Sparring Robot for Training and Rehabilitation

Roumiana Ilieva
Head of Dept. Management and Business Information Systems,
Faculty of Management,
Technical University of Sofia
Sofia, Bulgaria
rilieva@tu-sofia.bg

Antoni Angelov
Dept. Management and Business Information Systems,
Faculty of Management,
Technical University of Sofia
Sofia, Bulgaria
antoniangelov@tu-sofia.bg

***Abstract*—When training martial arts athletes would often use human shaped rubber dolls that are directly connected to either the floor or on a chain from the roof. While on first impression they look interesting and give some anatomical meaning to the trainee, eventually they seem no different than a regular punching bag. Today we have the opportunity to add the advantages we have in robotics to create a more realistic punching bag. One that not only can move but also hit back. This paper explores this project and how it can be achieved by only using technologies that already exist.**

Keywords—component, formatting, style, styling, insert (use style:** keywords**)

I. Introduction

This project focuses on the applications of modern technologies for the improvement of health. While the research of understanding of the human body is as old as time (recorded) there are several noteworthy rather recent achievements. One is the neural network technology which saves us from having to write complex programming regarding body motion and reaction to complex environments and so on. It may even be considered impossible to be written by human hand alone. However, with the Neural Network method and with a properly set up training environment, the control can literally write itself.

So, what is it all about? It is a combination of several projects which put together can essentially create a humanoid robot. But that is just a byproduct. Either way, the projects that are used are as follows: Training environment for neural networks, computer vision and finally the electromechanical representation for the real world. Only together they are combined into the sparring robot.

II. Training environment for the Neural Network

As mentioned before all technology is at the ready. So is this part. While using a game engine like Unity would not be a difficult task, it will still require some specialized setting up to be done. Instead, we focus on a product specifically created for the task at hand, and that's Gymnasium [1]. What Gymnasium provides are a set of environments designed for training AI. It goes from old Atari games all the way to physically simulated realistic environments.

One such environment could be perfect for deciphering the process of walking or standing up with an anatomically correct humanoid body as well as resisting forces that may throw it off balance. Wind, kicks, heavy objects hitting it are just of the things that can help in developing a sturdy and robust software that can keep that body up and standing no matter what.

As seen in Fig. 1. one such body in its training environment struggles with Gravity.

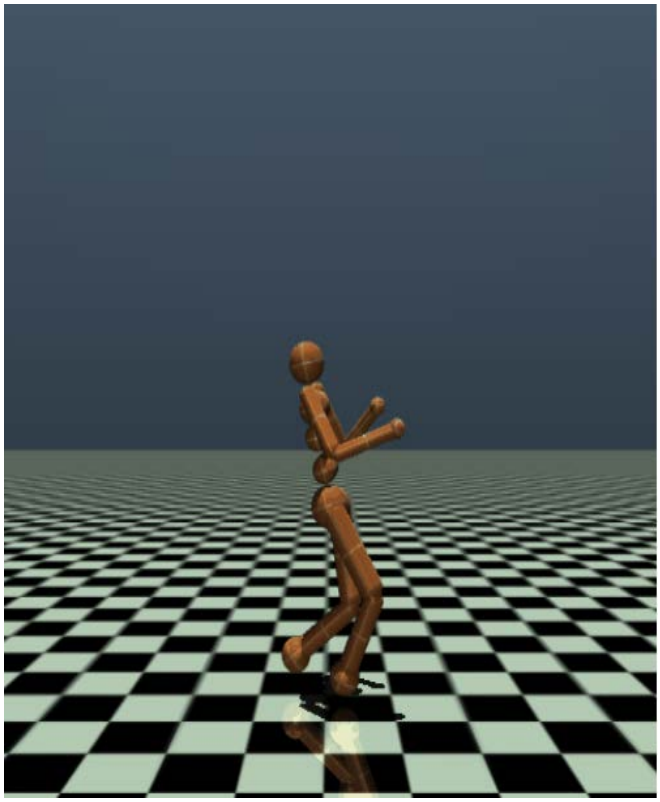

Fig. 1. Gymnasium in action [2]

Of course, the graphic part is only for reference and human management of the process. Without it the software can train simultaneously on thousands of bodies at a time.

What Gymnasium is a training environment optimized for machine learning via python. On its site it even has tutorials how to run those simulations and to prepare your own neural networks. And it works like most game engines, so we can spawn factors into the environment with code alone.

The specific training sim for Fig. 1. is called MuJoCo which stands for Multi-Joint dynamics with Contact. It is a physics engine for facilitating research and development in robotics, biomechanics, graphics and animation, and other areas where fast and accurate simulation is needed. There is physical contact between the robots and their environment -

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and MuJoCo attempts at getting realistic physics simulations for the possible physical contact dynamics by aiming for physical accuracy and computational efficiency.

Installation process is as simple as

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pip install gymnasium[mujoco]
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Working with the environment isn't difficult and it is designed to help with training in both working with Neural Networks as well as this sort of training environments. It is of course not full but for the purpose of the project it is perfectly sufficient.

A more complete training environment may have particle simulation for the fluid mechanics, FEM (Finite Element Method) Analysis for bending or breaking of materials and so on. However, all of those features would require processing power which in turns will increase the cost of a such project.

To determent what fields would be required in the simulation is to understand the needed feature in the robot.

III. Robot Specifications and Requirements for the Environment

It is a sparring robot by name, so combat would be its eventual function. But before it can fight it would need at least to walk or stay standing. Gymnasium provides the environment to train our own AI to handle that as well as tutorials on how to use the environment. The pre-set size of the neural network depends on how serious the application is.

A bigger pre – set not only trains much slower it will require a much stronger processing power to be used. In example if it's for a small toy a simple neural network can be trained and it wouldn't matter if the toy falls from time to time. If it's for a serious robot and especially if humans are involved in tasks around it, there can be no corners cut in preparing a professional level of AI.

So, for standing the training simulation would be: Random attacks of air and objects while the model is meant to stay standing and still resisting the attacks. While the model may not be able to sense the contacts as hits, it will notice that it's joints are being moved by outside forces. As well as its accelerometer may notice a motion that is neither expected nor desired by the AI at these points in time. The more real sensors are available for the robot in the real world, the more sensors can be simulated in the training environment. It is important that the real and the simulated robot are completely the same as any deviation may result in unknown behavior and lack of proper results.

On top of that the power of the robot may need to be trained to both control it as well as to be able to notice when its power is stronger or weaker and be able to adjust to the situation,

There are 2 ways to solve that. One is by training power output changes and how to react on it in the training simulation. And the other is by using step motors. With step motors you control the motion and not the power and therefore it's not a problem.

For actual training in combat however the things will become a lot more interesting. The training simulation will require at least 2 bodies, one for the robot and one for the opponent. The robot being technically blind in regards to the training environment will have to know the positions and rotations of its body parts as well as those of its opponent. And here is the trick in delivering this to the real world. A computer vision method can be added to the robot in the real world for it to be able to recognize the opponent in real time. Such a method is shown in Fig. 2.

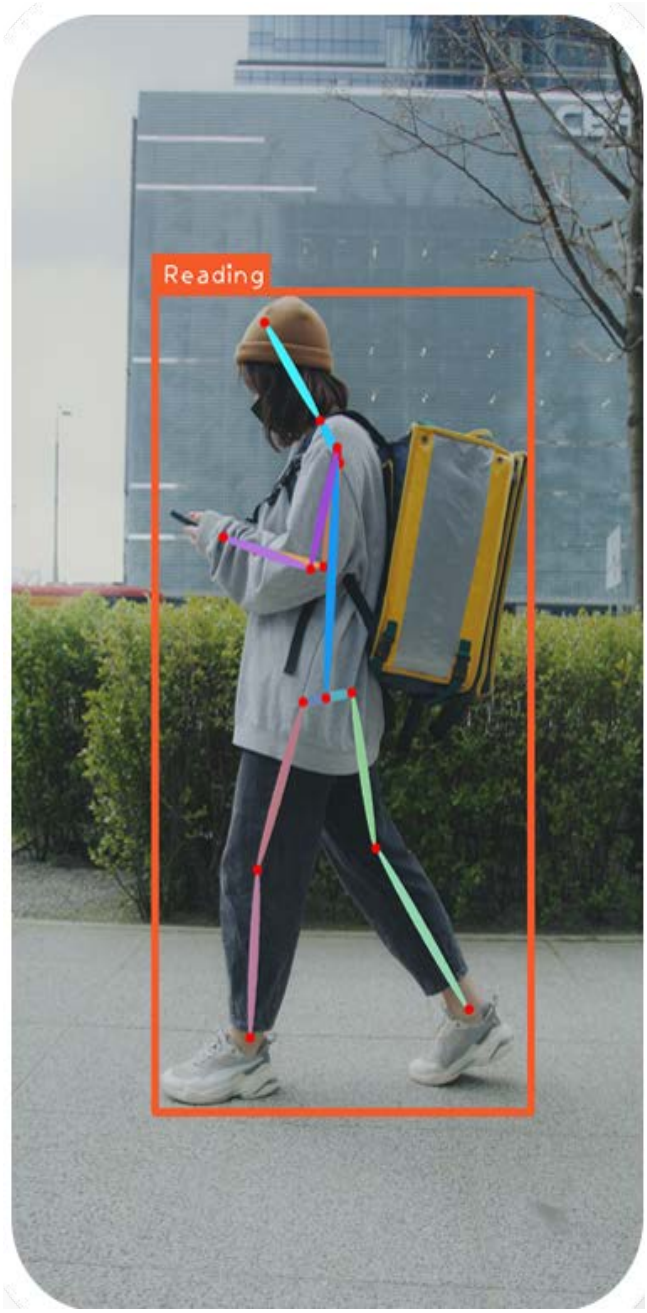

Fig. 2. Machine vision recognizing human and its limbs

Now there is a risk that it may recognize anyone in front of it as its opponent and attack them, however that is more of a usability feature than an issue as the sparring robot may be used by many in the gym without unnecessary setting up and eventually be turned off when not in use.

The computer vision is a stand-alone module and we will not require any research into. Just drop it in place, have it set to give data of the recognized human as sensor data and its done. The only things the sparring robot would need to care about are the flat terrain around it and its opponent. Anything else is basically a distraction.

IV. The hardware

The hardware or the physical body to be exact is the most important part of the project. And also, the most cost sensitive.

Over the years there have been many attempts at both training and setting up humanoid robot for human like tasks. And while it has been seen as a challenge, there are companies today that have results that far excel those early attempts.

And on top of that we have some very good reference material in regards to both pricing, capability and so on. The sparring robot is in many ways a simplified version and while the price may be considered relatively high, the sparring robot would only be a fraction of it.

According to official statement during a certain tech demo in California, a robot in many ways similar in size to our sparring robot is soon to be sold for 20 000$ and has 10 000$ cost of production. That is of course information about the Optimus by Tesla as shown in Fig. 3.

Fig. 3. Optimus robot [4][5]

One of the first things noticeable about the robot are its overcomplicated anatomically somewhat correct for a human hand. It has the same usability as a human hand, while it may not fully look the part. A complex and intentionally exposed device such as that is a clear money pit and it is safe to assume about half of the production cost for the Optimus robot is in its hands. The sparring robot does not need hands.

In Fig. 4. the sparring robot can be observed.

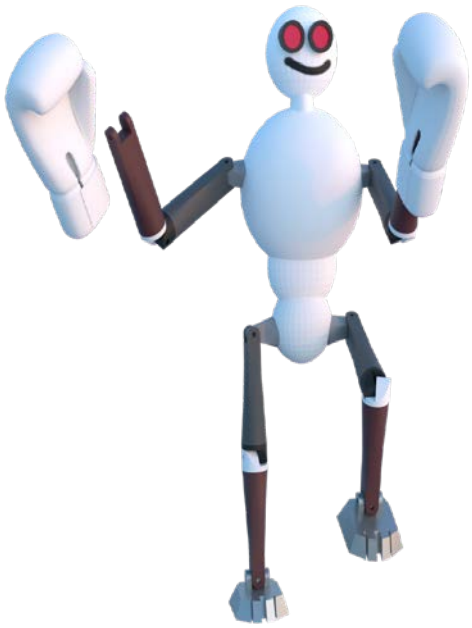

Fig. 4. Sparring robot

One thing to notice is, it doesn't need fingers or toes. A boxing glove is sufficient for the end of its arm. It's limbs either 3D printed or made out of polymer pipes can also be low on cost. However, a pipe limb may not be aesthetically as pleasing as a 3D printed one. But there is a catch with the 3D printers as well. For the body it would be built with foam and artificial leather as its soft, durable, pleasant to touch / punch and most importantly cheap. In the chest area is the location for the battery pack and it's a good idea to armor it in polymer or metal container with thick walls and frame to protect it from being crushed, pierced or anything that may cause it to catch fire.

The joints have step motor servos, usually 2 per joint area: One for angular movement and one for rotation. The same theme is repeated for both hands and legs, hence why they are basically the same limb.

The cameras in the location where for human there would be eyes are protected by the red googles. They are designed to take hits and not let the damage reach the cameras behind them. The sparring robot is not meant to be strong, but rather a relatively not very dangerous opponent on who you can test different techniques. Of course, improving the power of the robot is not a difficult task however that would lead to different consequences and risks.

In Conclusion

The neural network is a simple mathematical formula and many of the runs of it don't even require much hardware, however it has completely changed the world in so many ways. A humanoid walking robot was considered Science Fiction or an extremely high budget device with low capabilities that can mostly dance and do useless tasks. Nowadays the budget requirements are so low that it's a miracle they aren't everywhere. And the training isn't difficult

either. Of course, a combat sparring robot is a niche. Its use would be delegated as a gym training equipment or cinema stuntman for the unfortunate characters who exist only to take a hit that may hurt or kill an actual human.

In fact, its use in Cinema may easily be the most appropriate as action scenes often require expensive planning and setup just to prevent injury.

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