Increasing Interplanetary CubeSat Mission Science Return with Model Based Transmission Reduction

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Overview

- Discussion of the Problem
- Review of Prevailing Solutions
- The Gap Between Current Solutions and Needs
- Gap Analysis & Impact
- The Proposed Solution
- Implications of and Issues with the Proposed Solution

Discussion of the Problem

- The value of a science/exploration mission is constrained by the amount of quality data that can be collected and transmitted to project scientists
- For small satellite missions, communications capabilities are generally a significant constraint
- Communications capabilities are constrained by spacecraft antenna size, transmission power, ground antenna size and the available transmission window
- For most small satellite missions none of the aforementioned are particularly well-suited to the transmission of large amounts of data

Discussion of the Problem

- If you can't transmit sufficient amounts of data about your mission's subject, then there is little point to launching the mission
- Maximizing the amount of quality data that can be transmitted maximizes the mission's value (to the point that the relevant data isn't exhausted)

Review of Prevailing Solutions

- Conventional solutions take two forms:
  - Physical enhancement: increasing power, antenna size (gain)
  - Computational enhancement: compressing data
- Spacecraft mass and volume constraints apply limits to the power and gain levels possible (though enhancement beyond the current status-quo seems probable)
- Traditional compression techniques fall into two classes:
  - Lossless: which have a maximum level of possible compression
  - Loss-Causing: where quality degrades as a function of file size

Review of Prevailing Solutions

- The current approach to enhancing mission data throughput produces an incremental increase in performance
- Long-distance, small spacecraft; however, require more than this incremental increase

The Gap Between Current Solutions and Needs

- A CubeSat-class spacecraft in proximity to another planet may be able to take tens of images (or other data readings) per minute
- It may take tens or hundreds of minutes to transmit a single one of these images or data readings back to Earth
- Presuming that most (or a fraction) of this data is valuable, the disparity between collection and transmission capabilities is resulting in the loss of valuable scientific data

The Gap Between Current Solutions and Needs

- In order to resolve this problem, data transmission capabilities (for a given craft size and distance) or compression technologies would need to increase significantly
- Some expansion is likely, deployable antennas (e.g., configurable membranes or inflatables) may increase the available on-craft gain
- New compression technologies will likely be developed that produce marginal increases in effective throughput with an acceptable level of loss

Gap Analysis & Impact

- The impact of this disparity is that missions need to have an onboard capability to determine what data is most useful in order to maximize mission value

- For example, data that refutes or provides a strong confirmation for a hypothesis would clearly be more valuable than data that it not related to the hypothesis

- In order for this to be performed on-board, the spacecraft must have an appropriate level of computational capabilities and a mechanism to process and perform analysis of the collected data

The Proposed Solution

- With a marginal increase over the computational capability required to evaluate the utility of data, we can analyze it instead
- A model of the phenomena of interest is created prior to mission launch and included with the craft
- This model is updated by the onboard software based on the data that it collects and evaluates
- Changes to the model are prioritized and sent back to Earth along with data that can be used to validate the performance of the system

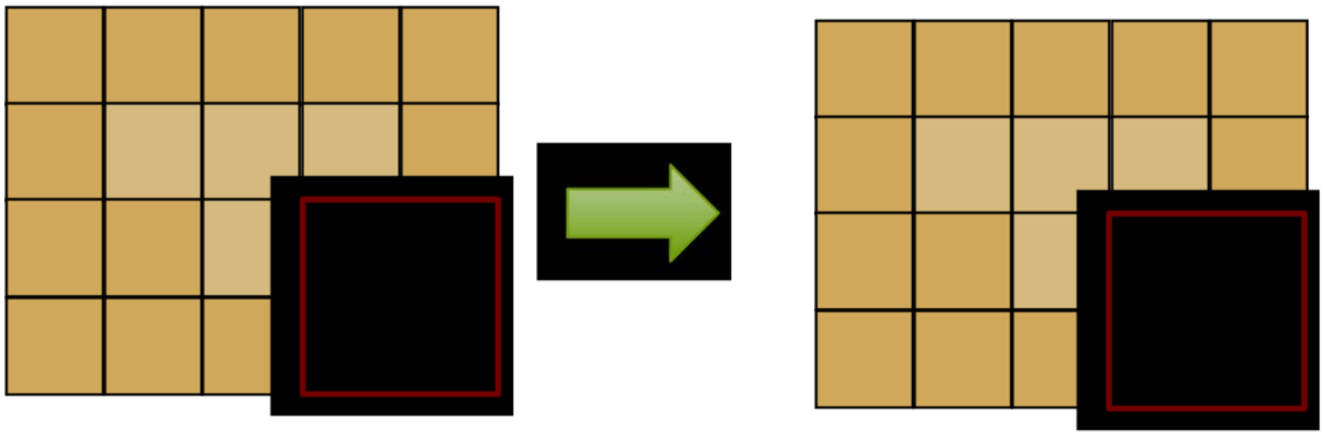
The Proposed Solution

For a gravity / mass distribution model, for example:

- A model of the target is created based on the best data (e.g., remote sensed data) available
- This data will likely include a basic shape model for the target, but not include significant information on the composition
- Basic material composition data from albedo analysis can be included, and refined based on the collected data

The Proposed Solution

- The proposed approach has a defined format for sending updates that includes mechanisms to redefine the base grid-location mass for regions or the whole body, to speed large corrections (by not requiring each grid-location to be updated individually)



Implications of and Issues with the Proposed Solution

- If the proposed approach can be applied to a prospective problem, the amount of data that is required to convey the nature of a phenomena of interest is dramatically reduced
- The level of reduction possible is dependent on the accuracy of the initially supplied model and a variety of data-type-specific characteristics
- This approach allows the amount of science (or other) data that is conveyed back to Earth to be increased for any level of throughput

Implications of and Issues with the Proposed Solution

There are several important considerations:

- The level of acceptance of AI analysis of data that is not available for further review is unknown
- Secondary uses of collected data would not be possible unless data was stored onboard and a program could be written and uploaded to perform the desired analysis and report a result
- Any issue with the analysis program (or methodology, etc.) that was detected after-the-fact might render the AI analysis, and thus the mission, useless

Future Work

- Current work involves the use of data from a model of the moon to quantify the exact level of data transmission savings that would be possible with this approach
- Expanding the model-based transmission reduction (MBTR) approach to other data types and characterizing performance will be a target of future work

Conclusion

- Model-based transmission reduction (MBTR) can be an enabling technology for interplanetary CubeSats
- It can make science missions that would otherwise be precluded or significantly constrained by data transmission possible
- It is also useful for larger spacecraft and in-Earth-orbit applications
- MBTR requires significant onboard processing capabilities

Thanks &
Any Questions?