and Robot 3 both use the above mechanism. Although it would have made the construction much easier, it was not practical for Robot 2. This robot was supposed not only collect the Botgal and the yellow cubes, but it was also tasked with stacking the cubes. For this reason, it was necessary to use a symmetrical system, that would be precise in the release of the grabbed cubes. Additionally, it was a goal of ours to make it work with only one servo, because it was both strong enough and made the programming part much easier.

In the case of Robot 1 the task was to pick up the Wireshark and transport it across the game table. The main struggle here was the ridge along the middle of the board, because of which, it was necessary to lift the Wireshark up a little.

Last but not least, there was Robot 3. Its job was simple. It had to drive forward to the red cube in the corner, grab it and drive backwards into the other corner. Therefore, only one servo was necessary.

III. Implementation of Sample Collection for Open-Botball

In Robot 2 and Robot 3 the grabbing mechanisms were a central part of the robot, so they were designed first, and then came the rest around it. Due to the high server racks on which the Botgal and the cubes were situated, the grabber in Robot 2 needed a way up and down. Therefore, a Winch system and sled were built. The winch consisted of a motor and a 3D printed coil. The sled was a part of the gripper and was built from Lego due to its perfect size for our needs. As mentioned earlier, the gripper was built with only one servo. This was connected to the “fingers” using gears, allowing them to move symmetrically. As the dropping of the cubes was not as stable and consistent as wanted, a secondary pair of “fingers” was added. Its job was to guide the cubes during the stacking process.

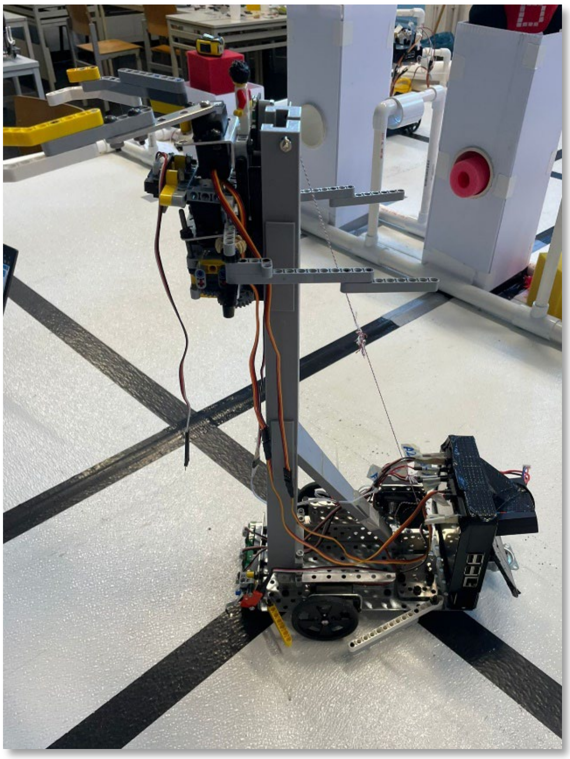

Figure 1: Robot_2

Contrasting this rather complicated assembly was Robot 3. Due to its simple task, it could be a very small robot with only one motor and one servo. The motor is the propulsion of the robot, and the servo is a part of the gripper. The rest of it are one stationary and one movable “finger”. The stationary one is attached to the chassis and the movable one to the servo. That way, both the construction and the programming of Robot 3 was rather simple.

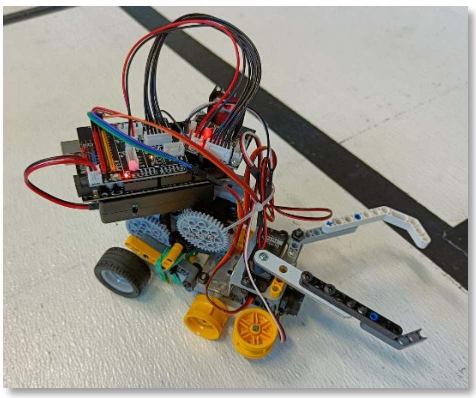

Figure 2: Robot_3

The implementation in Robot 1 was a little different. In this case the Wireshark not only had to be held tight, but it also had to be lifted. The entire Robot 1 was 3D printed, so some mounting brackets were included in the chassis, facilitating the assembly process. Because the robot already had a part that is being raised, the gripper was attached directly to it. This saved space and servos. Just like in Robot 3, there are one movable and one stationary “finger”. The entire fingers are made of Legos. For the stationary “finger”, holes with the same size as the ones in equivalent Lego parts were included in the 3D printed body of the robot. This was done to make the assembly and maintenance easier.

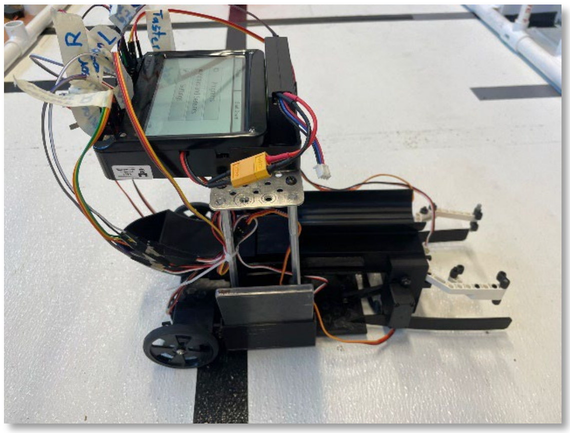

Figure 3: Robot_1

IV. Results

A. Benefits of Robotics in space exploration

The use of robotics in space exploration offers several advantages over traditional manned missions. One of the most significant benefits is reducing costs. Robotic missions are typically less expensive, as they do not require life support systems, food, sleep or other resources necessary for human survival. This makes it possible to explore more locations in space with the same budget. [2]

Another significant advantage of using robotics is that it eliminates the risk of human life in hazardous environments. Robots can be sent to explore planets with extreme temperatures, high radiation or toxic atmospheres without endangering human life. For instance, NASA’s Venus Exploration and Analysis Group is developing robotic explorers that can withstand the high temperatures and pressure on Venus. The explorers can provide valuable data on the planet’s geology and atmosphere. This mission aims at understanding how Venus became an inferno-like world and investigate how it developed differently than Earth. The robots will use a form of radar to examine surface elevations and will discover if volcanoes and earthquakes are still happening.

In addition, robots can remain operational for extended periods, allowing for continuous data collection and analysis. They can be programmed to perform a wide range of tasks, such as collecting samples, taking photographs and performing experiments. Robotic missions can be controlled remotely from Earth, allowing scientists to respond to unexpected discoveries.

B. Robotic sample return missions

Robotic sample return missions are another significant contribution of robotics technology to space exploration and planetary research. These missions are designed to collect samples from a planet or moon and return them to Earth for analysis. Different sample collection methods were also used on our robots. This is extremely important in cases where the sample cannot be analyzed on site or where a more detailed analysis is required. [3]

One example of a robotic sample return mission is NASA's "Mars Sample Return", which is an effort to bring samples of Martian rocks and soil back to earth, where they can be thoroughly inspected. The mission is planned jointly with the European Space Agency.

C. Robotic explorers

Robotic explorers are also known as planetary rovers. These machines are designed to travel across the surface of a planet, gathering data and conducting experiments.

One of the most famous robotic explorers is NASA's Mars Exploration Rover mission, which launched in 2003. The mission consisted of two rovers, Spirit and Opportunity, which landed on opposite sides of Mars. The rovers were designed to operate for 90 Martian Solar days, but they ended up exceeding their expected lifespan by several years. Spirit was active until March 22^{nd} 2010, while Opportunity was active until June 10, 2018. During their time on Mars, they traveled a total of 45 kilometers and made numerous discoveries concerning the planet's geology and history. [4]

D. Planetary Defense

Another important application of robotics in space exploration is planetary defense. Asteroids and comets pose a potential threat to Earth, and robotic explorers can be used to study them and develop strategies for deflecting or destroying them, if necessary. [5]

E. Autonomous Robots

Autonomous Robots are another significant development in robotics technology, that has contributed to space exploration and planetary research. These robots are designed to operate without human intervention, using artificial intelligence and other advanced technologies to make decisions and carry out tasks. Autonomous robots are particularly useful in situations where communication with Earth is difficult or impossible, such as when exploring the far side of the moon. [6]

F. Challenges of Robotics in Space Exploration

While the use of robotics in space exploration offers substantial benefits, it also presents several challenges. One of the most significant challenges is the complexity of the technology required to build and operate space robots. These robots must be able to operate in extreme environments and withstand the harsh conditions of space. This requires specialized materials, advanced electronics and sophisticated software.

Another major challenge is the communication delay between Earth and space. The distance between Earth and planets such as Mars can be substantial, resulting in communication delays that can last several minutes or more. This delay can make it difficult to control robots in real-time and respond to unexpected events.

In addition, the autonomy of robots can pose challenges, particularly when it comes to decision-making. Robots must be programmed to make decisions based on limited data, and their decision-making algorithms must be able to adapt to changing circumstances.

V. CONCLUSION

The use of robotics in space exploration and planetary research has revolutionized our ability to explore and understand the universe. The benefits of using robots, such as cost savings and the elimination of human risk, make it possible to explore more locations in space and gather valuable data. However, the challenges of building and operating space robots must be addressed to ensure the success of future missions. Despite the challenges, the use of robotics in this field will undoubtedly continue to play a crucial role in advancing our understanding of the universe and our place within it.

This competition also helped to realize the importance of robotics in general, because we would not have learned about topics like constructing and programming robots, and thus, we would like to thank for organizing the “European Conference on Educational Robotics” (ECER) [1], including the Botball, Open and Aerial competitions.

VI. Aknowledgement

This outcome would not have been possible without our teacher and advisor Johannes Tomitsch. He made the participation on the ECER possible and helped us with some advice and details. Special regards to the HTL St. Pölten for letting us use the laboratory room.

VII. Resources

[1] ‚ecer,“ 2022. [Online]. Available: https://ecer.pria.at/. [Zugriff am 04 03 2023].

[2] "Space_Place," 05 02 2021. [Online]. Available: https://spaceplace.nasa.gov/space-robots/en/#:~:text=Sending%20a%20robot%20to%20space,things%20that%20humans%20can%27t. [Accessed 04 03 2023].

[3] „nasa_jpl,“ jpl.nasa.gov, [Online]. Available: https://www.jpl.nasa.gov/missions/mars-sample-return-msr. [Zugriff am 04 03 2023].

[4] „wikipedia,“ 10 02 2023. [Online]. Available: https://en.wikipedia.org/wiki/Mars_Exploration_Rover. [Zugriff am 04 03 2023].

[5] „nasa,“ 2021. [Online]. Available: https://www.nasa.gov/specials/pdco/index.html#:~:text=in%20your%20browser.-,Planetary%20Defense%20at%20NASA,address%20the%20NEO%20impact%20hazard. [Zugriff am 04 03 2023].

[6] „frontiersin,“ 15 12 2022. [Online]. Available: https://www.frontiersin.org/articles/10.3389/frspt.2022.1080291/full. [Zugriff am 04 03 2023].