Development of a Digital Twin Model to Improve Disaster Debris Collection Operation

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Background: Vegetative debris makes up a large portion of the debris left in the wake of storms. They pose a threat to the population by damaging homes & power lines, and blocking roads.

Problem Statement: Currently, Post-disaster debris is temporarily stored in a Temporary Debris Management Site (TDMS) in mixed conditions. This decreases recyclability, which is important to the recovery process.

Proposed Solution: Since sustainable disaster debris collection and storage is very complex, a digital twin (DT) model was proposed. DT models are under-explored in their application to the post-disaster debris management process, but they have been used in projects such as improving global wildfire prediction. The dynamic updating system of a DT is expected to make post-disaster debris management much more efficient and sustainable. *This study looks into their incorporation into post-disaster debris collection on a small, experimental scale to evaluate their effectiveness within the debris management process.*

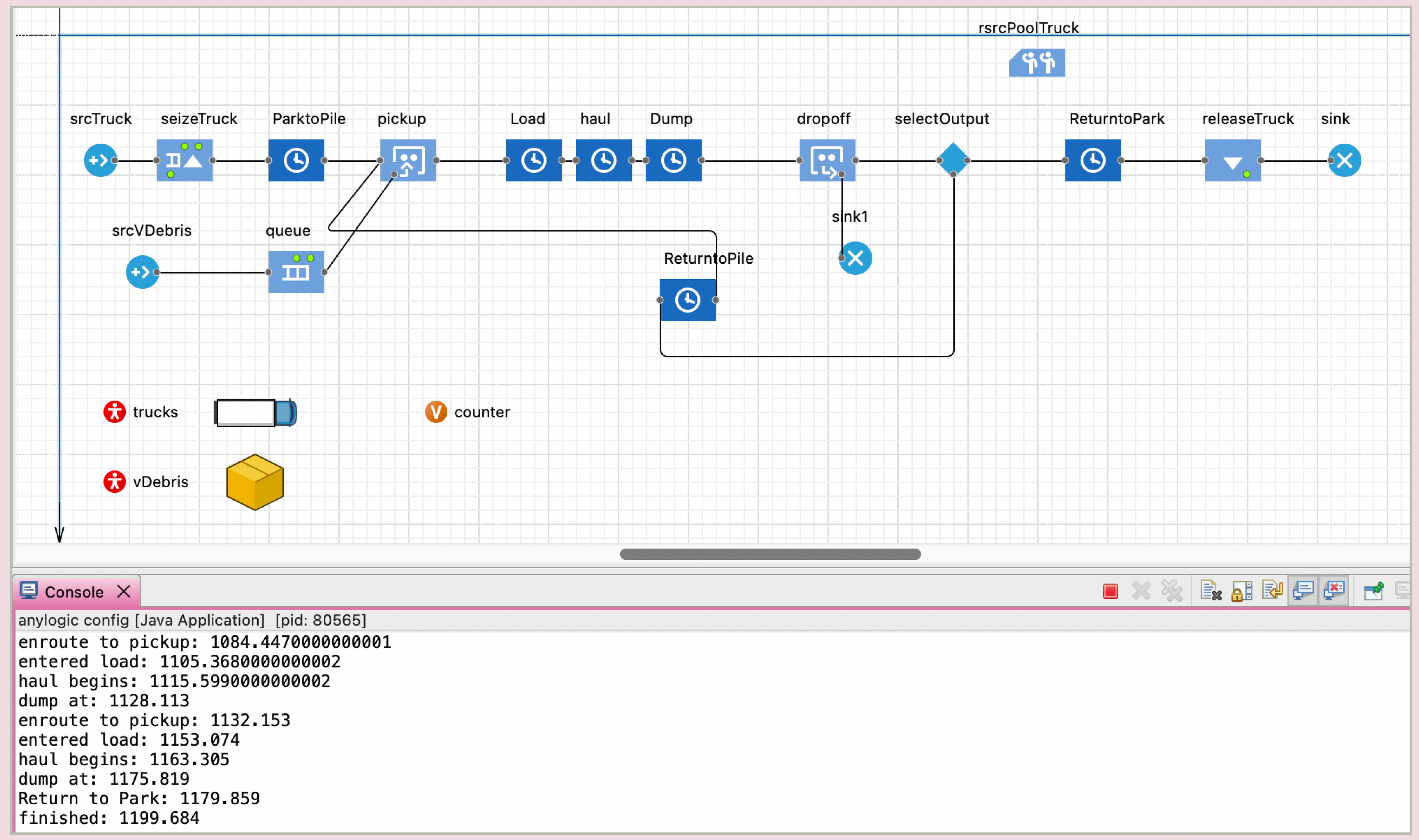
Methods

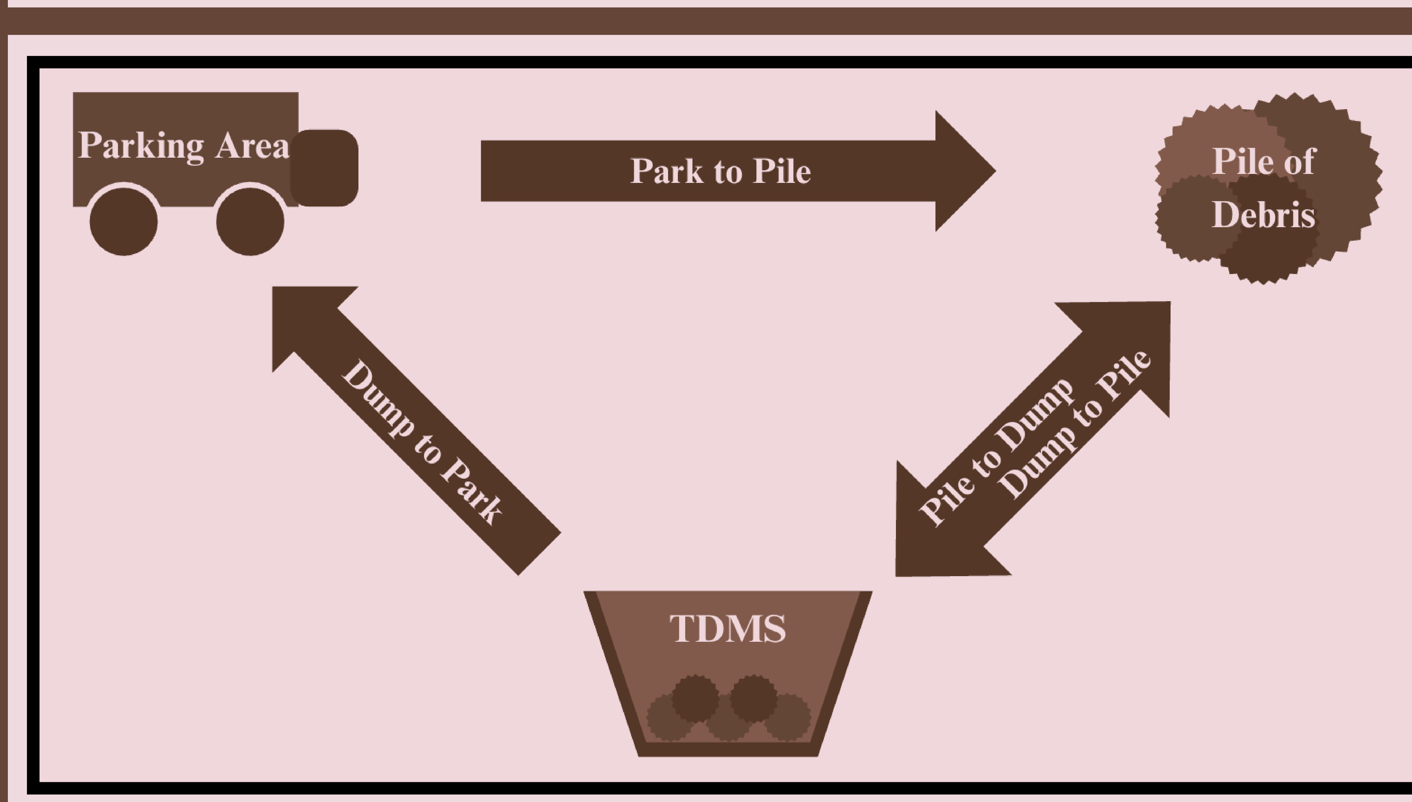
Objective: Determine if a digital twin model would be an efficient addition to the Post-Disaster Debris Management process by focusing on small-scale digital-twin incorporation into an experimental replica of a disaster debris collection situation.

Process Logic: Timed sections over 25 laps were averaged. These values were put into the AnyLogic Simulation, beginning with the first run of the original situation through the average of 1st–25th.

Model Developement: Once the averages were input in AnyLogic (a discrete event simulation system), simulation calculations were observed and system set up was adjusted until the simulated data reflected the gathered experiemental data and set up.

Verification/Validation: The average calculations were input into AnyLogic and the software was adjusted until the total time reflected the expected calculations and the programmed process reflected the experiment. To confirm, the calculations from just the first run were incorperated to see if total time still reflected the calculated time.





A Visual Representation of the Experimental Process.

Park → Pile,

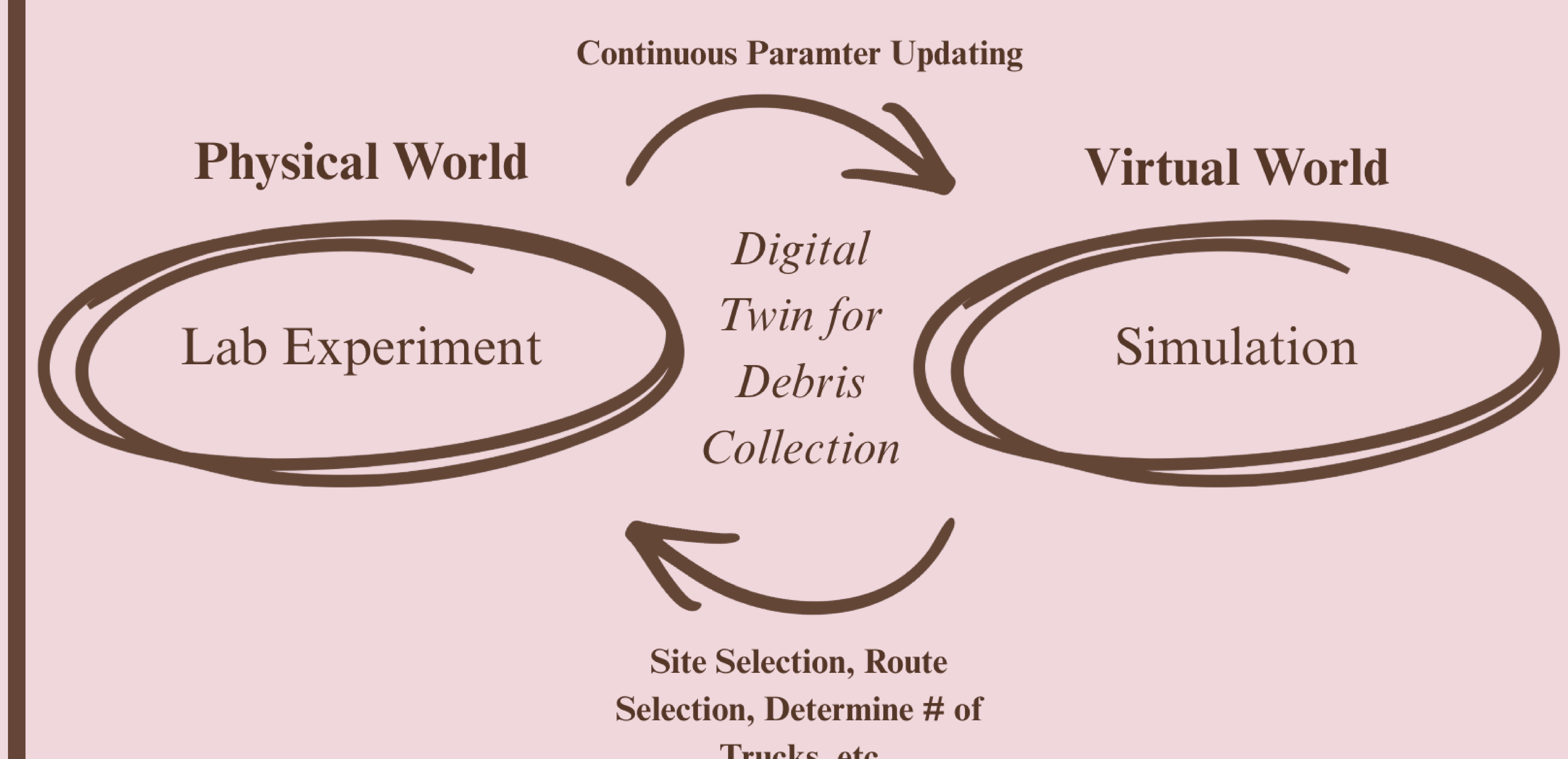
Pick Up,

Pile → Dump,

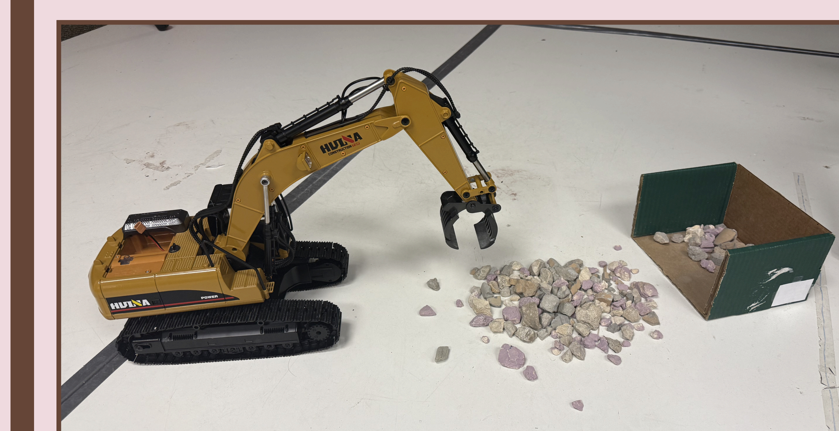
Dump → Pile

or

Dump → Park

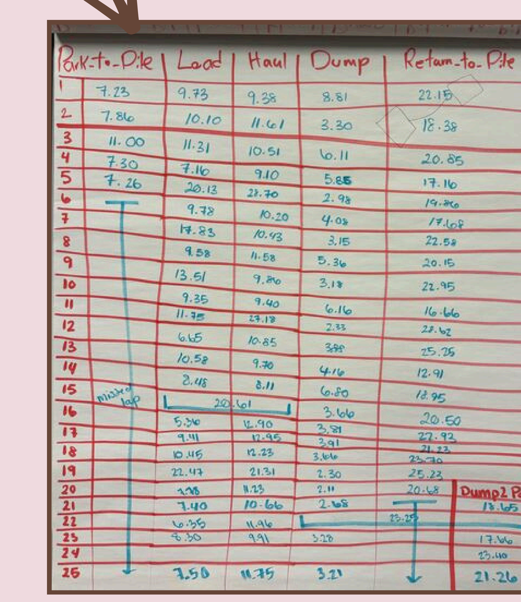


Case Study: In this experiment we created a small scale lab replica of debris collection to simulate the real situation. We collected data on 25 separate runs, timing each section of the process. Then, we found the average of each section and input that information into the digital simulation.



Miniature remote-control truck picking up "debris" represented by small rocks with its crane.

Data collected from repeating the experimental process 25 times



Results:

Statistical Results

Average Run Time (seconds):

- Park_to_Pile → 8.13
- Load → 10.23
- Haul → 12.51
- Dump → 4.04
- Return_to_Pile. → 20.92
- Dump_to_Park → 19.83

- ONE full cycle: 75.66
- 25 full cycles: 1199.68

Project Limitations:

- Base model (automatic real-time updates not included)
- Average run times used for operation calculations
- Doesn't take change in operation conditions into account
- Only tested within a simple-model lab setting

Future Progress:

- Use probability of distributions to represent collected duration data
- Baysian Method updating
- Expand into a multi-truck operation
- Consider congestion & optimal routing to TDMS
- Test model in full-scale post-disaster scenario

Conclusion

The next step after validation is a feasability test to deploy a real digital twin model. We did not test a full fledged feedback loop because simulation information was not applied to the real world situation.

The concept of digital help would increase the accuracy of estimation of "time to finish" for the project. Even though post-disaster conditions introduce uncertainty into the debris collection process that would cause deviation from the initial schedule, digital assistance with the ability to incrementally update cycle times would allow for fluid adjustments in the schedule. A digital twin model would introduce an automatic updating system. While the simple AnyLogic model created here is not automatically updating, it can still be adjusted to real-world situations more efficiently than the use of stagnant information.

Acknowledgements & References