Engineer's Conclave

Low-Prep Event (150 Points)

Project Report

Project Name: JerBot

Institute Name: IIT(BHU)

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Problem addressed:

(Not more than 100 words)

The three challenges that make terrain robots unrealizable even with this amount of advancement in technology are dynamic stability, mobile dexterity and mobile perception. The need for adaptive robots and cyber-physical systems that are as capable as even humans is still unachieved. There is a very high need for robotic systems to be deployed in highly unpredictable and adverse environments where a human's presence is simply infeasible and risky. This brackets a huge array of challenges like disaster management, recovery missions, outer space exploration and navigation or in short anywhere highly robust, competent and efficient robotic systems are required.

Proposed Solution:

(Not more than 500 words)

We propose a novel solution using the potential of Reinforcement Learning to develop compromisable, cost-efficient, and ready to deploy bipedal robots as a key to unlock all the above deadlocks of practical challenges. Years of evolution came up with the legged way of locomotion which still stands undefeated in terms of stability, dexterity and robustness. Though a significant amount of work has been done in this field, fairly any real-life deployable robots have not been built yet. The key obstacle that holds us back is the inability of our man-made systems to generalize and adapt to such highly complex environments. The advent of Reinforcement Learning in robotics has shown us some groundbreaking results. Reinforcement Learning is a branch of machine learning where the agent learns by actively interacting with its environment and thereby getting a reward or a punishment. This seemingly simple idea has helped various game-playing bots and other agents that generalized well over various tasks and were robust enough in their respective challenges. Utilizing this idea in the field of robotic locomotion seems empirically and intuitively correct as that's how we humans and animals go about learning. Another argumentatively appealing factor is the ability of Reinforcement learning agents to come up with more creative and novel ways to solve the problems that even we humans are unheard of. This proves to be a vital missing element in all the pre-existing legged robots. The second key problem that we realized was the very traditional approach to design bipedal robots like humans in spite of the presence of more robust two-legged animals. Biomimicry of these animals into our robots give us a whole new way to address the problem of locomotion. Development of gait sequences that give us an optimal combination of hopping, jumping and walking could prove to be a vital step in tackling the uncertainty in real-life conditions. Our sole inspiration for the design of our bot is extracted from a dessert rodent named Jerboa, whose unpredictable gait sequence makes it sustain and survive in such adverse conditions like that of a dessert in spite of relatively smaller size. The key element we tend to engineer here is the ability of this animal to make strategic decisions along its gait sequence which makes its motion more agile and unpredictable which will be well suited to serve the above problems. The third and final challenge is to make robots of this sort compromisable and cost-efficient so that they are easily deployable without much of a loss. Moreover, this will enable the fact that these robots will become a part and parcel of a common man's life thus propelling our efficiency and development. Thus the development of a strategic sequential decision-making agent with the ability to adapt and locomote in unconventional and hard to simulate environments and as well keep these robots economically feasible is the sole motive of this project through which we believe technology will be used to make a change in the world as we see it.

Summary:

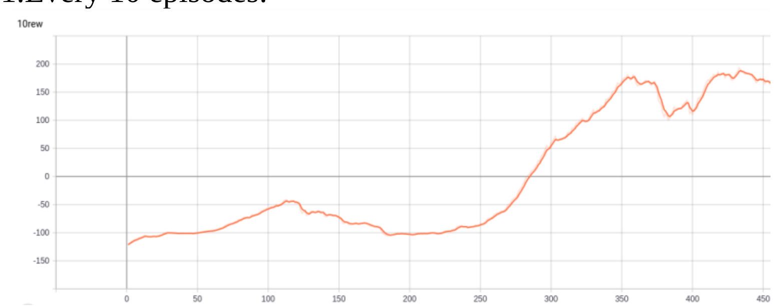
- ## Test Results:

Task:1

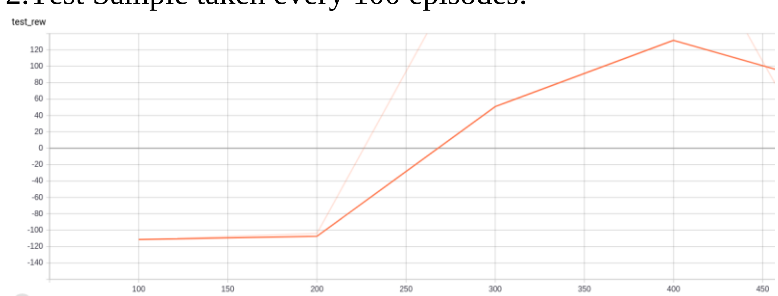
Our first step towards prototyping was to make a state of the art Deep Reinforcement algorithm to converge to our specific task. Hence we went about solving the "BipedalWalker-v2" environment from OpenAI gym using the "Proximal Policy Optimization (PPO) Algorithm. We used the Pytorch framework to develop our custom Neural Network setup. With no former knowledge about the environment or rather itself, our agent was able to solve the environment in 450 episodes with a justifiable gait sequence and a decent score.

Plots:

1.Every 10 episodes:



2.Test Sample taken every 100 episodes:



Task:2

The next step was to develop a simulation environment that closely resembles our real world situations. We went about building this environment using the Pybullet package which encapsulates the bullet physics engine with python. For greater ease of work we developed our environment as a third party OpenAI Gym module, which could be easily installed and is ready to be experimented with. The robot is imported in the Universal Robot Description Format (URDF), which in turn has the CAD files for our hardware already incorporated. This approach is expected to decrease the Simulation to reality gap that exists generally exists in such tasks.

Video demo:

https://www.youtube.com/watch?v=Cgz2M-3FWQ4&feature=youtu.be

- Surveys:

The primary technical goal of the DARPA Robotics Challenge(DRC) is to develop human-supervised ground robots capable of executing complex tasks in dangerous, degraded, human-engineered environments.

Of the top three robots in the DRC Finals, third place went to a robot that rolled on tracks; second place went to a walking biped, and first place went to a biped that had wheels that it could use instead of walking. Hybrid designs seemed to perform the best: KAIST had wheels and legs, CHIMP had tracks and legs and JPL's RoboSimian had a quadrupedal design with butt-wheels. In each of these cases, the robot had good mobility without having to worry about falling over all the time.

It's important to note, however, that in a real disaster area, wheeled mobility may be close to useless, so despite how well the wheeled designs did at the DARPA Robotics Challenge, it shouldn't minimize the future potential and value of bipedal walking. Bipedal walking lets you move across areas where you only have a footstep-sized safe place to move, and, unless you can fly, no other mobility design does that.

Video demo:
https://www.youtube.com/watch?v=g0TaYhjpOfo&feature=youtu.be

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- References:

1. STOCH, a quadrupedal robot developed by IISc (https://cps.iisc.ac.in/wp-content/uploads/2018/12/1810.03842.pdf)
2. The unpredictability of escape trajectory explains predator evasion ability and microhabitat preference of desert rodents, *Nature Communications* **volume 8**, Article number: 440 (2017) (https://www.nature.com/articles/s41467-017-00373-2)
3. CASSIE, a bipedal robot developed by Agility robotics(https://robots.ieee.org/robots/cassie/?utm_source=spectrum)
4. Bionic Learning Network of FESTO
5. SALTO, a mono legged robot developed at UC Berkeley(https://spectrum.ieee.org/automaton/robotics/robotics-hardware/salto1p-is-the-most-amazing-jumping-robot-weve-ever-seen)

- Video Links*:

(* = Optional)

- https://youtu.be/35MSBu7-mk0
- https://youtu.be/Is4JZqhAy-M
- https://www.youtube.com/watch?v=Wxx9pwwTIL4

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