Satellite Augmented Smart Control of Rovers

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***Abstract* - Space-based research has taken huge strides over the years, and planetary exploration has become a major part of interest for space agencies around the world. This has made robotic, or specifically rover centred, exploration has become the biggest trend in the present day. As rover powered exploration has brought with it many benefits, it has also posed numerous challenges, some of which are extremely hard to overcome. One of the major challenges is the control of these rovers. Presently, the rovers are fed with an instruction beforehand, which leaves very little space for corrections in case of emergency situations. This could prove to be a very dangerous problem if some unexpected situation crops up. In such a situation, this project intends to simplify the control process by streamlining the control structure using automation and satellites. By providing the control of the rovers to satellites and the on-board systems of the rover itself, the rover can be equipped with the abilities to overcome most of the situations faced by it.**

***Index Terms* - Rovers, Automation, Satellites, Control process.**

INTRODUCTION

After the development of rovers in the late 1960s and early 1970s, a new possibility was opened for space research- planetary exploration. Since then, space agencies around the world have developed newer and better rovers, some of which have permanently left their mark on history. Throughout this period, a major challenge that has accompanied these rovers is their control of movements. Presently, the movement of the rovers follow a pre-fed instruction, allowing for little room for corrections. Also, the fact that distance between the rover and ground station results in delayed execution of instructions as the sent instructions take some time to reach the rover. This is a major problem for the smooth operation of rovers as a lot of precious time is lost between the relay of instructions.

This project intends to streamline this process by reorganising the control process by using on-board computers and satellites. The on-board computers of the rovers will take input from satellite sensors as well as on-board sensors to make the decisions as to which movement path should be taken by it to maximise the optimisation of its movement. This would reduce, if not eliminate, the need for human intervention in the control of rover's movement.

For example, any radio signal from earth would take anywhere from 3 to 22 minutes to travel to Mars depending on the position of Mars at that point of time. This would mean that any instruction that needs to be relayed must be done so 3 to 22 minutes prior. By using automation, this time could be saved and could instead be used for other more productive uses.

Literature Review

The wheel type mobile rovers are one of the most practical and widespread type of robots. Wheel type rovers have a simple drive mechanism and are high in efficiency. The rovers considered here are two wheels rover Super Mario, four wheels rover Pioneer 3-AT, six wheels rover Zaurus, and eight wheels rover Lunokhod. Each rover has different design and different control system.

Super Mario rover is controlled by a PID controller which is implemented by an 8-bit ST6265 microcontroller for each wheel, with a cycle time of Tc = 5 ms.

The lower level controllers of the motors in Pioneer AT-3 are separated with a PID controller for each motor individually. Path tracking Fuzzy controller is used to direct the robot to follow the trajectory in a smooth and continues manner at the best possible precision.

Zaurus is six wheels rover. In this rover, the designer used neural network and PID controller as control methods. They used the direct type of neural network controller which is designed by the way of making an inverse model of the mobile robot. The neural network control using in Zaurus is divided in two parts, those are controllers for the horizontal motion and vertical motion. The climbing motion is analyzed in the vertical plane, while the linkage and the wheels in both sides behave the same motion. The main objective for the use of PID controller in Zaurus control system is to compare the performance of the control with the neural network controller.

Lunokhod control system depends on the self-propelled undercarriage. This undercarriage consists of wheels, electric motors, suspension, and automatic motion-control, a complex system of onboard sensors to monitor the assemblies and systems, and a device to transfer data to the telemetry system. The undercarriage consisted of eight rigid drive-wheels with perforated, created rims. The wheels did not swivel, so the rover was turned by imparting different velocities to the left or right side. It had a temperature-control system with an isotope heat source, a radio and television transmitter, a command receiver, a power plant with solar and back-up storage batteries, a remote control, a small-frame television, panoramic telephoto meters and a complex of scientific instruments.

The observations of spacecrafts are restricted to a small area. To obtain coverage over a wider area, spacecraft can carry robots that are able to rove over the surface. Crewed missions or robotic rovers provide not only mobility but also the capability to do complex tasks and make intelligent and selective observations.

Two Soviet mobile vehicles, the Lunokhods, have landed on the Moon, one in November 1970 and the other in January 1973. The Lunokhods were remotely controlled roving vehicles that carried television cameras and instruments to measure the physical and chemical properties of the lunar soil.

The six Apollo lunar landing missions demonstrated the value of manned exploration of planetary surfaces. The astronauts were able to set up scientific instruments, choose the most interesting samples for collection, and study the geology of the lunar surface.

The first Mars rover Sojourner traversed the rocky plain of Ares Valles. Since then, increasingly sophisticated vehicles have explored the hills and plains of Mars. Two Mars Exploration Rovers (Spirit and Opportunity) arrived on Mars in 2004. Operating long past their design lifetimes, they have explored Gusev Crater and Meridiani Planum, two locations on opposite sides of the planet.

Using an innovative "sky crane" landing system, the Mars Science Laboratory rover, named Curiosity, set down in Gale Crater in August 2012. Gale Crater is 150 kilometers (about 90 miles) in diameter and contains a large central mound 5 kilometers (3 miles) high. The mound is made up of many different rock layers that record the geologic history of the area and may tell the story of environmental change over millions of years of Mars' history. Early in its mission, the rover found signs of a past lake at Gale Crater, and evidence that the ancient environment in the area could have supported life.

Mars Pathfinder (MESUR Pathfinder) is an American robotic spacecraft that landed a base station with a roving probe on Mars in 1997. It consisted of a lander, renamed the Carl Sagan Memorial Station, and a lightweight (10.6 kg/23 lb) wheeled robotic Mars rover named Sojourner, which became the first rover to operate outside the Earth–Moon system.

Launched on December 4, 1996 by NASA aboard a Delta II booster a month after the Mars Global Surveyor was launched, it landed on July 4, 1997 on Mars's Ares Vallis, in a region called Chryse Planitia in the Oxia Palus quadrangle. The lander then opened, exposing the rover which conducted many experiments on the Martian surface.

This mission was the first of a series of missions to Mars that included rovers and was the first successful lander since the two Vikings landed on the red planet in 1976. Although the Soviet Union successfully sent rovers to the Moon as part of the Lunokhod program in the 1970s, its attempts to use rovers in its Mars program failed. In addition to scientific objectives, the Mars Pathfinder mission was also a "proof-of-concept" for various technologies, such as airbag-mediated touchdown and automated obstacle avoidance, both later exploited by the Mars Exploration Rover mission. The Mars Pathfinder was also remarkable for it’s extremely low-cost relative to other robotic space missions to Mars. Originally, the mission was conceived as the first of the Mars Environmental Survey (MESUR) program.

METHODOLOGY

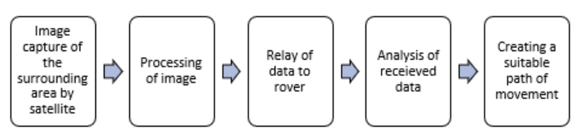

Fig 1: Block Diagram of the Process

The process begins with the orbital satellite capturing images of the surroundings of the rover with its on-board cameras. The images thus taken are then relayed to the rover’s on-board computer after a round of processing on the satellite itself. The rover after receiving the data, then compares the said data with data received from its own on-board sensors. The sensors on the rover provide a clear picture of the immediate surroundings of the rover whereas the satellite provides the aerial view as well as the complete view of a large area around the rover.

The on-board computer on the rover then compares and analyses the data received from the two sources and gets a clear view of its surroundings. The rover then plots aa path of movement that is best suited for itself and follows the path in its following movements, eventually reaching its desired destination. This process also takes into account any changes to the environment around the rover at any instance, even during movement, allowing for corrections to the movement path during the movement itself.

The image capturing by satellite is done by both colour cameras as well as IR cameras, while the sensors on the rover includes depth sensors and texture cameras. The combination of data from these sensors and cameras provide a clear image for the rover to analyse and plot its movement path.

The computation time for the operation can be calculated by considering the pixels of the images that are captured. Considering 3 different images with a standard pixel amount of 640x480 resolutions for each image, it would amount to a total computation of 921,600 pixels to be computed. Taking Curiosity rover's on-board computers as the standard for computational ability, which as 200 MHz processor with the capability of 200MIPS computation. Curiosity rover has less than 75% processor space for automation, which would mean at most 150MIPS for computation.

Each pixel takes up an average 3000 operations including any branch operations if present. This would amount to a total calculation time of 55.296 seconds. This could be approximated to 60 seconds when including the transmitting time as well as providing a buffer. Thus, considering the amount of processor space available for the process, the amount of time for computation can be approximated to anywhere from 1 to 2 minutes.

Calculate the amount of pixels for one image of 480*640 configurations,

480*640=3,07,200

Consider three images to be processes,

3,07,200*3= 9,21,600

Calculate the number of operations on pixel at around 3000 per pixel

9,21,600*3000= 2.7648e9

RESULTS AND DISCUSSION

Fig 2: Working model of the Rover

The above images show the working model of the rover. The rover contains basic automation controls as well as manual controls augmented for the movement. The Wi-Fi camera provides constant feedback of the imaging of the surroundings of the rover, which helps in the manual control of the rover. The laser circuit detects obstacles in the path of the rover and makes any necessary corrections to the movement path based on its feedback.

Configuration	Without autonomy	With autonomy
Instruction implementation time on Mars (theoretical)	~3 to 22 minutes	~1 to 2 minutes

From theoretical calculations of the time required for the processing of data by the on-board computers of a standard rover, we can come to a calculation for the time required for the implementation of the instruction by the rover which comes out to be around 1 to 2 minutes. Comparing this with the time required to relay the instruction from earth to Mars by means of radio waves, we can observe a large difference. Anywhere from 1 to 21 minutes of time could be saved by implementing this process of automation using a combination of sensors and satellites. This would also reduce, and in some cases, eliminate the need for human intervention for the control of rover.

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