INFORMATION TO ENERGY

FINAL WEEK

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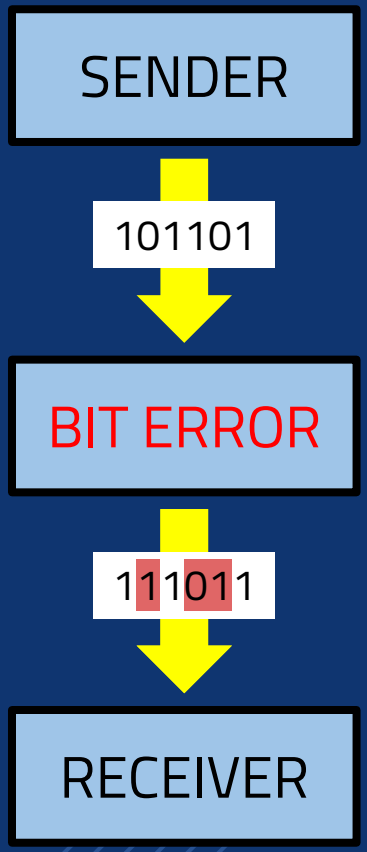
PROJECT GOAL

- Quantify the transformation of information to energy
- Observe effects of imperfect information on energy
- Code simulations for Maxwell’s Demon and High Pressure Demon
- Collect data from simulations

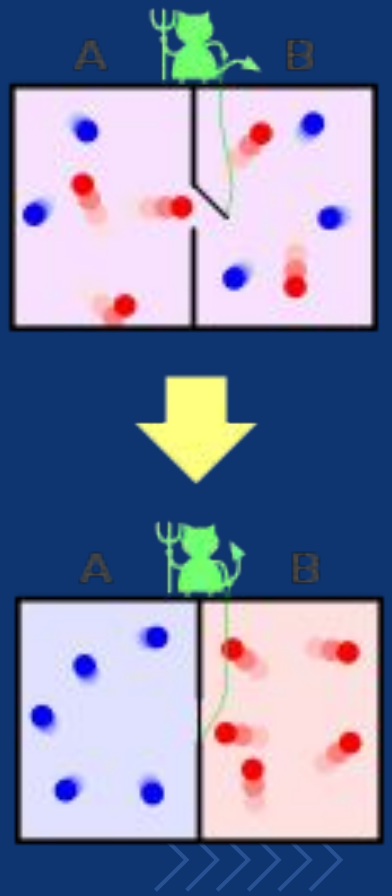
BASIC INFORMATION THEORY

- The amount of information carried by a message is $\log_2(1/p)$
- A bit is the unit of information
- Bit error can be used to create imperfect information



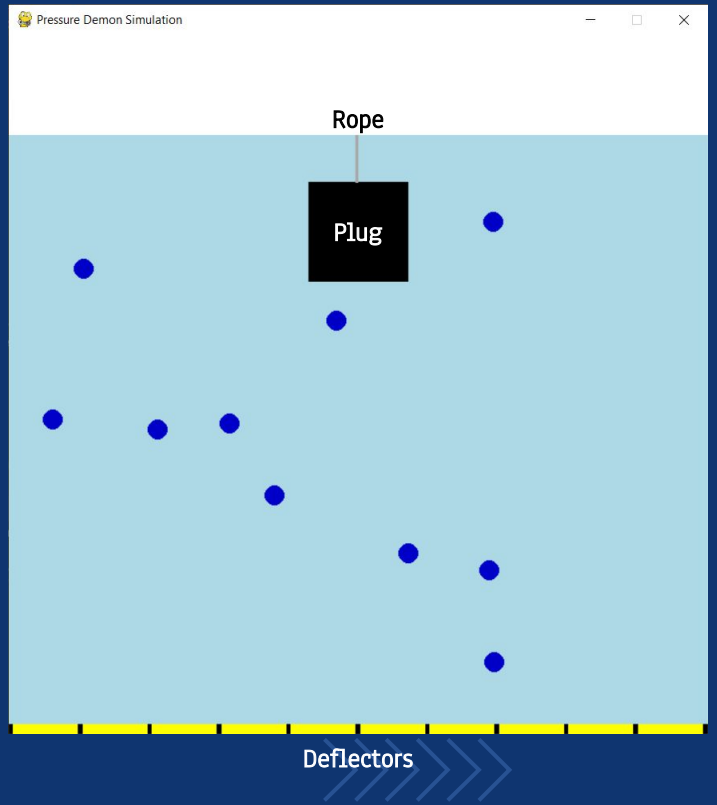
MAXWELL'S DEMON

- Hypothetical thought experiment that was proposed by James Clerk Maxwell in 1867
- Two chambers of gas, separated by a demon-controlled door
- Demon controls door to sort fast particles to one side and slow particles other side



HIGH PRESSURE DEMON

- Demon theorized by Professor Martin
- Components: container of water, plug, rope, deflectors
- Plug hangs from top of container via rope
  - When light, plug stays afloat due to particle-plug collisions
- Demon controls deflectors to redirect particles toward plug

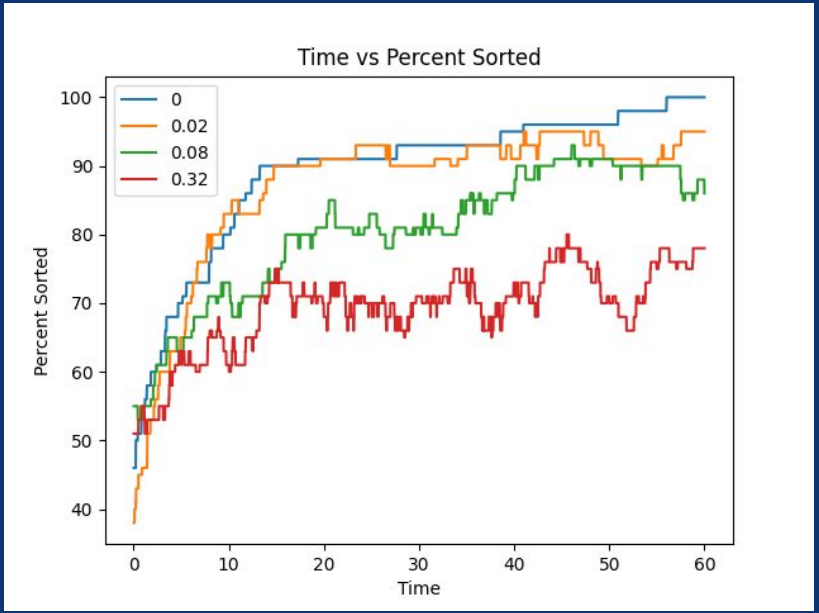


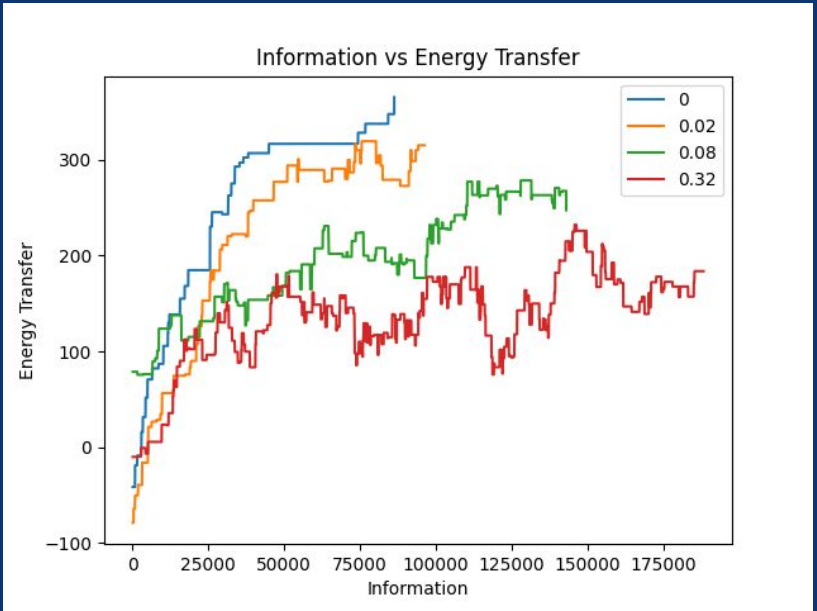
METHOD

- Used Python module Pygame to create both of the simulations
- In each demon simulation, the world (simulation) sends the position and velocity of each particle to the demon
- Demon uses this information to decide how to open/close door or rotate deflectors
- We create imperfect information by adding bit error to the communication between world and demon

MD - CODED SIMULATION

MD - RESULTS





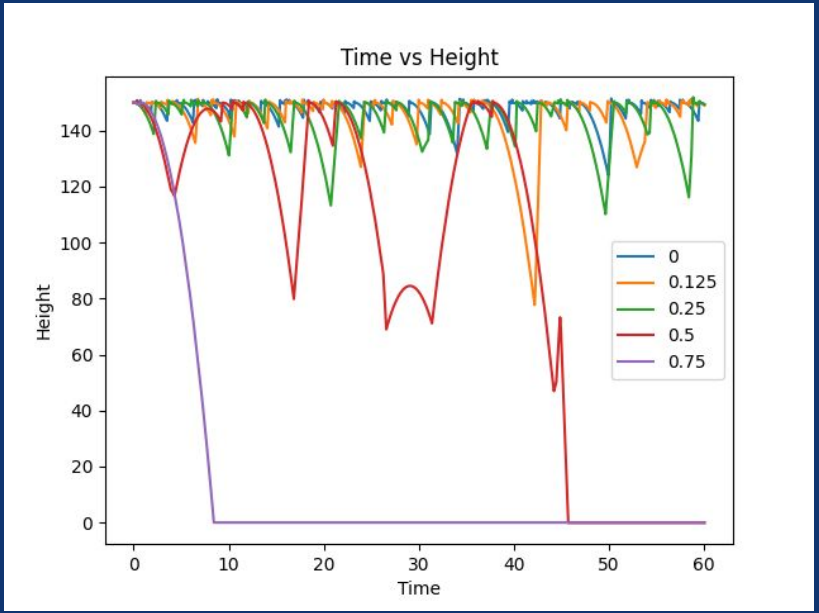
Bit Error Rate	0	0.02	0.08	0.32
Joules/Bit	236	305	577	1024

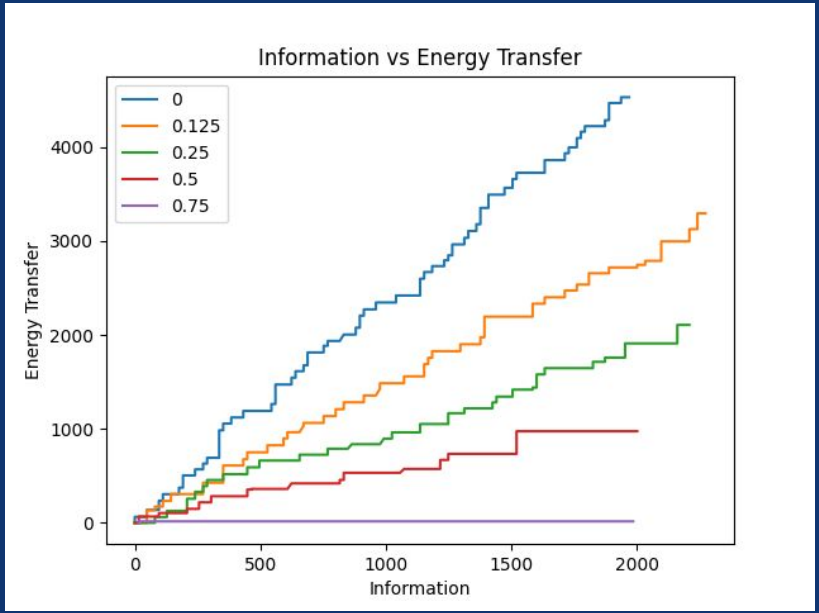
HPD - CODED SIMULATION

DEFLECTORS OFF

DEFLECTORS ON

HPD - RESULTS

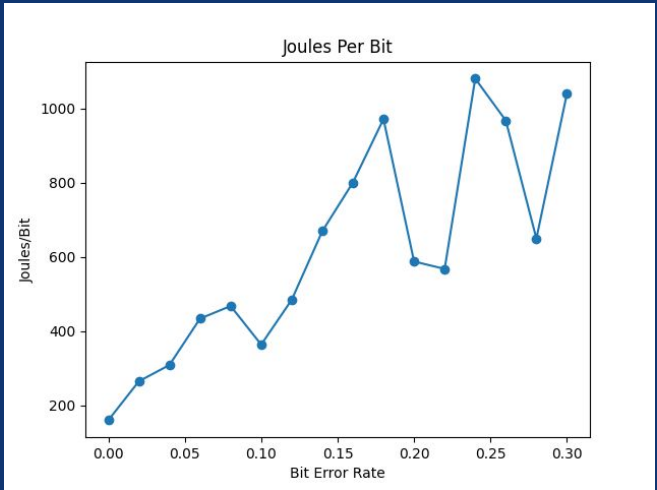




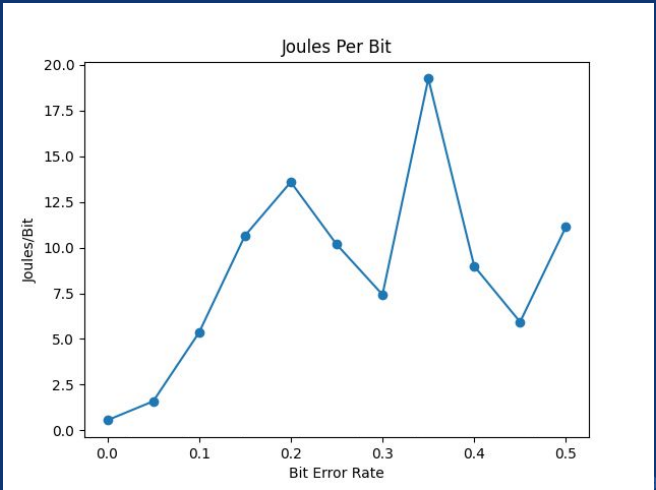
Bit Error Rate	0	0.125	0.25	0.5	0.75
Joules/Bit	0.43	0.69	1.05	2.05	125.76

CONCLUSIONS

- Increasing bit error causes the demon's effectiveness to decrease
- Increasing bit error causes the bits necessary for a message to transfer 1 joule of energy to increase



Maxwell's Demon



High Pressure Demon

CURRENT PROGRESS

- Coded simulations for Maxwell’s Demon and High Pressure Demon
- Collected data from these simulations showing information vs energy transfer at different bit error rates

FUTURE GOALS

- Formulate and code more demons
- Collect data from these demons
- Compare results across demons
  - We predict that results will vary from demon to demon

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WINLAB | Wireless Information Network Laboratory

Quantifying the Transformation of Information to Energy

Katherine Moreira, Yunhyuk Chang, Evan Xie

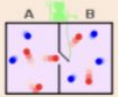
Advisor: Richard Martin

ABSTRACT

The lower bounds of energy used in communications and computing are not well understood. The objective of this project is to use the principles of James Maxwell's thought experiment, Maxwell's Demon, and of Claude Shannon's research document titled "A Mathematical Theory of Communication", to measure the Demon's effectiveness by modeling the relationship between the Demon and the physical system as a discrete channel with noise, and measuring the energy extracted as a function of the conditional entropy. The overall goal is to **plot the bit-error rate versus energy transfe**r of a digital model of the Demon.

INTRODUCTION and BACKGROUND

Maxwell's Demon:



- The demon can only open and close the sliding door between the sides to sort the particles as they move towards the hole.
- The Demon's goal is to move all the particles from the left side to the right.

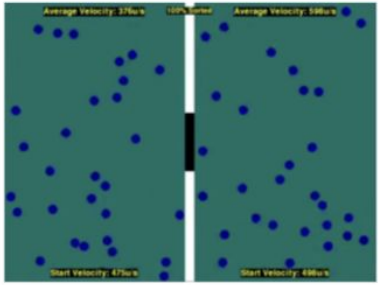
Information Theory:

- The scientific study of the quantification, storage, and communication of digital information.
- A key measure in information theory is entropy. Entropy quantifies the amount of uncertainty involved in the value of a random variable or the outcome of a random process.

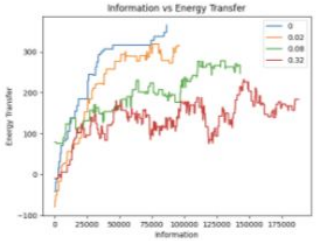
METHODS

This project utilizes the Python as well as **Pygame** - a cross-platform set of Python modules. Using **object-oriented programming**, the code for a Maxwell's Demon simulator was created and used to experiment hypotheses.

RESULTS



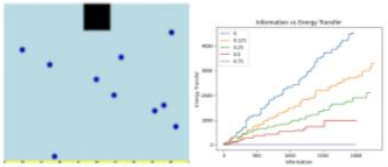
Coded Maxwell's Demon Simulation



Graph of Information vs Energy Transfer

DISCUSSION

The project also developed a **High Pressure Demon.** The plug hangs from the top of a container and floats when the container is light due to the water molecules colliding with its bottom. When the container becomes heavy, the deflectors controlled by the Demon are used to redirect water molecules to the plug again to allow the plug to stay suspended for heavier weights.



FUTURE DIRECTIONS

The next step for this project will be to write a **technical report** to document the data and results from both the Maxwell's Demon simulation and the High-Pressure Demon. The next steps will also include testing concepts for **more Demon simulations.**

ACKNOWLEDGEMENTS

Thank you to our advisor, Professor Richard Martin, for helping us and being our guide through this project. Thank you to WINLAB for allowing us the opportunity to learn participate in their summer internship

WINLAB


THANK YOU!
ANY QUESTIONS?