DESIGN AND PROTOTYPING OF A PORTABLE AI-POWERED FIELD DEVICE FOR FOREST MONITORING APPLICATIONS

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Introduction

Wood chip quality plays an important role in sustainable forest product management. Properties like moisture content and chip size directly affect how efficiently the material can be processed and used. However, the standard methods for measuring these properties often require lab-based equipment, which can be bulky, expensive, and impractical to use in field settings.

This project was motivated by the idea that with the right mix of small-scale computing, imaging systems, and thoughtful design, it's possible to bring key measurements—like wood chip moisture and size—directly into the field. The aim was to create a portable, easy-to-use device that could provide real-time analysis without relying on constant internet access or large lab equipment. To support this goal, the project also made use of advancements in additive manufacturing, allowing for the rapid prototyping and fabrication of custom enclosures through 3D modeling and printing. This approach made it easier to iterate designs quickly and build a device tailored for forestry environments.

Methodology

The process and procedure approached for research can be categorized into 3 sections:

1. Hardware Selection:

The project began with identifying what components were needed to make the system work reliably and independently.

At the core of the device is an NVIDIA Jetson Nano, a small computer powerful enough to run machine learning models locally. It connects to an 8-megapixel USB camera, which captures images of the wood chips, and a 7-inch touchscreen display, which lets the user interact with the device and see results in real time. To keep the device portable, it runs on a rechargeable NP-F970 battery, supported by a buck converter to regulate power and NP-F Battery Adapter plate.

2. CAD and Prototyping

All of these components are housed in a custom 3D-printed casing, designed using SolidWorks and Fusion 360. The designs were sliced and prepared for printing using PrusaXL Slicer, and printed using PLA material on PrusaXL and Bambu Lab X1 Carbon printers.

The trial-and-error approach was used for the Designing and Prototyping the product. The Figure (1) shows the procedure implemented.

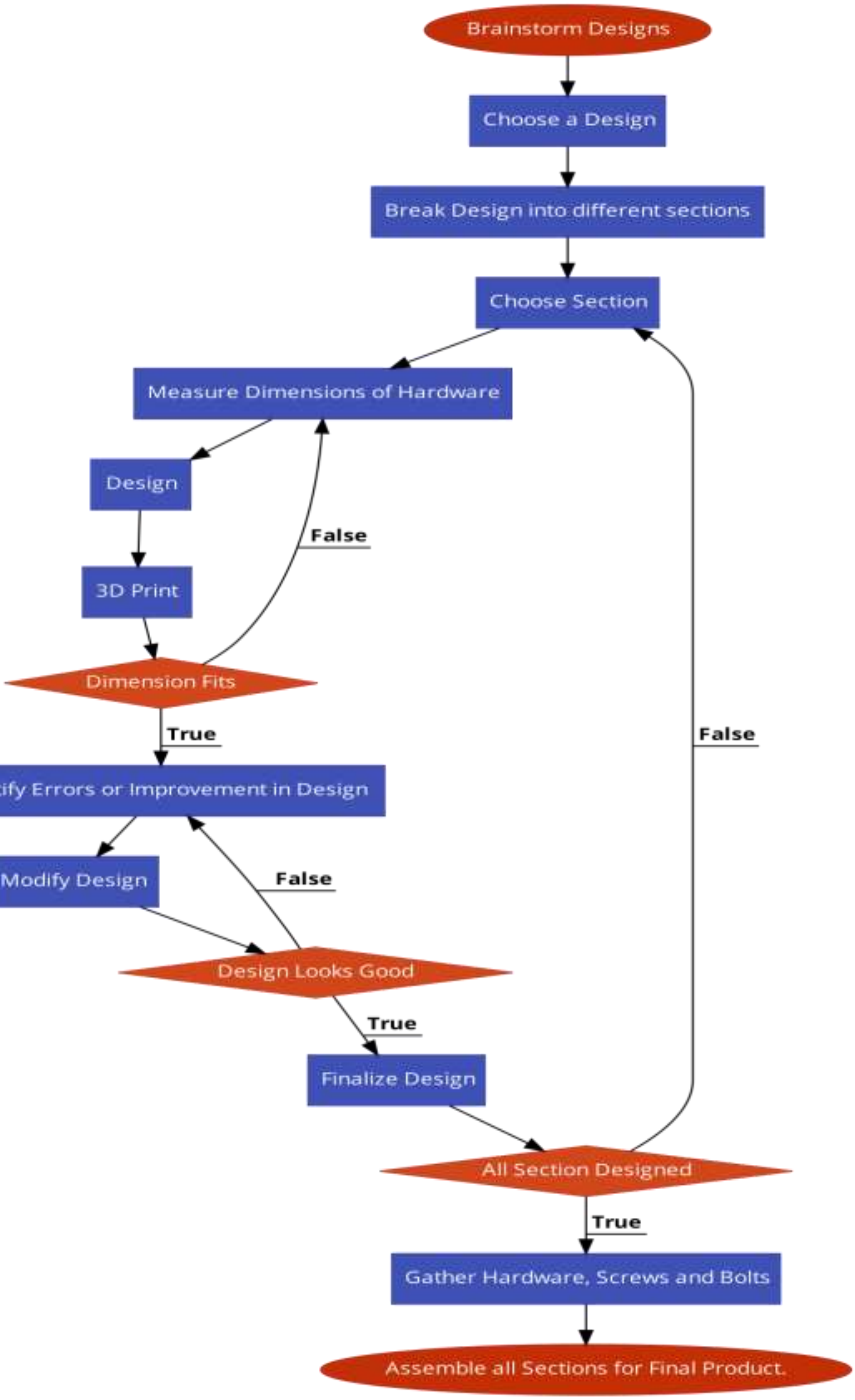

Figure 1: Flowchart explaining the process used for Designing and Prototyping

3. *AI Model Deployment:*

The machine learning models used to predict moisture content and chip dimensions were deployed directly onto the Jetson Nano, allowing the system to work entirely offline.

Results

The final prototype met the core goals of the project. It brought together all required components into one portable unit that could be operated without internet access.

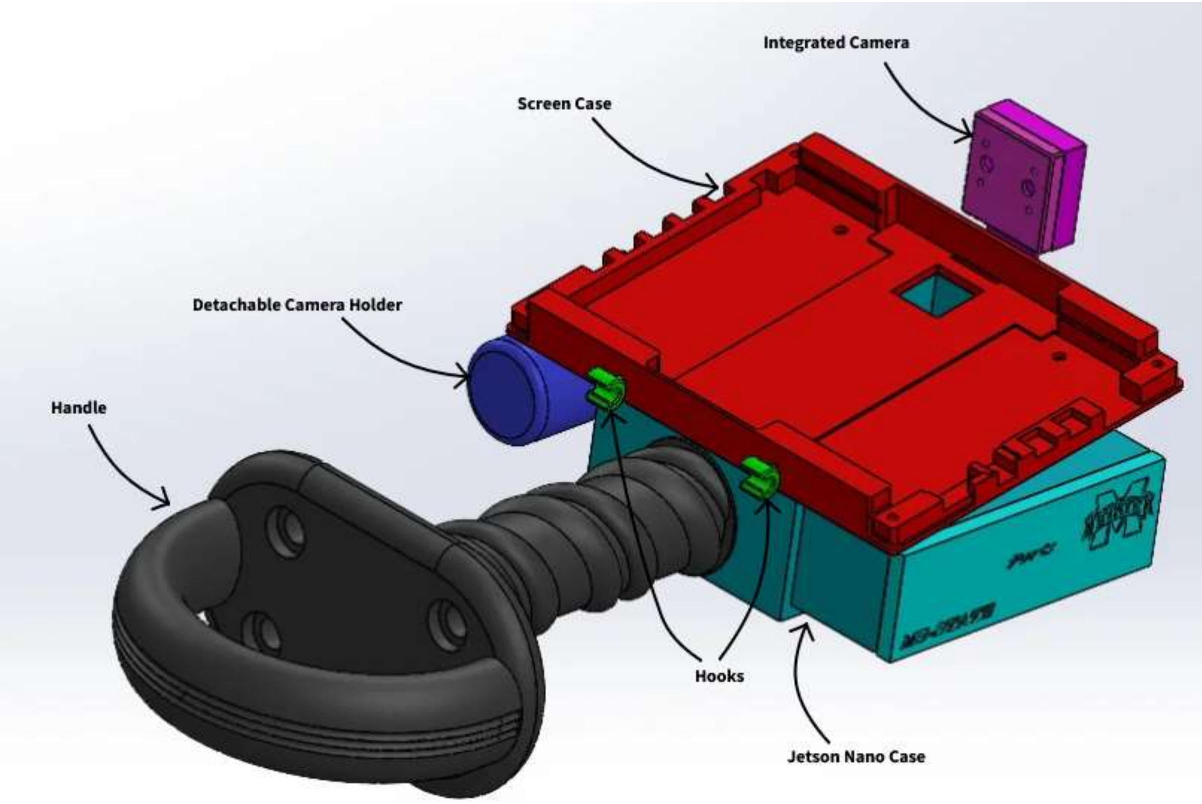

Figure 2: Final Assembled Design of Product in Isometric view in SOLIDWORKS

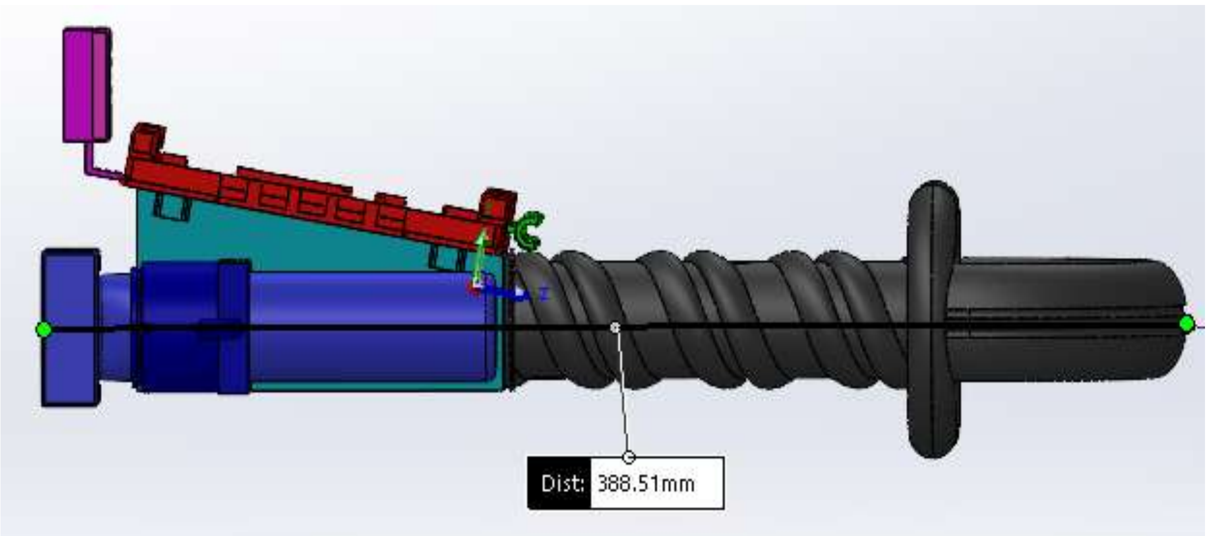

Figure 3: Final Assembled Design of product in Left view in SOLIDWORKS

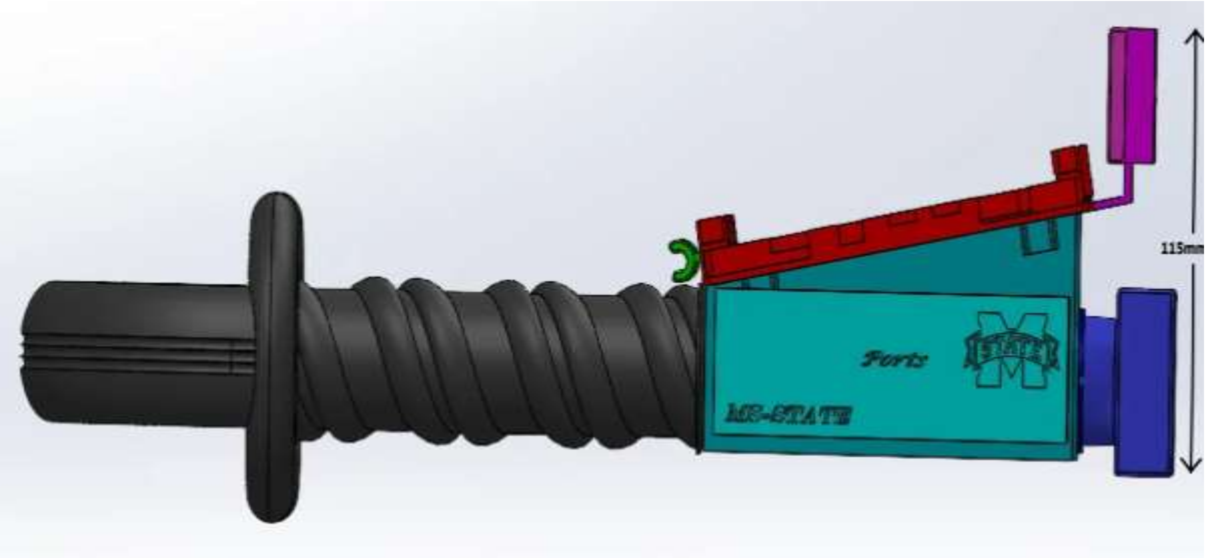

Figure 4: Final Assembled Design of product in right view in SOLIDWORKS

Some key features of the final design include:

- **Real-time image capture and analysis using a built-in camera:**
  The device is equipped with an 8.0-megapixel USB camera mounted within the housing, capable of capturing high-resolution images of wood chip samples. These images are immediately processed within the device, allowing for quick and efficient evaluation of physical characteristics on-site.

- **Moisture and size estimation using pre-trained machine learning models:**
  The system runs pre-loaded machine learning models directly on the Jetson Nano processor. These models analyze the captured images to predict both moisture content and chip dimensions, eliminating the need for traditional lab-based measurement methods.

- **Fully offline operation using a swappable battery system:**
  Designed for use in field conditions, the device operates independently of Wi-Fi or cloud access. It is powered by a rechargeable NP-F970 battery and includes a buck converter for power regulation, ensuring stable performance during extended outdoor use.

- **Integrated 7-inch touchscreen for user interaction and data display:**
  A built-in touchscreen interface allows users to easily control the device, initiate image capture, and view analysis results in real time. The user interface is designed to be intuitive, even for those with minimal technical background.

- **Compact, modular, and durable 3D-printed housing:**
  The entire enclosure was custom-designed using CAD software and fabricated with PLA material on high-resolution 3D printers. Its modular layout makes it easy to assemble and maintain, while the compact form factor ensures portability in field applications.

As the Product was designed by breaking it into sub-sections, the design is modular and easily modifiable according to need and use. All core components—including the camera, Jetson Nano, touchscreen, and power system—were successfully integrated into a single functional unit, with stable performance during testing sessions. The custom 3D-printed housing securely held all internal components, withstanding repeated assembly and transport without damage.

Figure 5: Final Assembled 3D Printed Flied-ready Product

Discussion

One of the most rewarding aspects of this project was seeing how accessible tools—like open-source software and desktop 3D printers—can be used to create working prototypes in a relatively short time. Iterative design played a major role. Each version of the enclosure taught something new, whether about 3D printing, design, power layout, or camera placement. Being able to make quick changes and test them the next day helped move the project forward efficiently.

Some challenges included managing space inside the enclosure, keeping components stable during movement, and making sure the 3D printed orientation doesn't have overhangs. These were addressed with internal reinforcements, improved camera holders, and modular design rather than single design.

This project also emphasizes the importance of interdisciplinary collaboration—spanning forestry, bioproducts, and engineering—to solve complex environmental monitoring problems.

For Future use or research, one could use this prototype as a starting Design and work on some improvements that could be done in this design for better use. During the testing phase, we have realized some ideas for improvement in the design. These include: better and internal wiring between components, alternate placement of Power Adapter and batteries for less stain in handle, and internal threaded fastener rather than screw and nuts fastener.

Conclusion

This project successfully produced a working prototype of a portable field device for assessing wood chip quality. The system integrates imaging, processing, and display capabilities into a single unit that works offline—making it suitable for use in outdoor or remote areas.

Participating in this project provided a valuable learning experience beyond just the technical outcome. Throughout the design and prototyping process, I became more confident and skilled in using CAD software such as SolidWorks and Fusion 360, as well as in 3D printing techniques for building functional hardware enclosures. The experience also helped me understand how design decisions impact real-world implementation, particularly when working with space constraints, power systems, and user interfaces.

Through weekly meetings and progress reviews, I developed stronger collaboration and documentation skills, learning how to communicate effectively within a multidisciplinary team. Additionally, the project introduced me to the fundamentals of machine learning and the Python programming language, which gave me a broader perspective on how artificial intelligence can be applied to solve practical problems in forestry and beyond.

Overall, this experience has strengthened both my technical foundation and my ability to work in a research-driven environment.

Acknowledgments

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