ElectroCap Project Proposal

Intelligent Post Box: A remote monitoring solution for residential buildings

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1. Advisors and Mentor

- Scientific Advisor:
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2. Problem definition

In multi-unit residential buildings, managing post box access and tracking incoming mail can be challenging. Traditional post boxes are often situated in common areas, with no means for residents to monitor when or if their mail has arrived. This leads to inefficiencies such as missed deliveries, unnecessary trips to the mailbox, or issues with lost or stolen mail. With increased reliance on online shopping, important deliveries, and sensitive documents, managing these deliveries has become a critical need, particularly in high-density urban environments. There is currently no effective system to allow residents to remotely track the status of their post boxes, leading to frustration and potential delays in receiving important parcels and letters. The lack of real-time monitoring also increases the possibility of postal theft, as residents may not check their mail regularly, leaving packages vulnerable. As a result, many postal services and residents are seeking innovative ways to improve mail delivery and tracking. This presents an opportunity to develop an intelligent, automated solution that enables remote monitoring of post boxes, providing residents with notifications, security features, and overall convenience. Such a system would allow residents to know the status of their mailboxes, improving both security and the overall user experience.

3. Solution beneficiaries

- **Residents of multi-unit buildings**: Particularly in urban environments where multiple residents share a building's common areas, individuals who rely on timely and secure mail delivery will benefit from this solution.
- **Postal services**: Delivery personnel can be informed about the status of mailboxes, ensuring that parcels are not undelivered due to inaccessible or full mailboxes.
- **Building management companies**: They can ensure efficient management of common areas by knowing when mailboxes are full or if any issues arise, thus reducing the risk of complaints or security concerns.

4. Technological solution

- Raspberry Pi Camera Module 3 - takes a picture of the mailbox from the inside and sends it to the application.
- Raspberry Pi - programs the camera and smart lock.
- Infrared sensor - Sensor that checks the opening and locking of the door.
- 4*4 keypad module - For opening the door.
- LCD Display - Shows messages to the user.
- Leds - light up the box for the camera to take a picture.
- Application with access to the camera inside the post box, with a notification system for when a package arrives and a database to keep track of when packages arrive.

5. Competitors and previous work

- Competitors: Super e-Technology Services Limited; The Safety Letterbox Company LTD; Handover; ShipRite; Locky.
- Previous work: Parcel Boxes.

6. Solution requirements

- Managing mail delivery in multi-unit residential buildings presents challenges such as missed deliveries, unnecessary trips to mailboxes, and concerns about theft. To address these issues, an effective solution must include **Mail Delivery Detection** that reliably senses when mail is delivered to individual post boxes and sends real-time notifications through a mobile app. These notifications should provide delivery timestamps and mailbox status updates, keeping residents informed without the need for frequent physical checks.

- A critical focus is ensuring **Low Maintenance**, with hardware designed to minimize the need for frequent battery replacements or manual repairs. This can be achieved with sensors and smart locks featuring self-diagnostic capabilities and modular designs for easy servicing. Additionally, the system should prioritize **Affordability**, using cost-effective materials and scalable pricing models to remain competitive with traditional mailbox systems, while keeping **Maintenance Costs** low for both residents and building managers.

- Battery efficiency is another key consideration, with components designed to last 12–24 months on a single charge, reducing the need for constant upkeep. The system should also be built for **Weather Resistance**, ensuring reliable performance in harsh conditions, such as temperatures ranging from -20°C to 50°C, and exposure to humidity, rain, or dust, through the use of durable materials and protective coatings.

- By meeting these requirements, the solution provides a reliable, cost-effective, and user-friendly experience, enhancing both security and convenience for mail delivery in urban residential settings.

7. Technical challenges

- Developing and implementing a Smart Post Box System comes with several technical challenges that must be addressed to ensure its effectiveness, reliability, and scalability. These challenges span across hardware, software, communication, and scalability, each presenting unique obstacles.

- **Hardware Challenges** include ensuring that sensors accurately detect mail of varying sizes, weights, and materials without false positives or negatives. This requires sophisticated detection mechanisms to differentiate between actual mail deliveries and irrelevant disturbances. Battery life is another critical factor, as components like sensors and smart locks need to balance energy efficiency with functionality, lasting 12–24 months on a single charge. Durability is also essential; the hardware must perform reliably in extreme weather conditions, from -20°C to 50°C, and withstand humidity, physical wear, and other environmental factors. Additionally, the system must be compatible with existing mailbox designs, allowing for seamless retrofitting without significant structural modifications.

- On the **software side**, ensuring real-time notification delivery is a key challenge. The system must provide instant updates to residents, even in areas with network latency or unstable connectivity. The mobile app must also be designed for usability, offering an intuitive interface that caters to users of all technical skill levels, along with features like multilingual support and accessibility options. Furthermore, the system must support secure and reliable remote firmware updates to address issues or add new features without disrupting its functionality.

- **Communication challenges** are also significant. Establishing reliable wireless connectivity is crucial, especially in dense urban environments where interference and congestion are common. The system must also ensure seamless data synchronization between sensors, cloud servers, and mobile apps, providing accurate and timely updates. Managing bandwidth efficiently is critical, particularly in large residential buildings with multiple connected devices, to avoid delays or performance bottlenecks.

- As the system grows, **scalability challenges** come into play. It must support hundreds or even thousands of users in a single building without compromising performance or responsiveness. Additionally, the cloud infrastructure must be capable of dynamically scaling to handle increasing data streams and connected devices as the solution expands to other buildings and regions.

8. Partners

Currently we have no partners and are still looking. Some companies that we would like to work with are CTT (Correios de Portugal) or other private courier companies, smart home and IOT companies as well as security ones. Telecommunication providers and hardware manufacturers would be helpful to work with to ensure more reliability in the systems such as network connectivity, cloud services, and good sensors and smart locks.

9. Testing and validation metrics

- **Functional**: Requirement Coverage, Defect Detection Rate, Pass/Fail Rate
- **Performance**: Response Time, Throughput, Scalability
- **Usability**: Task Completion Rate: Percentage of packages successfully detected and notified; Percentage of times where the smart lock opens. Time on Task: Time taken to send a notification since a new package is detected.

10. Division of labor (I)

Ludmylla Wonsoscky	Carolina Lopes	Chencheng Liu
Main role: Eletronics Engineer	**Main role: Eletronics Engineer**	**Main role: Hardware-Software Integration Engineer**
Circuit Design and Programming	Application Design	Communication Between Hardware and Software
CAD - 3D Modeling	System Integration	Hardware Programming
Mailbox Prototype Design	Mailbox Prototype	Camera and Lock Testing

11. Division of labor (II)

Beatriz Moreira	Sofia Nunes	Pedro Yin
Main role: Front-end Developer	**Main role: Back-end Developer**	**Main role: Eletronics Engineer**
Website Development	Application Design	Hardware Design
Blog Updates	Application Development	Hardware Development
Application development	Database Development	Mailbox Tester
	Notification System	

12. Schedule

Task	Start Date - End Date	Duration	Description
Site + Blog	21st Feb - 10th March	17 days	Website development and design; blogue updates
Camera and Sensor Prototype	March - 26th May	3 months	Hardware assembly and programming
Application Prototype	25th Feb - 7th April	41 days	Development and design of the application prototype using Figma
Application Development	16th March - 26th May	72 days	Application development; database development; notification system; incorporation of the hardware prototypes
Smart Lock Prototype	April - 26th May	1 month	Hardware assembly and programming