S.M.A.R.T DOCUMENTATION

PROJECT NAME - S.M.A.R.T - Simulation, Monitoring and Augmented Robot Training

FRAMEWORKS - Unity Game Engine, Vuforia Augmented Reality SDK, Arduino, Sockets, Serial Communication

PROJECT DESCRIPTION -

*Objective -*

Robots were developed to automate and ease out human labor especially in areas involving repetitive tasks eg. the Manufacturing Industry, Healthcare. However, programming, monitoring and attending each and every robot is a tedious task and requires well-trained robot operators. Our work is focused mainly on two domains -

* Robot Control and Programming -

Programming a robot to perform a required task is extremely crucial to its functionality but it requires proper training. Currently, an operator is trained to do the job of programming these robots in two ways. The first way is through the use of bulky simulators, which are not readily available and are extremely costly. The Second way is training by another trained operator through practical demonstration.

We feel that both of these approaches have their own flaws. In the first one, the trainee is not able to get an actual feel of the system as everything is contained within a screen. In the Second Approach, although the trainee can visualize what is happening on the actual robot, one cannot freely experiment with the system by giving a plethora of instructions as this might damage the actual robot. So, our system aims to combine the flexibility of a simulator with the visualisation power of an actual system into an Augmented Reality Powered Mobile Application.

* Real-Time Robot Monitoring -

Other than Programming, monitoring a Robotic System is another vital issue we want to simplify. There is a need to monitor any robotic system and control it in case of any discrepancies. This requires continuous real-time visual monitoring of the system. Since there are multiple such systems in an industrial plant, coordination and collaboration are essential to automate the production line. Monitoring such a cluster of robotic systems thus requires a dedicated and alert team. Therefore, not only is this process tedious, but it also requires a lot of human effort. Therefore, our solution aims to address this problem by introducing Real-Time Augmented Reality Based robot Monitoring.

This technology will enable the robot operator to monitor the working of the robotic system anywhere and will act as a portal for mediation.

IMPLEMENTATION -

We aim to solve the problems mentioned above by using an Augmented Reality based Smartphone Application. For a demonstration of the Digital Twin, we have built a 3 DOF (Degrees of Freedom) Robotic Arm using Servo Motors. This robot is connected to an Arduino board. The Arduino is connected to a control PC and sends/receives data through serial communication. The PC is connected to the a which is hosted online. The server acts as the link between the PC and the User Smartphone. The server is based on Socket Programming. Details of our implementation can be divided into two parts -

* Robot Control and Programming -

To address this problem we developed a digital twin of an actual robot ( an Arduino based robotic arm for prototyping purposes). The user can learn how to operate the arm ( via programming ) on the “ Virtual Arm Twin “ by entering a set of commands and pressing the Visualize Button on the Smartphone Application. This will cause the Virtual Arm to execute the given instructions. If the user is satisfied with the response, the commands can then be sent to the actual robot wirelessly. This Virtual Arm can be accessed by the operator anytime and anywhere by opening the Application on a Smartphone and facing its camera towards the Marker provided. The Commands can be typed in the Smartphone Application itself. As an additional feature, we have added a “Virtual Lathe Machine” to highlight the versatility and scalability of our System. The user can select the Lathe Machine Option in the Main Menu and visualize the commands given to the Machine in Augmented Reality. There is no Send Button for this Machine since we didn’t have access to such a sophisticated System.

* Real-Time Robot Monitoring -

The Operator/Manager can monitor the actions of the Actual robotic Arm from our Smartphone Application directly. The Arm communicates with the Application wirelessly through a web Socket Connection over a server. All the user needs to do is to hold the Smartphone facing towards the Marker of the Virtual Arm and press the Monitor Button on the App. Then the Virtual Arm will start moving according to the movements of the Actual Arm. Basically, it is a Real-Time Object Tracker.

APPLICATIONS -

Our system has a wide variety of applications ranging from domains such as Industry, education, and healthcare to name a few. Due to time constraints, for our demonstration, we have currently focussed on robot operators in industry - to help them in training and monitoring of Robotic Systems. We have successfully developed an end to end solution for 3 DOF (Degrees of Freedom) Robotic Arm System and also provided a flavor of how such visualization can be extended to a wide variety of Machines through our demonstration of the Lathe Machine. The system is highly scalable and can be used for a variety of Robotic Systems such as CNC machines, Surgery Robots, etc.

FUTURE WORK -

In the future, we plan to -

* Improve the system to incorporate monitoring and visualization of multiple robots arranged in a production line simultaneously
* Develop an App exclusively for training Doctors in Robotic-Assisted Surgery
* Store data over the server to keep track of System Health

INSTRUCTIONS -

1) Download and Install the .apk file from the Repository link provided. Please note that our Application is currently available for the Android Platform only.

2) Take out a print out of the Marker provided in the Repository. Otherwise, you can also open it digitally on another Smartphone/Tablet. The Virtual Robots / Digital Twin will be displayed on top of this Marker when it will be in front of the Smartphone Camera (in which an instance of the App is running).

3) Currently, there are two modes in the Application - Monitor and Program.

4) By default, the Robotic Arm will be selected on the Menu Screen. You can either go to Monitor or Program Options by clicking on the respective Buttons.

5) In Monitor Mode, place the Marker on a Level Surface and point your smartphone camera towards it. The Virtual Model of Robotic Arm should now appear on top of it. The arm will now move according to the movement of the real arm. Please note that this feature will only work when the Actual Robotic Arm is connected to the Server and is made to move by feeding commands on the server.

* Since this part needs the presence of the Actual Arm, you would have to refer to a video we have put up regarding the same.

6) In Program Mode, place the Marker on a Level Surface and point your smartphone camera towards it. The Virtual Model of Robotic Arm should now appear on top of it. Next, you feed the commands in the Text box in the Smartphone. The Syntax of the Commands is as follows -

0 -> First Servo ; 1 -> Second Servo ; 2 -> Third Servo

Examples -

* **0S120;** - Moves the first servo motor to an angle of 120 degrees
* **0S45;2S150;** - Moves the first servo motor to an angle of 45 degrees and then moves the third servo to an angle of 150 degrees
* **L(1S30;1S60;)** - Moves the second servo motor to an angle of 30 degrees and then moves it to an angle of 60 degrees in a loop. To Stop the Loop, press the Stop Button which will then be displayed on the screen.

Please note that the angle values are absolute and not relative to the previous position of the servo. A servo motor can rotate only from an angle of 0 degrees to 180 degrees. Any commands given outside this range will be trimmed appropriately. The user can enter any number of commands in the proper syntax. All of them will be executed one after the other.

7) After typing the Appropriate Commands, the User can press two buttons - Visualise or Send. Visualize will make the Virtual Arm move according to the Commands provided. Send will push the commands to the Actual Robot through the Server, provided the Actual Robot is connected to the Server. The Status of connection of the App with the Serve is displayed on the top part of the Screen.

* Please note that this does not tell whether the Actual Robot is Online or not. If it is active the top part of the screen will show the Servo Rotation angles of the Three servos.
* The aim of the “Visualise” button is for the user to check the effect of Commands provided in the Virtual Arm. The Virtual Arm needs to be placed in the Real-world environment so as to analyze whether the Actual Arm will not break anything in the Real World Scene.

8) As an additional feature, to highlight the versatility and scalability of our system, we have added a Lathe Machine for demonstration. To access it, click the right arrow button on the Menu Screen beside the Robotic Arm. The Lathe Machine model should be visible now. Click on the Program button to control the Virtual Lathe Machine.

9) In Program Mode, place the Marker on a Level Surface and point your smartphone camera towards it. The Virtual Model of Lathe Machine should now appear on top of it. Next, you feed the commands in the Text box in the Smartphone. The Syntax of the Commands is as follows -

Examples-

* **M12;** - Moves the stage towards the jaw by a distance which is proportional to 12. The maximum value that can accompany M is 18 and the minimum value is 0.
* **R250;** - Rotates the jaw by an RPM which is a factor of 250. The minimum value that can accompany R is 0 and the more the given value is, the faster the jaw will rotate.

The user can enter any number of commands in the proper syntax. All of them will be executed one after the other.