Direct Control with High Latencies: the Case of Tele-Operated Lunar Robots

Duration: 4-6 months
Team: Loki (Inria Lille – Nord Europe & CRIStAL)
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Context
The European Space Agency’s (ESA)’s Luna missions aim to send one orbiter and two landers to the Moon within the next decade, to study the composition of the soil near the lunar south pole, and in particular to search for underground frozen water. Besides scientific knowledge, these missions will also pave the way for future manned lunar missions. The distance between the Moon and Earth allows operators on Earth to control lunar orbiters, and through them lunar landers and rovers, with up-and-down transmission delays of around 6-10 seconds. This is to be compared to Earth’s second closest neighbour, Mars, which has an average delay of 20 minutes!

Nevertheless, 6-10 seconds remains a challenge when attempting to control a system in real time, particularly under uncertain environments such as the Moon surface. There is limited understanding about how users behave under such latencies, and how to best design control systems that address these issues. In the field of Human-Computer Interaction (HCI), the effects of latency on user behaviour is often explored below 200 ms, see e.g. [3], but some models of performance successfully describe target-acquisition tasks with (fixed) latencies up to 4 seconds [1, 2]. This project will investigate whether these models hold with higher levels of (variable) latency, and how to improve user control in such unfriendly environments.

Objectives
The intern will first gather a comprehensive survey of existing research on (a) high-latency Human-computer interactions, (b) tele-operated spatial robots and their constraints on lunar terrain, and (c) open-source rover simulations. These will help characterise the next steps of the project.

Second, she or he will design, implement, and conduct a controlled experiment to validate and extend existing models of user behaviour with delays similar to those encountered between Earth and the Moon. This first experiment will involve abstract operations such as target acquisition (“pointing”) and path-following (“steering”) to simulate classic robot control tasks in a controlled environment, and latencies distributions designed to mimic Earth-Moon delays. Solutions to the observed performance issues, such as using input prediction [4] or programmed interruption thresholds when the controlled system is put at risk before the user can obtain a feedback of its status, will be designed and tested in subsequent controlled experiments, if time allows.

Third, the intern will design and implement a basic lunar rover simulator with Unity, which will be used to conduct more realistic experiments on lunar robot control. In particular, the simulator must be able to reproduce realistic response errors and misalignments, such as when uneven ground causes the rover’s motion to end at a different position than the operator intended. It will also need to be usable as a controlled experiment platform.

References

1 https://www.esa.int/
2 https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Exploration/Luna
3 https://mars.nasa.gov/mer/mission/timeline/surfaceops/navigation/
Candidate

The candidate must demonstrate an interest in HCI, and programming skills; knowledge of cognitive science or 3D programming is a plus. He or she will have to demonstrate technical and conceptual creativity.

A good level of technical and scientific English is also a plus.
Challenges and some solutions (not unlike ours)

Really cool work on pointing motion under high latency, up to 1s in this study and to 3.5s in re-analyzed previous work.

Continuation of the one above, they go together.


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