3D printed Robot Dog Walking on Terrain for STEM education

Intermediate Report

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1. Project Background

1.1. Quadruped robot

1.1.1. Definition and relevant background

At present, quadruped robot is usually defined as a robot that has four legs and can walk autonomously similar to quadruped animals. Similar to other robots, quadruped robot is also composed of robot main body, drive system and control system. It mainly has certain technical requirements for high sensitive sensor, high performance drive motor, control module, power module and so on.

In terms of development history, the research on quadruped robots began in the last century. M. Raibert of MIT developed the first quadruped robot that could walk and run and was fully dynamic and stable in 1986, and founded Boston Dynamics in 1992 to design large quadruped robots for the U.S. Department of Defense and the Army. Subsequently, Japan's Toyota, Honda, SONY and other automotive and electronics giants have also set up relevant departments to conduct research on quadruped and multi-legged robots.

In China, however, relevant research started relatively late, with the first generation of products only successfully developed in 2010. However, the development speed is relatively fast. At present, the representative enterprises are international well-known brands like Unitree Robotics, Weilan and other Internet giants like Tencent, XiaoMi and so on.

1.1.2. Features and related application value

The biggest feature of the quadruped robot is simple structure, strong stability, strong passability, and wide application scenarios. Compared with 6-legged and more-legged robots, it has a simpler structure, can achieve a more compact layout and a relatively lower complexity and failure rate. Compared with biped robots, it has lower technical requirements and stronger stability.

In terms of practical applications, the value of current quadruped robots is mainly reflected in military, commercial and special industries related fields. A small number of products have also begun to experiment with some consumer-grade products.

Military: heavy object transport, unmanned reconnaissance, wounded rescue under complex terrain, etc.
Public safety: on-site assessment, remote operation in hazardous environments
Industrial production: patrol and early warning in the production, detection and data
collection in a specific risk environment, etc.

Consumer level: family security, medical escort, etc.

1.2. STEM education on quadruped robots

1.2.1. STEM definition

STEM is an acronym for Science, Technology, Engineering and Mathematics. STEM programs focus on strengthening education in four areas: scientific literacy, which is the use of scientific knowledge (such as physics, chemistry, biological sciences and geospace sciences) to understand and participate in the processes that affect nature; Technical literacy, which is the ability to use, manage, understand and evaluate technology; The third is engineering literacy, that is, the understanding of technical engineering design and development process; The fourth is mathematical literacy, which is the ability to discover, express, explain and solve mathematical problems in various situations.

1.2.2. The value of using quadruped robots in STEM education

Quadruped robot is a topic that has been widely discussed and recognized by the public in the field of robotics. It has a certain foundation and strong attraction in STEM education.

The construction of quadruped robot is relatively comprehensive, which can well exercise the educational needs of different dimensions in STEM fields.

The basic technology of quadruped robot has been much mature after decades of development. Combined with 3D printing and Arduino hardware platform, it is easy to realize the development of related functions. Which means it has the possibility of STEM education practice.

1.2.3. Limitations of existing content

At present, the existing content is relatively shallow, which only realizes the very basic functions of quadruped robot: walking, steering, etc.

In order to meet the higher level of STEM teaching needs, it is necessary to expand and improve related functions.

1.3. Possibility of complex terrain

1.3.1. The importance of this function
Passibility is one of the biggest characteristics of quadruped robot. Therefore, research in this direction is more in line with the public expectations for quadruped robots.

1.3.2. Research value

The realization and improvement of complex terrain passibility involves almost every aspect of STEM knowledge. Moreover, this function have certain requirements especially in the sensor, control module, algorithm and others, which can be a good exercise of the ability in these aspects.

2. Project Objective

2.1. Enhancing the passibility of existing quadruped robots

Existing quadruped robots kit for STEM education has realized basic functions such as walking and steering. The core of my project is to realize the walking ability of quadruped robot in complex terrain based on the existing kit and algorithm, and try to expand more educational function.

2.2. Produce the content suitable for STEM education

Other than realization of core functions, I will also disassemble and summarize the technical points involved in the process, and carry out modular transformation. For example, the balance function, algorithm construction, abnormal case processing and other contents are divided into several thematic modules. And then disassemble corresponding technical requirements and implementation methods respectively. In order to achieve more flexible, more detailed STEM education needs.
3. Project Methodology

3.1. Learn the existing quadruped robot and related algorithms

With the development and maturity of quadruped robots, there are a lot of open source contents (including 3D printing models and algorithms, etc.) for me to learn. At the very beginning of this project, I will build a more comprehensive understanding of quadruped robots by learning these contents. And I will also try to achieve the basic function of quadruped robot by myself.

3.2. Develop programs and algorithm to enhance passability

After preparing enough relevant knowledge, I will further study and analyze the existing kit and began to expand related functions. In this process, I will focus more on sensors, data processing methods, algorithms and other aspects needed for walking on complex terrain, and constantly improve the core functions.

3.3. Modular disassemble based on principles behind

After realizing the improvement of core functions, I will integrate and transform the important and relevant contents. Through the classification and collocation of important modules to facilitate STEM teaching.

3.4. Develop instructions and related tools for STEM education

I will prepare related STEM education content and guidance for the split modules. And began to make necessary auxiliary explanatory tools, such as walking algorithm demonstration. Enhance the convenience and value of this function in STEM education.
4. Tasks completed in the 1st semester

4.1. Study open source project

At the beginning of the first semester, I found an open source project by myself and bought some equipment related to it for assembly and learning. This open source project is much simpler than the robot dog kit in the Makerlab. It uses Arduino nano board and supports some very simple actions. In this process, I mainly learned about the basic manufacturing process of robot dog and the material types needed (such as a certain type of 180 degree servo motor). At the same time, I used this small project to learn basic Arduino programming. Finally, I also understand the basic walking principle of quadruped robot through its mechanical structure.

![Image of open source project and quadruped robot](image)

4.2. Study existing project

After the first stage, I started to make robot dog formally. I first communicated with Dr. David for several times and focused on learning the operation principle of the existing program. The most important parts are how ESP32 board run arduino programs and special programming requirements, adding necessary runtime libraries, etc. At the same time, I also focused on learning the function and significance of each part of the existing code, which helped me better conduct subsequent function test and calibration process. Finally, I also focused on the use of MPU module and do several test to find how it works and what data it can obtain. Lay the foundation for the subsequent development of related programs.
4.3. Learn 3D printing

After I get an overview of the project, I began to learn 3D printing related technologies and operations. In this part, I mainly learned process involved in the 3D printing including the use of Cura software, configuration of various printing parameters, modification of 3D model files, and etc. At the same time, Through the process of printing components of robot dog, I better understand the processes of 3D printing and matters need special attention. For example, The picture in the lower right corner is one of the parts that I failed to print, because I put the position of the file too close to the edge, which caused the parts of the printer to affect the printing process. After summarizing the reasons, I did not have similar problems in my subsequent printing.
4.4. Assembly and calibration

The last part is I completed the assembly and calibration of the robot dog during the winter vacation.

In this period, I first used a small size of robot dog to familiarize myself with the installation process. Through a small size verification, I fully understand some points and key problems that are easy to occur in the installation process, such as I need to install the servo motor while it is power on, and can only turn it by hand when it is power off. This saved me a lot of time and equipment during my subsequent full scale assembly. This verification process is very meaningful, and I will consider related operations in similar situations in the future.

After that, I successfully assembly the full scale robot dog, and at the same time completed the calibration of each servo motor, which corrected some small errors that could not be avoided in the installation process.
5. Plans for the 2\textsuperscript{nd} semester

5.1. Develop basic functions

In the first stage, I will modify the existing code of the robot dog to make it capable of walking on uneven ground. In the previous study, I learned that it is necessary to collect various uneven data in real time through the MPU module and calculate the corresponding angle of each servo motor on each leg through a proper algorithm. The core of this stage is building the algorithm to combine the adjustment and the original walking, and that's where I'm going to give it the most priority. In addition, I plan to distinguish this ability from the original state as an independent function, and its selection can be controlled through wiring or APP, so that people can better compare the influence brought by this function.

5.2. Make demonstration for STEM

In the second part, it is more about the demonstration of this new feature to achieve the purpose of STEM education. For this aspect, I have two improvement plans at present.

5.2.1. MPU function demonstration

The first one is that I will try to demonstrate the MPU module function by using two robot dogs, one big and one small. The specific design is that by designing a new part and making it by 3D printing, the big Robot Dog will have a platform that can carry the small robot dog. By using MPU and combining real-time computing, Small Robot Dog can stay stable on it all the time. The users can freely control the big robot to make various movements to change the posture of the platform. Such a design mainly reflects that we can achieve stability through the MPU module. Walking on the uneven terrain can actually be understood as the superposition of the movements as well as calculations made by the two robots at the same time. It can help STEM learners better understand the relevant principles.
5.2.2. Image transmission system integration

Another design is to try to integrate the image transmission system into robot Dog, so that the users can intuitively feel that there is a great difference in walking on uneven ground whether stability is turned on or not. This idea mainly comes from one of my hobbies. I usually play FPV drone and I find that people's feelings regarding ups and downs and rotation can be amplified through the first-person view.

Besides, as it is a very special perspective, it is relatively more attractive to STEM learners. Thus I believe that this approach can better help STEM learners realize the value of this function.

5.3. Prepare materials and instructions for STEM

Finally, I will prepare some easy to understand materials and instructions to help people understand the relevant content and further improve the experience of the STEM education regarding the functions I developed.
6. References

- [1] Development of quadruped walking robots: A review

- [2] What is STEM Education?

- [3] Defining STEM
  https://www.fldoe.org/academics/standards/subject-areas/math-science/stem/defining-stem.shtml