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Design & Development of A 6 DOF Bipedal Robot with Imitation Learning

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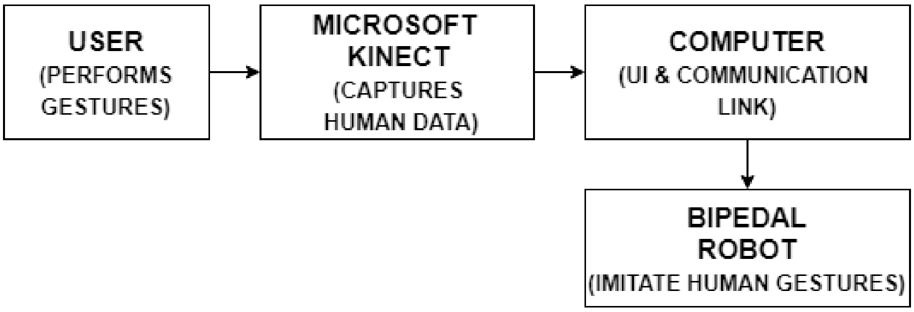
Abstract - Real-time remote operation of humanoid robots is a very interesting area of research through the detection and monitoring of human motion. This document mainly designs a remote humanoid robot control system based on Kinect sensor. The manipulator can simply communicate with the computer by simply relying on the movement of the body to control the movement, coordination and coordination of the remote robot in real time. The design combines new methods such as human motion capture, intelligent agent control methods, network transmission, and multi-sensor fusion technology. This document analyzes the key technologies used in the system. The theory and method proposed in the paper were tested experimentally. The experimental results show that the control system of the humanoid robot is correct and feasible.

I. INTRODUCTION

The robots are found in practically all areas of manufacturing, military, mining, space and health care. Since these robots can function in the same human environment without any modification, much research is being done to develop and use anthropomorphic robotic robots in these departments. The robots have begun to run in human shared spaces, in increasingly personal and social tasks. Regardless of the field of application, one of the main problems found in humanoid robots is the understanding of the processing of human information. Even today, most robots cannot respond adequately to the actions and actions of human partners, which is essential in a dynamic social environment. Therefore, the development of adaptive learning algorithms is fundamental to guarantee the behavior of the robots related to the interaction of the human robot. There are some learning models that are implementing adaptive behaviors such as imitative learning, reinforcement learning or demo programming. Learning to imitate is a promising way for humanoid robots to infer and learn new human behaviors and abilities in the same way that infants and human adults learn from each other by observing each other. In this project, our goal is to design and develop our own humanoid robot and teach it to respond to human gestures. Human gestures will be taken by the Kinect camera. The recorded data will be processed to analyze the gestures made and effectively train the robot to respond to gestures with the help of various learning agents.

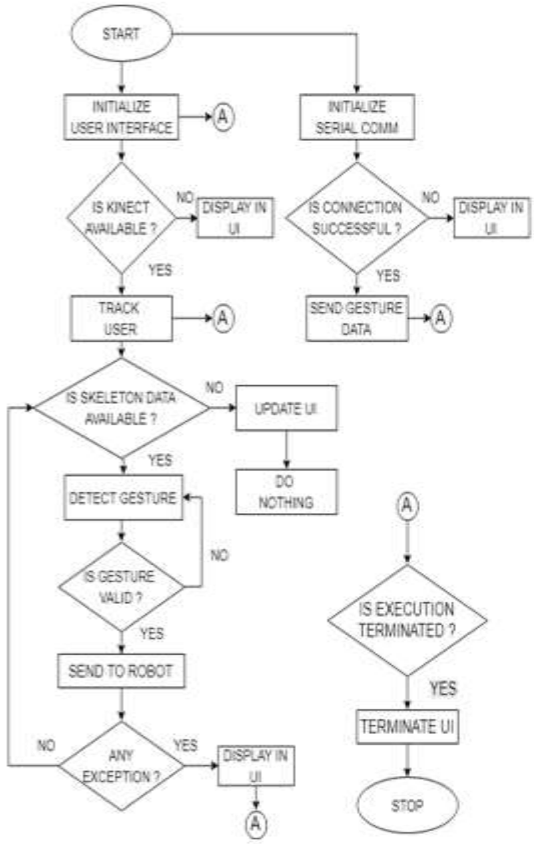
I. SYSTEM LEVEL BLOCK DIAGRAM



The real-time remote operation of humanoid robots by detecting and monitoring human movement is a research entry point. In our project, we are designing a biped walking robot that can be controlled by human gestures. His planning of the march and the cinematic investigation is fundamental to allow that the robots realize controlled and stable movements (like walking forwards and backwards, to turn towards the left and towards the right, to kick, etc.). Given that the recognition of gestures is one of the key areas of research, our goal is to use RGB-D cameras, such as Kinect sensors, to track human movement and implement it in the developed bipedal structure.

II. WORKING OF THE SYSTEM

The user stands in front of the Kinect sensor. The algorithm reads images from Kinect's frame buffer. Images read from the frame buffer will be processed to extract features such as hip angle, knee angle and toe. The extracted data will be sent to the biped robot control unit via the communication link. The necessary mechanisms for handling and retransmitting errors will ensure reliable communication. The data is then received by the biped robot control unit. Will verify if there is any wrong information. If the received data is correct, the communication link will send an acknowledgment about the correct receipt of the data. The control unit then rotates the servo motor at the received angle. After all motors have reached their final position, the control unit sends another confirmation indicating that the assigned task has been completed. The previous steps will be repeated until the operator leaves the program.

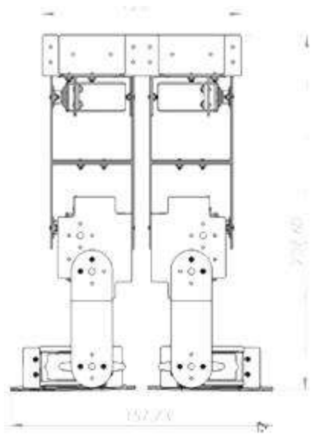


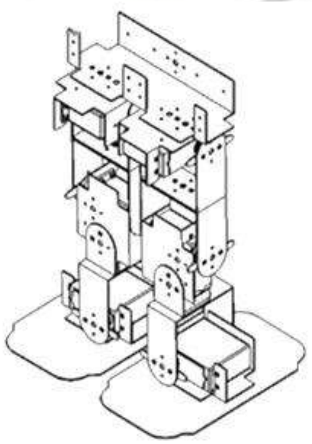
III. HARDWARE DESIGN AND IMPLEMENTATION

The design of the project includes two mechanical structures with a minimum configuration of the human legs to perform basic gestures. This chapter describes the hardware design and the implementation of the developed robot. The hardware design can be divided into two parts, namely:

1. Mechanical Design & Implementation :

The design of the robot as described above should support at least the basic minimum configuration of the human leg and perform the movement accordingly. Considering several robot designs, the implementation of six degrees of freedom robots was effectively completed. Figure shows the CAD model and the assembled robot.





The robot is modeled in Solid Works. The designed bipedal robot has 2 legs and 3 degrees of freedom for each leg. Each leg consists of three links, one for the hips, knees and feet. Each link has a degree of freedom. The link uses a servomotor to move. The robot also has an upper body that contains all electronic circuits.

2. Electronics Design & Implementation:

The electronic circuits to be included in the robot must perform the following tasks:

1. Provide optimal power for all devices connected to the system, such as actuators, regulators, etc.

2. After receiving the appropriate command from the system UI, process the relevant data and perform the move accordingly.
The electronic hardware used in the system is as follows:
1. AT-mega 2560 development board.
2. Servo motor NRS995
3. The power supply unit consists of SMPS and buck converter
4. Kinect V2 camera

IV. SOFTWARE DESIGN AND IMPLEMENTATION:

The proposed system communicates the gestures made by the person tracked to the robot. The Kinect V2 camera has been used to track humans. To detect gestures, the Visual Gesture Builder (VGB) package from Kinect SDK has been used, which uses machine learning concepts for gesture detection. Gestures can be divided into discrete (for example, Hello, Namaste, etc.) or continuous (for example, walking, kicking, etc.). Visual Gesture Builder uses the ADAPTIVE BOOST TRIGGER (ADA-Boost) algorithm and the Random Regression Regression (RFR) algorithm to detect discrete and continuous gestures, respectively. Once gesture recognition is complete, the same gesture recognition should be displayed in the user interface. The UI interface shows 8 images depending on whether a gesture has been made. The list of gestures includes 8 basic human gestures, such as standing, squatting, sitting, lifting legs and bending backwards.

1. ALGORITHM:

ADA-Boost, short for "Adaptive Boost", is the first practical pulse algorithm proposed by Freund and Schapiro in 1996. It focuses on classification problems and aims to convert a set of weak classifiers into strong classifiers. The final equation of the classification can be expressed as:
Where FM represents the weak MTh classifier and theta is the corresponding weight. It is the weighted combination of M weak classifiers.

$$F(x) = sign(\sum_{m=1}^{M} \theta_m f_m(x)),$$

The entire process of the ADA-Boost algorithm can be summarized as follows:

Given a set of data that contains n points, where:

$$x_i \in \mathbb{R}^d, y_i \in \{-1, 1\}.$$

Here -1 represents a negative class and 1 represents a positive class.

Initialize the weight of each data point to:

$$w(x_i, y_i) = \frac{1}{n}, i = 1, ..., n.$$

For the iteration m = 1... M:

1. Set the weak classifier to the data set and select the classifier with the lowest weighted classification error:
2.

$$\epsilon_m = E_{w_m}[1_{y \neq f(x)}]$$

3. Calculate the weight of the weak classifier mestizo:
4.

$$\theta_m = \frac{1}{2} ln(\frac{1 - \epsilon_m}{\epsilon_m}).$$

For any classifier with a precision greater than 50%, the weight is positive. The more accurate the classifier, the greater the weight. For classifiers with less than 50% accuracy, the weight is negative. This means we combine your predictions by turning the symbols. For example, we can increase the accuracy of the classifier by 40% and the accuracy to 60% by flipping the predictive symbols. Therefore, even if the classifier is worse than the random hypothesis, it will help the final prediction. We just don't want any classifier with 50% precision, it doesn't add any information, so it doesn't contribute to the final prediction.

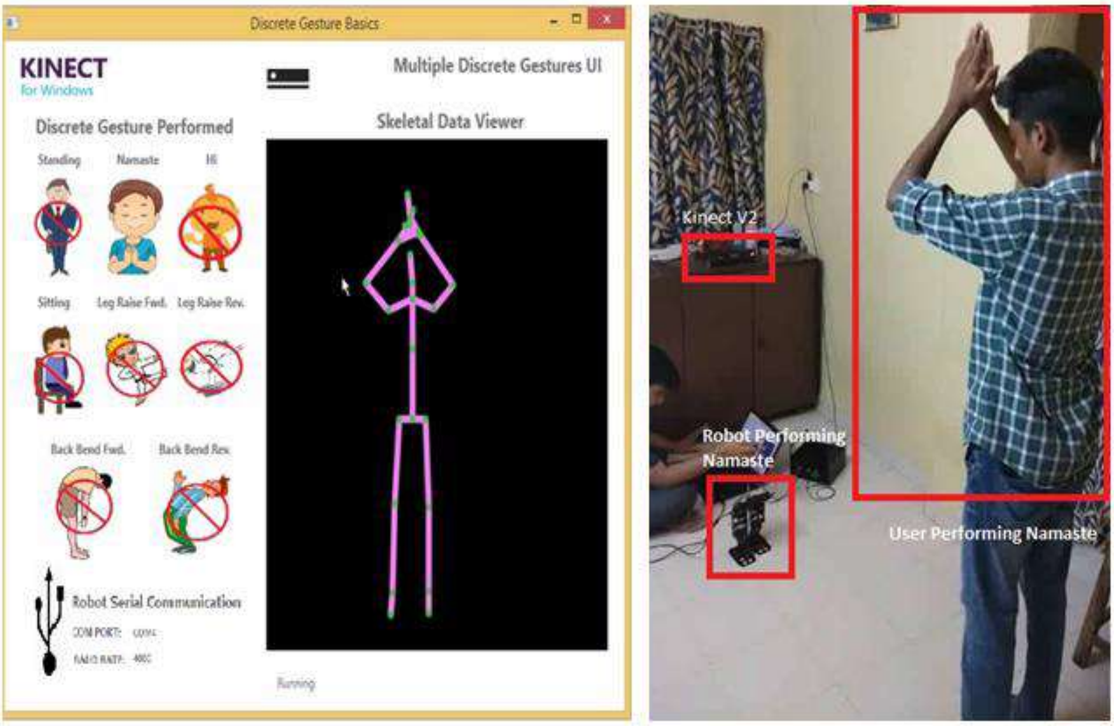
5. Update the weight of each data point to:

$$w_{m+1}(x_i, y_i) = \frac{w_m(x_i, y_i)exp[-\theta_m y_i f_m(x_i)]}{Z_m},$$

Where Zm is a normalization factor that ensures that the sum of all the instance weights is equal to one. If the classification error comes from a positive weighted classifier, the term "exp" in the numerator will always be greater than 1 (and * f is always -1 and theta is positive). Therefore, cases of misclassification will be updated with greater weight after the iteration. The same logic applies to negative weighted classifiers. The only difference is that after flipping the flag, the original correct classification will be misclassified. After the M iterations, we can obtain the final prediction by summarizing the weighted predictions of each classifier.

RESULTS.

This section describes the results of the project. The tests have shown that the imitation is in real time, however, sometimes, due to the limitations of the machine that performs the test, the software sometimes gets blocked, resulting in an unexpected delay in the imitation of the gesture of the robot. As the process is completed, the serial communication part becomes the program flow. However, this problem still exists, and sometimes there is a map. This figure shows the robot imitating the 'Namaste' gesture, referring to the human 'Namaste' made by the user interface, and showing the imitation gesture of the robot in real time when the user raises his leg and lifts his leg forward.



The power consumed by the robot can be easily measured by the power unit. The power supply unit has two pairs of plugs that can be easily measured using a voltmeter and an ammeter. Typically, the robot consumes approximately 1.3 A at 7.36 V supply voltage, resulting in approximately 10 W of energy consumption.

CONCLUSION

This project describes the design of a 6-DOF bipedal robot controlled by human movement captured by a Kinect V2 camera. For better results, the system can run on a GPU instead of a normal processing machine for better speed. Tools such as CUDA and Open CL can be used to generate more optimized programs. Bipedal robots can be designed without further ado. The degree of freedom allows robots to imitate complex and varied gestures. If you use mature human robots like Darwin Junior, Bio-loid, Nao, you can imitate a better exercise. Low-power wireless connectivity methods such as Zig-Bee, Bluetooth, Wi-Fi or RF modules can be used to remotely control the robot.

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