Executive Summary: (2 pages)

The age of space exploration led to significant progress in the understanding of microgravity, but with the continued higher demand for research and development, easier access to these conditions is required. Microgravity conditions are characterized by low/no gravitational impact, resulting in floating objects and bodies. Currently, to understand the impact of microgravity tests are run using drop towers, where objects are dropped from a tall height in a vacuum, experiencing weightlessness for a maximum of about 5 seconds [1]. A more effective technique is parabolic flights, where jets fly and experience microgravity at the peak of the flight [2]. Additionally, a device called a clinostat rotates an object over long periods of time around one axis.

Figure 1: Electric clinostat [3]

The monoaxial design of the clinostat is beneficial to achieve zero gravity quickly and makes it more accessible. However, clinostats do not achieve as accurate values of acceleration compared to the RPM design because when rotated on only one axis there are continuous accelerations in one direction. The dual axis allows the RPM to orient the object in any direction which reduces these centripetal forces [4]. These methods have their proper use cases, but lack significant qualities for long-term studies. Drop towers are too short in time. Parabolic flight is extremely expensive, well beyond $10,000 for research flights, and can't be done for long enough, only about 25 seconds per parabola. Clinostat does not hold up for large objects. To address these shortcomings, a random positioning machine (RPM) is frequently implemented, which, like a clinostat, rotates the subject but instead on two axes to more effectively negate the normal force vector over time.

This project aimed to iterate on an already existing RPM at UCSD. The main differences were the 0.762 m x 0.762m x 0.762 m frame, weight capacity of 45.4 kg, and the need for 120 VAC and 15 A supplied through the machine. These requirements allowed for the furnace to be placed within the machine, or a variety of different experimental equipment for future experiments. The goal was to generate a perceived gravitational vector of 0.001 g while minimizing the auxiliary tangential and centripetal accelerations. To achieve this, the machine had to be able to run at low speeds for a long period of time.

Figure 2: RPM 2.0 operating with a furnace

The RPM 2.0, as seen in Figure 2 features two frames, one inner and one outer, that rotate on perpendicular axes. The inner frame held the sample bay, and the outer frame anchored the machine to a stationary base. Each frame had two custom-machined shafts connecting it to the next one. On one side, the driveshaft connected to a CubeMars AK60-6 brushless DC motor, serving to rotate the machine. On the opposite side, a through bore Motion ER025-12P3 slip ring was housed on the second shaft, allowing the machine to rotate without twisting or potentially damaging the power and signal wires. Through these slip rings, the machine supplied the required energy into the sample bay, allowing researchers to run any number of experimental devices. Underneath the sample plate, a Phidget Spatial inertial measurement unit (IMU) was centrally located, allowing for machine performance data collection. The IMU was displaced from the machine's rotational center to better accommodate specimen placement, and in doing so, measured a worst-case scenario for the effective acceleration. The mounting procedure supports experimental samples from below with the sample plate, and from above with a brace that features lateral supports.

The RPM 2.0 was successfully manufactured, and then run through a variety of tests to determine its viability as a research tool. Initially, the machine was run while empty for periods between 30 minutes and 3 hours using a bounded walk algorithm. These tests ensured that the machine ran without complications for a decent amount of time. Once the furnace was fully installed, six 2-hour tests were run under the same algorithm. Afterwards a numerical average over the test was computed for each component in the measured acceleration vector. The vector norm for each average was determined to be the perceived gravity. Over the three tests the average perceived gravity was: 0.0157 g, with a standard deviation of 0.0032 g. The resulting error between experimental and theoretical gravity was 92.4%

References

[1] https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Research/Drop_towers
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[3] https://www.hbarsci.com/products/bi0244v1
[4] https://www.frontiersin.org/journals/plant-science/articles/10.3389/fpls.2019.01577/full