Improving Throttle Control of Reusable Rocket Engine Using Artificial Intelligence

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ISEF category - ROBOTICS AND INTELLIGENT MACHINES (Code: ROBO)
ISEF subcategories - Control Theory and Machine Learning

1. **Problem** :

   Right now, rockets are treated as trash once they've taken off, so companies must spend millions of dollars on manufacturing brand new rockets for every single flight. It costs $60 million to make the Falcon 9, and $200,000 to fuel it, according to SpaceX CEO Elon Musk.

   SpaceX company is the first company which developed the reusable launch system technology in 2017 and initially used it for the first stages of the Falcon family of rockets. The company realized that the current reusable launch system technology were not perfect and several new technologies needed to be developed and tested to facilitate successful launch and recovery of the first stages of Falcon 9 and Falcon Heavy and both stages of Starship and Super Heavy.

   One of seven challenges need to be resolved is

   - How to make the rocket engine to be throttleable and fuel-efficient to achieve zero velocity at the same time the rocket reaches the ground?

   Sources:

   (a) https://www.theverge.com/2015/12/24/10661544/spacex-reusable-rocket-refurbishment-repair-design-cost-falcon-9
   (b) https://www.engadget.com/2017/04/06/spacex-is-saving-a-ton-of-money-by-re-using-falcon-9-rockets/
   (c) https://en.wikipedia.org/wiki/SpaceX_reusable_launch_system_development_program

2. **Origin of Project Idea** :

   President Donald Trump has asked NASA to accelerate our plans to return to the Moon and to land humans on the surface again by 2024. We will go with innovative new technologies and systems to explore more locations across the surface than was ever thought possible. This time, when we go to the Moon, we

will stay. And then we will use what we learn on the Moon to take the next giant leap - sending astronauts to Mars.

Sending 12 astronauts to Mars will cost an estimated $10 billion per person, Musk said. But if we can find a way to make the rockets reusable and one million people sign up, the cost would drop to a mere $200,000 per traveler, which he compared to the price of a house.

Sources:

(a) https://www.nasa.gov/moontomars/
(b) https://www.vox.com/2016/9/27/13081488/elon-musk-spacex-mars-colony-space-travel-funding-rocket-nasa
(c) https://www.mars-one.com/faq/finance-and-feasibility/what-is-mars-ones-mission-budget

3. **Hypothesis:**:

The control systems they use for the rockets to land them back on the ground are all classical controls. My question is, why? Given the difficulty of the problem, why not use more sophisticated optimal or robust control? Is it possible to improve the throttle control system of reusable rocket engine using artificial intelligence algorithms to pilot landing of the first stage of the rocket?

After the first stage successfully separated from the main rocket, it will begin to fall. As it falls, it accelerates. The landing of the first stage is so fast that no human could react quickly enough to ensure a smooth touchdown. Also, there is a limited amount of fuel. Once the fuel is exhausted, the first stage will simply fall, and nothing can be done.

Artificial Intelligence may be applied on the throttle control system of the rocket first stage to pilot the landing process. It doesn't need training data to be created ahead of time and no assumptions will be made about how the Artificial Intelligence should pilot the first stage. Artificial Intelligent algorithm will learn everything on its own. The Artificial Intelligent algorithm will decide when to fire the thrusters or not to fire the thrusters.

Sources:

(a) https://cosmosmagazine.com/space/launch-land-repeat-reusable-rockets-explained

(b) https://www.reddit.com/r/spacex/comments/7t2tb2/a_paper_by_lars_blackmore_of_spacex_on_soft/
(c) https://www.semanticscholar.org/paper/Lossless-Convexification-of-Nonconvex-Control-Bound-A%C3%A7ikmese-Carson/9209221aa6936426627bcd39b4ad0604940a51f9

4. **Possible Solutions to the Problem** :

Need to develop an Artificial Intelligent algorithm and then feed it with environmental information such as fuel remaining, altitude and current velocity. The Artificial Intelligent algorithm will then output a single value that will indicate if it wishes to thrust.

This is a text-only simulation. The goals are summarized here:

1. React quickly enough to ensure a smooth touchdown
2. Cover as much distance as possible in order to conserve fuel

Need to do some research in the below areas :

- Explore different kinds of Artificial Intelligent algorithms
- Java programming language
- open source Deep Learning 4 Java library
- open source Apache Spark to do Big Data computation to optimize Artificial Intelligent models.
- open source free chart to display research results

Sources:

(a) https://medium.com/datathings/neural-networks-and-backpropagation-explained-in-a-simple-way-f540a3611f5e