SIMULATING DISTURBANCES IN TACTILE INTERNET TO STUDY DESYNCHRONIZATION

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1 Tactile Internet and the “1 ms challenge”

- **Tactile Internet (TI) = Transmission of physical movement and haptic feedback over the internet.** Use case example: Remote surgery.
We call *master domain* the side the user is in and *controlled domain* the side containing the environment the user interacts with.
- **TI requires max. 1 ms of delay. Latency above this threshold causes destructive behavior [1] and is noticeable to the user [2]. Physical limitations, like the speed of light, make this requirement unachievable over long distances through a simple feedback loop.**

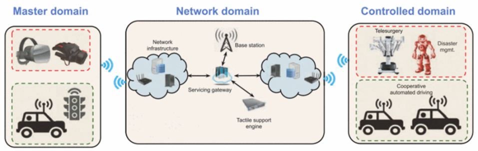


fig. 1: Tactile Internet Structure [3].

- **A local simulation of the opposite domain can be made through modeling with point clouds. The simulation is then used to provide direct feedback. This solution solves the “1 ms challenge” but brings about new challenges to overcome.**

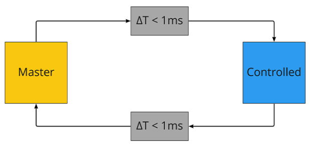


fig. 2: Simple TI Feedback Loop.

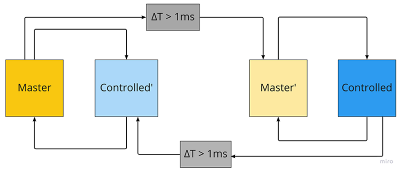


fig. 3: TI Feedback Loop With Local Simulations.

2 The Desync Problem

- **Network disturbances and incorrect modeling cause desynchronization between models and reality.**

Examples of disturbances: network delay, packet loss, and wrong physical estimations like wrong object weight or friction.

- **This means that the same object can be at two different locations, a destructive effect on the system that still needs a fix.**

3 Method

- **To find solution: study the problem and its cause & effect.**
- **Add controlled disturbances in a TI application. In this work, the tested disturbances are wrong mass and friction.**
- **1D & 2D simulation to reduce complexity.**
- **Use of TI Demo developped in Unity with bullet physics to build the simulations.**

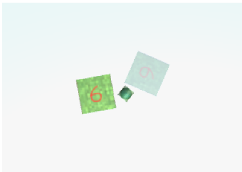
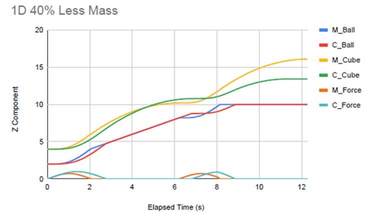
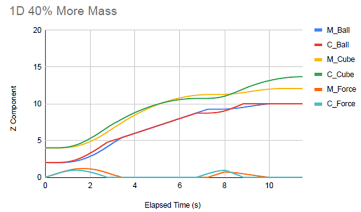


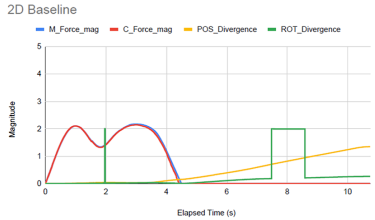
fig. 4: Desynchronized Master and Controlled Domains in 2D simulation.

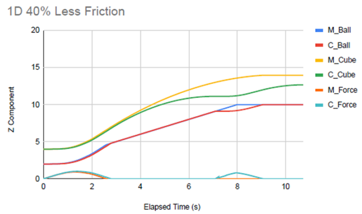
4 Results

- **(1D) Underestimating mass and friction causes bigger desync than overestimating.**
- **(1D) Long time period when pushing an object during which divergence between master and controlled is small. Opportunity to fix the wrong data in time before desync.**
- **(1D) With wrong friction the system desyncs faster than wrong mass.**
- **(2D) Non-deterministic behavior of the system when objects rotate limits observations. The *2D Baseline* graph shows how divergence occurs even without disturbances.**









5 Future Work

- **Update wrong physical properties during manipulation to avoid desync.**
- **Study effect of lower packet reliability by implementing/simulating network component.**
- **Ensure deterministic 2D behavior to further study desync.**

6 Conclusion

- **Gained understanding of the effects of incorrect mass and friction information. Found possibility of correcting desync in certain situation.**
- **Implemented framework for adding controlled disturbances and trying out possible solutions.**

5 References

[1] E. Steinbach, S. Hirche, J. Kammerl, I. Vittorias, and R. Chaudhari, “Haptic data compression and communication,” IEEE Signal Processing Magazine, vol. 28, no. 1, pp. 93–94, 2010.
[2] Gerhard Fettweis and Siavash Alamouti. “5G: Personal mobile internet beyond what cellular did to telephony”. In: IEEE Communications Magazine 52.2 (2014), pp. 140–145. DOI: 10.1109/MCOM.2014.6736754
[3] V. Gokhale, K. Kroep, V. S. Rao, J. Verburg and R. Yechangunja, "TIXT: An Extensible Testbed for Tactile Internet Communication," in IEEE Internet of Things Magazine, vol. 3, no. 1, pp. 32-37, March 2020, doi: 10.1109/IOTM.0001.1900075.