TURUN YLIOPISTO

AI-Powered Recycling and Repurposing of E-Waste in Finland

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Overview

While Finland excels in e-waste management with recycling rates of around 55% to 60%, the volume of e-waste in Finland is increasing due to higher electronic device usage and shorter product lifecycles. Despite meeting or exceeding EU recycling targets, challenges remain in handling the complexity of e-waste and adapting to evolving regulations. Advancing waste management and innovative solutions is key to improving recycling and handling the growing e-waste in Finland. AI can help manage e-waste more effectively and address the challenges of its growing volume. Our project is developing a minimum viable prototype of an AI-powered mobile application designed to address the challenges associated with the increasing volume of e-waste. Additionally, we will provide a detailed model for the future management of e-waste at the individual level.

Introduction

Safe disposal of electronic waste (e-waste) is crucial for environmental protection due to the hazardous substances it contains, such as lead, mercury, and platinum. Additionally, maximizing resource recovery through the proper handling and repurposing of old electronic devices is essential for promoting a circular economy. However, many users are unaware of the correct procedures for disposing of or reusing their outdated electronics. Consequently, devices are often stored indefinitely or discarded improperly, bypassing recycling protocols and reuse opportunities. Currently, there is a lack of comprehensive solutions for the end users that provide personalized guidance on the disposal and repurposing of individual e-waste or obsolete electronic devices. This highlights the need for an innovative mobile application designed to assist users in making informed decisions about their old electronic devices. Such an application would offer AI-powered tailored recommendations on whether to recycle, repair, or donate electronic devices, thereby supporting environmentally responsible practices and advancing the circular economy. We aim to first develop a functional prototype and collect real-time feedback from users, enabling us to continuously enhance the app's features and tailor solutions for specific customer segments. As part of the grant deliverables, we will provide a functional prototype of the application (AI-powered recycling and Repurposing mobile app) along with detailed user feedback, demonstrating the app's effectiveness and potential for further development.

Project Objective:

The primary objective of the "AI-Powered Recycling and Repurposing of E-Waste in Finland" project is to develop an innovative mobile application that leverages artificial intelligence to enhance the management of electronic waste. This project aims to achieve several specific goals: first, to create an AI-driven object detection system capable of accurately identifying and categorizing various electronic devices from images captured by users. Second, to provide actionable guidance on how to recycle, repurpose, or properly dispose of these devices based on their model and condition. Third, to increase awareness and empower Finnish residents about responsible e-waste management practices.

The core of our project is the development of a user-friendly mobile application that will be able to analyze the images of old electronic devices and guide the users on how to handle those unused old devices. Users will be able to take a picture of their old or unused electronic device using the app, at the same time users will also insert some information about the unused device manually on the mobile application and the app will guide how to handle the devices by ensuring that the old devices are either donated, recycled, repurposed or sold in an environmentally sound manner. This process ensures that users can easily determine the best way to manage their unused devices based on the specific model and age of the product. Given the computational demands of training and running complex AI models, such as Faster R-CNN with ResNet101 (a powerful object detection model), all major data processing will occur on a remote server. This decision ensures that the application remains accessible to all users, regardless of the technical specifications of their mobile devices. The mobile device will simply act as an interface for capturing images, and the data will be processed on a cloud-based server where the AI model will run. Once the image is analyzed, the server will return recommendations to the app regarding the appropriate next steps for handling the device. This architecture allows for scalability while maintaining high accuracy in identifying devices and providing customized instructions for each user.

Details of the project objective Step-by-step

Database Preparation: We will start by collecting a comprehensive dataset of images of old electronic devices. This will involve collaborating with local recycling centers, electronics manufacturers, government agencies, and open-source available data to gather information about various device models, including their proper recycling or disposal procedures. Additionally, metadata such as model, and manufacturing year will be collected to ensure accurate recycling guidelines.

Image Annotation and Model Training: The collected images will be annotated to create a labeled dataset for training an AI model. Using the TensorFlow object detection API, we will train a Faster R-CNN model with ResNet101 as the backbone to detect and classify electronic devices. This model will be executed on a remote server to ensure optimal performance and reduce the processing load on mobile devices.

Mobile Application Development: The mobile application will be designed for simple user interaction. It will feature photo-based device identification, barcode and QR code scanning for faster identification, and manual input options (e.g., whether the device is functional, partially functional, or dead) to enhance usability and encourage frequent app use.

Decision-Making Algorithm Development: An algorithm will be developed to recommend the most appropriate action based on the identified device and user-provided data, ensuring accurate guidance for recycling, repair, or reuse.

Feedback to Users

User Choices and Recommendations: Based on the usability score and the system's suggestion, the user can choose one of the following actions or the system will suggest the appropriate available options among these choices:

- Donate the item.
- Fix the item and use it themselves.
- Sell the parts of the product individually.
- Sell the whole item.
- Dispose of the item.

Details of Action-Specific Suggestions

Donate the Item: The system provides tentative donation locations or individuals who can accept the donation if it identifies that the uploaded device is still useable and will not harm the environment.

Technical Component:

- Location Services API: Fetches nearby donation centers or individual recipients.
- Integration with Donation Platforms: Allows linking with third-party charity organizations or community.

Fix the Item and Use for Themselves: The system displays tentative repair shops that can fix the item if it identifies that there is still probabilities to use the device after fixing and decision is economically viable.

Technical Component:

- Location Services API: Fetches nearby mechanic or repair shops.
- Repair shop Database: Contains details of authorized repair centers based on item type.

Sell the Parts Individually: The system provides documentation on how to sell the parts individually, store locations for such component sale and potential buyers for specific parts if it identifies that the device is on the category of selling part by part and the action will not harm the environment.

Technical Component:

- Location Services API: Fetches nearby mechanic or repair shops. Give some suggestions of dismantling the device or equipment if the procedure do not harm the environment or do cause any safety issue.
- Marketplace API Integration: Connects with third-party platforms where the user can sell parts.

Sell the Whole Item: The system provides tentative buyers and seller locations where the user can sell the entire product if it identifies that selling is environmentally and economically beneficial

Technical Component:

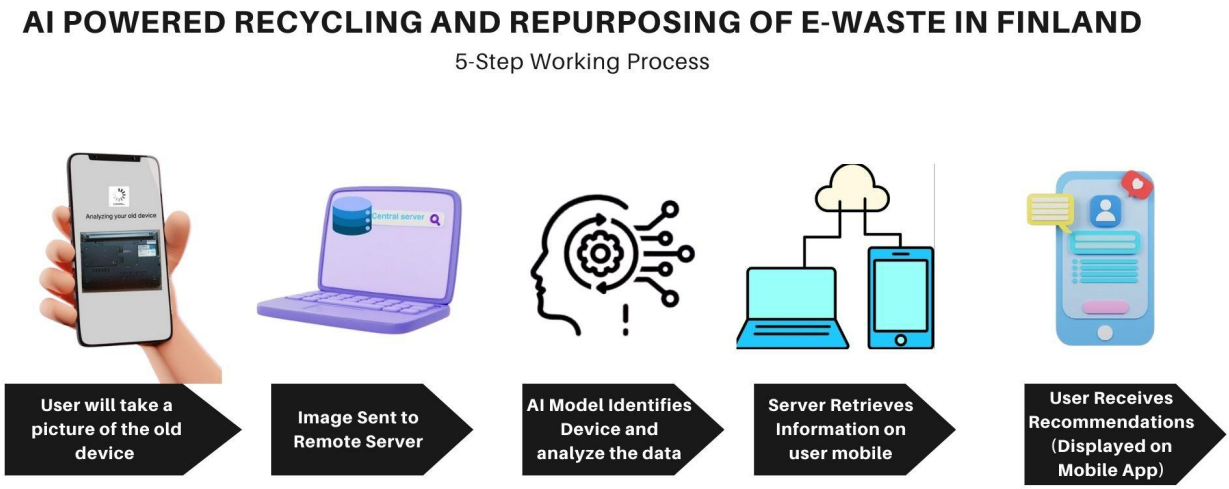
- Buyer Database: List of businesses or individuals who buy used electronic goods.
- Location Services API: Shows nearby seller locations.

Full Wastage or recommendation for recycling: If the item is deemed unusable, the system shows:

- Hazardous percentage of the item, indicating the level of environmental hazard.
- Nearby disposal locations that handle hazardous waste.
- Disposal solutions, such as the best way to discard the item safely.

Technical Component:

- Hazard Assessment Model: Analyzes the hazardous content based on the item's material composition.
- Disposal Database: List of authorized disposal centers.
- Disposal Solutions API: Provides recommendations for proper disposal.



Expected positive impact

Expected positive impact on Circular Economy

Ernströmgruppens Academic Grant has put stress on the circular economy section which aligns with their 100+ years of commitment of building a better entrepreneurship along with a palpable positive impact on building a better sustainable world for tomorrow. Keeping such strong commitment in mind, we designed our product which has remarkable impact on circular economy as we have identified that our system will provide significant impact in the sections of Environmental Impact, Extending product life cycle, Maximizing resource Recovery, Reducing waste, Promoting local circular System which are noted as key components of circular economy.

Extending Product Life Cycle: By assessing the condition of unused e-products and offering repair suggestions using our cutting edge deep learning based mobile application, the idea promotes reuse and repair over disposal. We will also provide details information on how the user will use the old device through repurposing or nearby repair shops.

Maximizing Resource Recovery: Our product encourages users to sell functional parts, ensuring valuable materials are recirculated, reducing the need for new resources.

Reducing waste: By providing users with options to sell, repair, or repurpose electronics, the system prevents e-waste from reaching landfills thus encouraging and keeping the earth safe from numerous harmful chemical objects.

Promoting local circular System: By recommending local shops for selling or repairs, it supports regional circular economy businesses and minimizes environmental impact from transportation.

Environmental Impact: Supporting local repair shops and resale options reduces transportation needs, cutting down carbon footprints associated with new product manufacturing and logistics.

In a nutshell, our system contributes to the circular economy by facilitating reuse, resale, and repair, keeping electronics and materials in circulation longer.

Expected positive impact based on Desk research outcomes

In Finland, many of us don't know or do not have any idea how to treat our unused electronics eg. monitors, phones, and laptops. About 50% of households have unused electronics products left in their house which they do not need any more [3]. They can recycle them by selling them and can be benefited financially. From our desk research, we have identified several key positive impacts that can be achieved using our next generation e waste management system.

Expected Positive Outcome on Viability

Many households, especially in Finland, are unaware of how to properly manage their unused electronics. In fact, 50% of households have e-waste that could be recycled or sold. Our app will help close this gap by providing clear, actionable steps. By highlighting the potential resale value and of unused electronics, the app will motivate users to recycle or sell their devices, creating a financial benefit. Simplifying the process of accessing recycling, repair, and resale services will encourage users to actively manage their e-waste. The app will promote eco-friendly disposal methods, educating users on sustainable practices and contributing to a positive environmental impact. Personalized impact tracking will allow users to see the environmental and financial benefits of their actions, further motivating responsible behavior. The app will feature simple, user-friendly functions such as quick item scanning to ensure accessibility for all users. Offering the app for free or at a low cost will increase user adoption and engagement.

Expected Positive Outcome on Achieving users trust

The existing deep learning model suggest that the app will be able to deliver Reliable, relevant suggestions for recycling, repair, reuse or donation. We have conducted research and estimate that this kind of deep learning model can deliver feedbacks from images retaining more than 90 percentage of accuracy. Therefore, we are confident that the application will be able to build trust with users, even if the system is not 100% perfect. Moreover, we will ensure user privacy and data security will be paramount, ensuring sensitive information is handled securely.

Target group

We are primarily focused on the target group of Finnish Households, Small Electronic Repair Shops, Environmental Advocates, and Sustainability Enthusiasts for our AI-powered e-waste management application however after the first functional prototype we will gather customer feedback and refine our target group more specifically.

Finnish Households Demographic: Individuals and families residing in Finland, particularly those between the ages of 25–55 who frequently use electronic devices such as smartphones, laptops, tablets, and other small electronic appliances. They often accumulate unused or obsolete electronic devices over time but are unaware of proper disposal or recycling methods. A study revealed that approximately 50% of

Finnish households store unused electronics, contributing to unnecessary e-waste buildup. They lack accessible, user-friendly guidance on how to either sell, repair, or recycle their devices in an environmentally responsible way. Our app simplifies the process of identifying what to do with outdated electronics through AI-powered image recognition and actionable recommendations (repair, resell, recycle, or donate).

Small Electronic Repair Shops and Recycling Centers Demographic: Small businesses and service providers involved in electronics repair and recycling across Finland. These repair shops and recycling centers struggle to connect with consumers who are looking for sustainable ways to manage their e-waste. Many potential customers are unaware of the repair options available to extend the life of their devices, or the locations of nearby recycling facilities. The app will promote local circular economy systems by suggesting nearby repair shops and recycling centers to users, creating a direct link between businesses and households seeking responsible e-waste solutions. Recycling centers will also benefit from increased e-waste diversion, as users are guided to appropriate facilities for recycling their obsolete electronics.

Environmental Advocates and Sustainability Enthusiasts Demographic: Individuals and organizations passionate about environmental protection, sustainability, and the circular economy are already committed to responsible consumption but they may lack efficient tools or platforms that make it easier to actively participate in e-waste management. The app will offer a practical and actionable way to contribute to environmental sustainability by reducing e-waste, making it a valuable tool for those who seek to minimize their environmental footprint. The personalized guidance on sustainable disposal, repair, or repurposing of devices aligns with their values, helping them extend the lifecycle of their electronics and reduce waste.

While initially, we focus on Finnish households and small businesses, later the app's target group can easily expand to include: educational institutions, corporate offices, and workplaces where electronic device turnover is frequent, allowing the app to promote sustainable practices at a larger scale. By focusing on these target groups, our app addresses both immediate consumer needs and broader environmental goals, contributing to a more sustainable future.

Budget and Spending

Budget for Developing Prototype: Our primary goal is to build a full functional prototype of the above-mentioned mobile application (AI-Powered Recycling and Repurposing of E-Waste) As initially it is very hard to develop our own database of the annotated, we will use a smaller data set from the Finnish perspective otherwise we might use any third-party API for the trail basis.

Spending for MVP (Minimum Viable Prototype)		
Type of Work	**Back-End Development**	**Mobile Application development**
Features extraction and algorithm development	**80 hours**	**80 hours**
Framework and library integration	**16 hours**	**16 hours**
UI/UX Design	**8 hours**	**80 hours**
3rd party API (Image classification) or preparing own small dataset	**16 hours**	**16 hours**
Quality Assurance	**40 hours**	**40 hours**
DevOps	**40 hours**	**40 hours**
Total hours	**200 hours**	**272 hours**

Total hours: 472 hours
Total spending: 472*25 € = 11800 €

Implementation period: We are a team of two, dedicating an average of 5 hours each day to this project. With this commitment, and by utilizing third-party services and resources, if necessary, we expect to meet the initial requirements and complete the development of the application within a maximum of one and half months.

Budget for Developing End User Product: Developing such high-tech end-user product is much more complex and we need the feed back and experiences of the prototype building stages to make this calculation. However, we have prepared a very rough estimation

Type of Work	Back-End Development	Mobile Application development
Features extraction, Data preprocessing, Domain expertise	**160 hours**	**240 hours**
Framework, library integration, Cloud datalake server integration	**56 hours**	**56 hours**
UI/UX Design according to customer segments	**60 hours**	**96 hours**
Image Annotation, Database preparation	**320 hours**	**N/A**
Algorithm development, integration	**200 hours**	**N/A**
Quality Assurance	**120 hours**	**120 hours**
Total hours	**916 hours**	**512 hours**

Total hours: 1428 hours
Total spending: 1777*30 € = 42840 €

Implementation period: Depends on the quantity of manpower and other aspects.

Revenue

Our AI-powered e-waste management application can generate revenue through multiple streams. We will employ a freemium model with optional premium features, integrate in-app advertising relevant to electronics and recycling, and establish partnerships with local businesses and corporate sponsors. Additionally, we can charge transaction fees for marketplace sales, offer subscription plans for advanced benefits, and monetize aggregate data insights with user consent. Other revenue opportunities include paid educational content and workshops, user donations, crowdfunding, white-label solutions for businesses, and affiliate marketing for related products.

Tangible End Result

We are highly optimistic of a positive and comprehensive result of our project that will be included fully functional prototype of an AI-powered mobile application designed to assist people in managing their e-waste responsibly. The app will have the following key features and deliverables: AI-Driven Object Detection: A robust image recognition system that identifies electronic devices from photos taken by users, categorizing them based on make, model, and condition. Personalized Recommendations: Tailored guidance for users on whether to recycle, repair, repurpose, or donate their old electronics, supported by a decision-making algorithm based on the specific device and its state. Local Integration: The app will integrate local recycling centers, repair shops, and donation points to provide users with nearby options for environmentally responsible disposal or repair. User Feedback and Data Insights: We will gather real-time user feedback during the prototype phase to improve functionality and ensure that the app meets user expectations. This feedback will be included in the project report as a key outcome. We have previously successfully developed similar prototype that experience will be a valuable asset for me.

Conclusion

Our project, "AI-Powered Recycling and Repurposing of E-Waste in Finland," aims to address the pressing issue of growing e-waste in Finland by leveraging cutting-edge AI technology to develop a user-friendly mobile application. By providing personalized, actionable guidance on how to manage outdated electronic devices, the app will promote recycling, repair, and responsible disposal, contributing to the circular economy. The app not only offers a practical solution to individual users but also supports local repair shops and recycling centers, fostering a regional circular economy. Additionally, it addresses environmental concerns by reducing the volume of e-waste and minimizing the carbon footprint associated with new device production and disposal. By the end of this project, we will have a functional prototype, valuable user feedback, and a roadmap for future development—all aligned with the goals of promoting sustainability and reducing e-waste.

References:

1. https://ym.fi/en/national-waste-plan
2. https://unitar.org/about/news-stories/press/global-e-waste-monitor-2024-electronic-waste-rising-five-times-faster-documented-e-waste-recycling
3. https://www.theseus.fi/bitstream/handle/10024/821074/Prajapati_Ritesh.pdf?sequence=2&isAllowed=y