UtiliStation: Increasing the Utilization of the International Space Station with Big Data Analytics for Stowage

Ellis R. Giles
ACM Student Member
Rice University

Peter Varman
(Advisor)
Rice University

ABSTRACT

The International Space Station, is one of the most expensive and complex objects ever constructed. One way in which the ISS fulfills its role to benefit humanity is by functioning as a National Laboratory, offering a unique microgravity and extreme research environment.

Sending experiments and materials to the ISS is costly and logistically complex, and can take a long time to materialize. Many items are being stowed and tracked onboard the ISS. However, stowage space onboard the ISS is very limited, and, as more items are stowed, the more time it takes to retrieve an item.

This research involves creating a software analysis tool called UtiliStation, which may increase the utilization of the ISS by optimizing onboard stowage of resources over time. It utilizes Map-Reduce functions on inventory and crew procedure data, and possible future work may include collaborations with NASA.

Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous; D.2.11 [**Software Engineering**]: Software Architectures

General Terms

ISS, International Space Station, Utility, Stowage, Utilization, Big Data, Analytics, Map-Reduce

1. INTRODUCTION

The ISS is comprised of fifteen pressurized modules each with a different size, orientation and function, spanning an area over the size of a football field with a weight over 460 tons.

The price to put an item in orbit has recently dropped to under $3,000 per pound with recent commercial space flight. Astronauts spend a large amount of their time managing tens of thousands of objects, as much as 25% of their time [5].

Figure 1: Astronaut John L. Phillips among stowage bags in an airlock. Photo Credit NASA.

Demand is high for trained astronaut time to conduct experiments and is expensive. The time it takes to manage items may not only lead to a dollar loss, but may also to a loss on the overall effectiveness and utilization of the ISS. By optimizing the placement of items and maximizing the stowage configurations onboard the ISS, time may be reduced and effective utilization of the National Laboratory may be increased.

2. BACKGROUND

Figure 1 shows the complexity and large number of items that are onboard the International Space Station, which can make it time consuming to perform procedures.

Big Data is described by [7] [6] as being comprised of three components: Volume, Velocity, and Variety, adding to complexity and difficulty in managing data sets. Big Data Analytics refers to methods for advanced analysis performed on dynamic, complex, and large data sets. MapReduce [4] is a programming model for processing large, complex data sets in parallel, consisting of a computation model producing key-value pairs from input pairs.

Optimizing placement of items in a set of containers, like in Figure 2, is NP-hard. However, there are a number of approaches that attempt to reduce the complexity of the op-

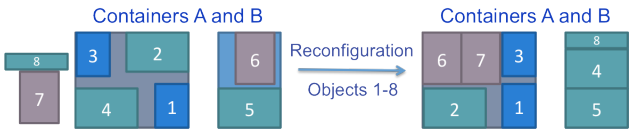

Figure 2: Stowage configuration optimization.

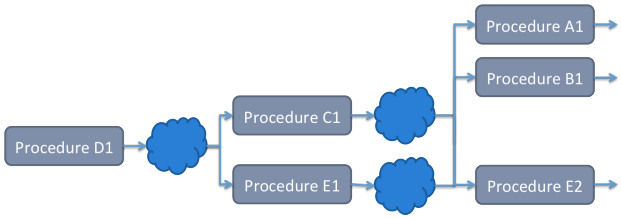

Figure 3: Procedures and object state reconfigurations.

timal object placement. One such method [8] is used for data object placement that relies on a Linear Programming (LP) relaxation that allows for complexity based on the product of the number of objects and locations. Another approximation algorithm solves a data placement problem [2] in a similar LP relaxation manner.

Other algorithms may only find a local maximum or minimum and miss a global optimization. Hybrid algorithms for global optimization [1] can combine various methods with iterative searches. Spatial planning for the ISS using geometric reasoning has been investigated for operations and stowage planning [3]. A packing algorithm with database search capabilities for the ISS was also investigated [5].

3. UTILISTATION

Given a set of procedures, as new items are manifested, Initial Placement (IP) of cargo can be analyzed for best overall use of time and utilization of the ISS. Allowing for small movements or reconfigurations of items on investigation completion or down time can reduce the search space. Additional restrictions, such as the amount of physical space needed to perform reconfigurations, moving an object out of the way which requires space, also reduces the solution search space.

The overall goal is to minimize procedure and reconfiguration times given a set of object states, crew procedures, and schedules, which could lead to increased productivity and utilization of the ISS. Figure 4 shows an approach that uses Map-Reduce to optimize stowage placements. With thousands of items onboard, searching the entire solution space is not possible. However, reconfiguration time by crew and physical space is limited, so only small changes need to be explored, reducing the set of possible configurations between events and crew procedures.

This research is in optimizing stowage configurations over time with little to no burden on crew members and may increase the utilization of the ISS.

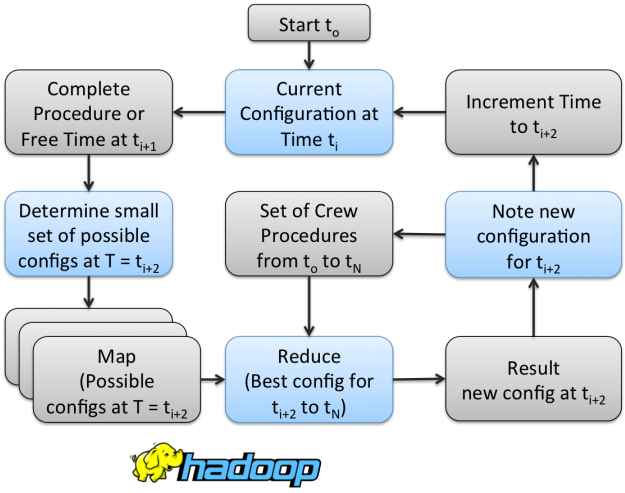

Figure 4: UtiliStation uses Map-Reduce to choose the best configuration of items for minimizing crew time.

Future work would include collaborations with NASA and analyzing with inventory data and procedures. Business offices and individuals needing planning and space management solutions are possible additional applications.

4. REFERENCES

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