Development of an Automated Medical Inventory System for Deep Space Exploration

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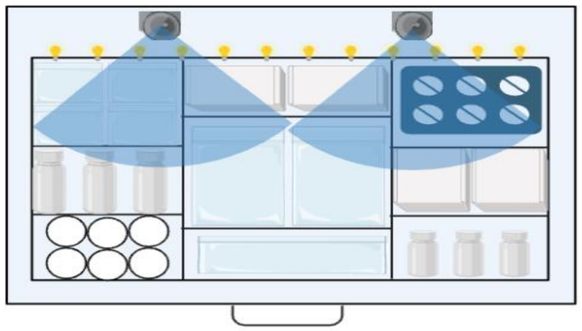
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Introduction & Problem Statement

Problem: Current space logistics for medical inventory rely on astronauts manually scanning barcodes or using RFID tags. During long term missions in deep space, astronaut time is a critical resource, and untracked expired medications pose several health risks.

Goal: Eliminate cloud-dependency and prove that complex medical logistics can run entirely on low-power, local “edge” hardware.

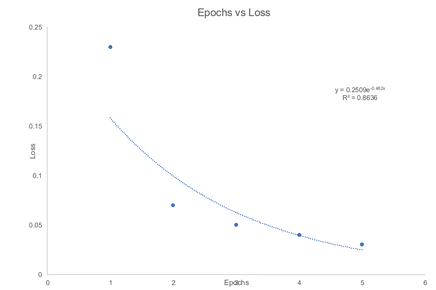
Solution: A completely passive, automated inventory system using a camera-equipped medical storage drawer. The system relies on a lightweight Artificial Intelligence model to visually track medication usage in real-time without human interaction.



Software Architecture

We utilized a MobileNetV3 Convolutional Neural Network (CNN) that reduces required computing power by up to 90% compared to traditional CNNs with the use of “depth wise separable convolutions”, making it ideal for spaceship hardware [1]. Through transfer learning, the model was trained on a custom dataset to perform binary classification (“Medicine” vs. “No Medicine”).

Current Performance: Software inference testing successfully identified medical supplies with 86.5% confidence and reduced the training loss to 0.0302 over just 5 epochs.

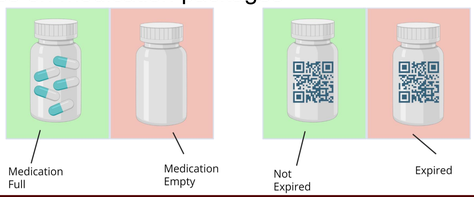


Risk Analysis & FMEA

The most severe risks we have identified that are:
- Innacurate identification of expiration dates on medication packages
- Empty medication packages

Mitigation strategies:
- QR codes on medication packages
- Training the model on empty packages

Risks were identified using a FEMA analysis



Physical Prototype

To develop the first prototype, we designed a laser engraved and laser cut box that would simulate traditional medicine storage in space. The camera was fitted onto the box.

Proposed System Architecture

Hardware Stack: The physical enclosure will utilize a Raspberry Pi 5 (8GB RAM) paired with a 12MP Camera Module 3 for optical capture

Controlled Environment: An internal LED strip guarantees consistent lighting (preventing shadow casting), while a passive active cooler prevents thermal malfunction, which is a major risk in microgravity environment

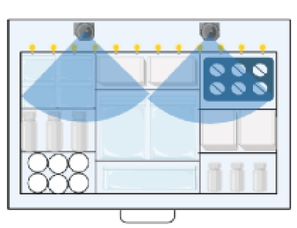
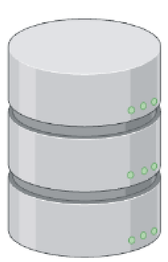


Image capture cameras take images of drawer contents, facilitated by internal lighting.



Onboard Processing Unit runs the CNN model to identify items and compares inventory to the database, updating quantities and locations live.



Inventory database stores item name, quantity, location, and expiration data.



User interface displays real time inventory and alerts for low quantities and expirations in a manner accessible to crew members.

Next Steps

With our solution being simple and automated, our goal is to train the model so that it can function in multiple orientations and fail states.
Example Conditions:
- How well can the model function with obstructed camera views?
- Does the model accurately read expiration dates?
- Can the CNN accurately run with multiple compartments containing different medications and quantities?

We plan to develop a real-world prototype that simulates the actual medical kits used in space and test our system to determine its compatibility. We want to aim for a 90-95% accuracy score and to identify the inventory change in under 60 seconds.

References

[1] A. G. Howard *et al.*, "MobileNets: Efficient Convolutional Neural Networks for Mobile Vision Applications," *arXiv preprint arXiv:1704.04861*, 2017. [Online]. Available: https://arxiv.org/abs/1704.04861