The Avocado Alarm: A Low-Cost Anti-Theft Alarm for Personal Bags in Shared Spaces

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ABSTRACT

This paper aims to present a user friendly, anti-theft device especially suitable and accessible for students, commuters and tourists. Combining Arduino-based electronics and 3D modeling, the proposed project makes use of magnetic reed switch to detect unauthorized access and trigger an alarm.

CCS CONCEPTS

Human-centered computing → Ubiquitous tools

KEYWORDS

Anti-theft alarm, magnetic reed switch, low-cost security, 3D-printed design, shared spaces, Raspberry Pi Pico, portable security device

1. Introduction

The majority of students, travellers, and everyday commuters today travel with a bag. It is up to each of us to figure out how to keep the items in the backpack safe when we are out in public. People's awareness of the importance of protecting private property has grown as living conditions have increased[1].

As a result, higher standards for backpack security are needed. The typical backpack is merely a basic tool. Theft can occur through a number of methods, regardless of how clever the design is, how robust the material is, or how unique it is[1].

1.1. Target Audience

1. Students

Usage Scenario: People who have to leave their bags on public transportation (bus/metro) on a daily basis.
Need: An affordable, portable, and instantly responsive security solution.

2. City Travelers

Risk Factor: Pickpocketing and bag-opening attempts in crowded subways and at stops.

Solution Expectation: A loud alarm that can be heard even in public environments.

3. Tourists and Travelers

Weakness: Distraction in new environments; forgetfulness about bag security.
Prototype Advantage: Simple trigger mechanism (magnet separation) that works automatically without user interaction.

1.2. Hypothesis

The prototype, working with a magnetic reed switch and an alarm, will reduce the need for users to constantly monitor their bags and help them to respond quickly during thefts.

2. Solution

2.1. Existing Solutions

To address the challenges associated with bag security, a variety of anti-theft device solutions have previously been released. Using infrared sensors and zipper position detection, [1] a multipurpose anti-theft backpack can be operated through a smartphone app. Despite being creative, this system's complexity and cost are increased by the need for highly complex circuitry and more energy sources. Another method is, [2] SMS alerts during unauthorized action by using motion detection and GPS/GSM units. Despite being efficient, this approach may not be the best in all situations because it relies on cellular networks and active user participation to react to notifications.
In addition to these, [3] studies on urgent mobile alert systems have identified important patterns of behavior. According to their systematic analysis, "milling" behavior—the practice of receiving confirming messages before taking action—often causes delayed public response to SMS-based notifications.
This draws attention to a significant disadvantage of text-based systems: even when they are technically sound, human error can make them less useful in critical situations.

A different strategy was adopted in [4], where a smart bag based on a Raspberry Pi takes pictures of the intruder using a USB camera and emails them to the owner when opened without authorization.

Although this technology is interesting for post-theft recognition, it is expensive and has limited offline capacity due to its constant power and internet connectivity needs.

There are other safety-focused products on the market. For example, Tile Trackers help locate lost items via Bluetooth, but are only useful after theft, not during. Birdie is a personal safety alarm triggered manually, and it's not designed for bags or motion detection. Bags like Loctote and Pacsafe offer strong physical protection through slash-proof materials and hidden zippers, but they lack real-time alerts or active theft detection. While these solutions enhance security, they fall short when it comes to immediate response and smart sensing capabilities [7]–[10].

By combining the strengths of previous systems while addressing their limitations, we bridge the gap between technical feasibility and real-world usability in anti-theft solutions. The 3D-printed design further ensures accessibility without compromising core functionality, making it particularly suitable for students and travelers in shared spaces.

2.2. Concept

A uniquely designed 3D-printed case in the shape of an avocado was created to house the alarm system components. The magnet is embedded within the seed portion of the avocado, while the reed switch is installed in the top side of the fruit, which serves as the main body of the enclosure. When the seed is removed or separated from the main body (causing the magnet and reed switch to lose alignment), the system detects this change and triggers the alarm. The completed 3D-printed prototype is shown in Figure 1.

Fig. 1. 3D-printed avocado prototype

2.3. Setup and Technology

This project involves the creation of a compact alarm system centered around the Raspberry Pi Pico W2 microcontroller.
The system utilizes a reed switch (MK04 1A66B) paired with a magnet to detect separation, which serves as the trigger for the alarm. When triggered, a DFPlayer Mini module in combination with a 4Ω, 3W speaker plays the alarm sound. Power is supplied by a 3.7V, 400mAh LiPo battery, which is rechargeable via a USB-C charging module that supports 1A charging.
The components are assembled securely using a breadboard, jumper cables, and soldering to ensure reliable connections. An on-off switch is included to allow for easy power control. To keep everything compact and protected, all components are enclosed within a custom 3D-printed case.
The alarm functions by detecting when the magnet moves away from the reed switch, triggering the sound. Designed for portability, the device is both rechargeable and housed in a durable, custom-fitted enclosure.

3. User Testing

3.1. Goal of the testing

The purpose of user testing is to try the prototype in a real environment, to see if it works as intended and if it is properly equipped to keep students' belongings safe. We also aim to collect feedback from users and improve the device in the future.

3.2. Participants

8 volunteer students between the ages of 22-28 from the Hochschule Rhein-Waal participated in the user testing. In addition to these participants, there were 3 observers to take notes and 3 outsiders who had no background idea about the prototype as thieves.

3.3. Task Scenario

Participants were observed in various public settings such as crowded public transport, parks, restaurants etc. In the crowded train, our user took her seat along with the device attached to the bag. She then got up from her seat and walked a few meters to see if the restrooms were empty. Meanwhile, the thief came and tried to open our user's bag, but the thief was asked to do this as fast as possible. Considering the possibility that someone who would do this in the real world would show hasty and stressful behavior, the scenario should be as similar as possible. After the thief opened the bag, the alarm started to ring and he could not understand how to turn off the device and he quickly ran away. Meanwhile, the observer took notes.

3.4. Methodology

To measure the usability and effectiveness of the prototype, a mixed-methods approach have been used, integrating quantitative performance metrics with qualitative user feedback.

A standardized tool was used to collect quantitative data to evaluate usability as well as user satisfaction in the prototype. The System Usability Scale (SUS) was used as the first tool for all participants. Mean reaction time and alarm clarity ratings were calculated [5]. This commonly utilized tool has 10 Likert-scale items (1 = strongly disagree to 5 = strongly agree) designed to assess effectiveness, efficiency, and customer satisfaction. Alternating between positive and negative wordings, the statements were designed to reduce acquiescence bias, as per standard procedure [6].
Qualitative feedback after field testing—e.g., casing size and switch visibility—was established through the use of semi-structured interviews. The interviews were designed to elicit participants' personal experiences and observations of the prototype while being used in the real environment. The questions explored areas of perceived trust, usability, reliability, and how the device might be improved.

Each interview lasted approximately 5–10 minutes and was conducted in the same location where the user had tested the device (i.e., train, park bench, bus). All of the feedback was recorded and analyzed in detail.

Example questions:

1. “In the moment you triggered the device, did it respond fast enough to feel helpful?”
2. “Did the magnetic trigger work every time you tried it? Did you feel confident using it?”
3. “Did you ever feel like the device was too visible or drew unwanted attention?”
4. “Can you imagine relying on this device in a real emergency? Why or why not?”
5. “Was the design or appearance of the device clear enough to understand how it works?”
6. “If you could change one thing about the device, what would it be?”

Through these interviews, feedback was collected from the participants representing many different perspectives. This feedback was also evaluated together with quantitative data, and our mixed method was applied accordingly. Since the prototype is still at the MVP level, the opportunity will also be provided to compare and interpret this data in the next iterations and user tests.

Table 1. User Testing Results

Test Location	Reaction Time (sec)	Alarm Clarity Score (1–5)	User Feedback
Train (peak hours)	1.53	3	Sound is effective, but casing is bulky
Public Bus	0.68	5	Could use a more compact design
Café	1.16	4	Very reactive, impressive speed
Park Bench	0.82	5	Great idea, just needs to be smaller
Train (off-peak)	1.42	3	Toggle switch could be hidden better
Park Bench	0.94	4	Works well, but toggle might be tampered with
Café	1.12	5	The alarm is loud enough for public spaces
Campus Walkway	0.73	4	The device is too big to stay hidden

4. Conclusion

4.1. User testing results and interpretation

The prototype successfully addresses a common challenge faced in public settings: the constant need for users to monitor their belongings. By utilizing a magnetic reed switch and alarm mechanism, the device offers an immediate, externalized alert system that shifts the responsibility of vigilance away from the user.

User evaluation results indicate that even at its MVP stage, the prototype effectively fulfills its core objective. Most notably, 6 out of 8 participants (75%) reported that they no longer felt the need to frequently check their bags during testing. This finding supports the initial hypothesis, suggesting that the prototype can significantly reduce users’ cognitive load related to theft prevention in shared environments.

Participants consistently emphasized the ease of setup and the effectiveness of the alarm in drawing attention during simulated theft scenarios. While qualitative feedback revealed areas for further refinement—particularly regarding the device’s form factor and concealability—the overall response confirmed both the usability and utility of the concept.

In summary, the avocado alarm has a strong potential as a low-cost, user-centered anti-theft solution. It provides a compelling foundation for future iterations that aim to optimize form, expand context adaptability, and improve long-term user experience through broader testing.

4.2. Further user testing suggestions

As this prototype represents a Minimum Viable Product (MVP), further user testing with a larger and more diverse sample group will be recruited. Long-term evaluations could be conducted to better understand how the prototype affects user behavior and their feelings of security over time.

A contextual inquiry approach could be adopted to observe how users naturally interact with the device in their daily routines and to uncover pain points or unexpected usage patterns. This method allows researchers to gather richer, more authentic insights by engaging with users in their real-life contexts rather than relying on self-reported data [11].

Additionally, A/B testing, different design variables—such as casing materials, alarm volume, and power supply types—could support performance optimization. Field tests in a variety of public environments (e.g., public transport, libraries, cafés) would further ensure that the device functions reliably across different contexts and user habits. Collecting feedback from individuals using different types of bags or carrying setups will also be crucial for informing future iterations and making the product adaptable for a broader range of users.

4.3. Prototype improvements

As a result of our user feedback, we plan to update and modify our device for the next user-testing. A common feedback point revolves around the size and dimensions of the device. As a first modification, we plan to shrink the size of our device to make it more compact and portable. To achieve this, eliminating the breadboard and soldering necessary components to the wires can help us to a decent extent. Secondly, we plan to switch to a sleekier speaker size, replacing the current speaker component. As per the user feedback, we also plan to make the manual toggle switch more discreet and secure. Lastly, we will explore some advanced control options such as app pairing or bluetooth alerts.

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APPENDIX

A. Implementation

The source code for the implementation of the prototype

```
#include "Arduino.h"
#include "DFRobotDFPlayerMini.h"
#include <SoftwareSerial.h>

#define FPSerial Serial1
DFRobotDFPlayerMini myDFPlayer;
void printDetail(uint8_t type, int value);

// Pin connected to the reed switch
const int reedPin = 3;

void setup() {
   FPSerial.begin(9600);

  Serial.begin(115200);

  pinMode(reedPin, INPUT_PULLUP); // Use internal
pull-up resistor

  Serial.println();
  Serial.println(F("DFRobot DFPlayer Mini Demo"));
  Serial.println(F("Initializing DFPlayer ... (May take 3~5
seconds)"));

  if (!myDFPlayer.begin(FPSerial, /*isACK = */true,
/*doReset = */true)) {  //Use serial to communicate with
mp3.
    Serial.println(F("Unable to begin:"));
    Serial.println(F("1.Please recheck the connection!"));
    Serial.println(F("2.Please insert the SD card!"));
  }
  Serial.println(F("DFPlayer Mini online."));

  myDFPlayer.volume(28);  //Set volume value. From 0
to 30
}

void loop() {
  int state = digitalRead(reedPin);

  if (state == LOW) {
    Serial.println("Magnet detected - Reed switch
closed");
    myDFPlayer.stop();
  }
   else {
    Serial.println("No magnet - Reed switch open");
    myDFPlayer.play(1);  //Play the first mp3
    if (myDFPlayer.available()) {
    printDetail(myDFPlayer.readType(),
myDFPlayer.read()); //Print the detail message from
DFPlayer to handle different errors and states.
    }
  }
```

```
  delay(2000); // Short delay to debounce and reduce
serial spam
}
void printDetail(uint8_t type, int value){
  switch (type) {
    case TimeOut:
      Serial.println(F("Time Out!"));
      break;
    case WrongStack:
      Serial.println(F("Stack Wrong!"));
      break;
    case DFPlayerCardInserted:
      Serial.println(F("Card Inserted!"));
      break;
    case DFPlayerCardRemoved:
      Serial.println(F("Card Removed!"));
      break;
    case DFPlayerCardOnline:
      Serial.println(F("Card Online!"));
      break;
    case DFPlayerUSBInserted:
      Serial.println("USB Inserted!");
      break;
    case DFPlayerUSBRemoved:
      Serial.println("USB Removed!");
      break;
    case DFPlayerPlayFinished:
      Serial.print(F("Number:"));
      Serial.print(value);
      Serial.println(F(" Play Finished!"));
      break;
    case DFPlayerError:
      Serial.print(F("DFPlayerError:"));
      switch (value) {
        case Busy:
          Serial.println(F("Card not found"));
          break;
        case Sleeping:
          Serial.println(F("Sleeping"));
          break;
        case SerialWrongStack:
          Serial.println(F("Get Wrong Stack"));
          break;
        case CheckSumNotMatch:
          Serial.println(F("Check Sum Not Match"));
          break;
        case FileIndexOut:
          Serial.println(F("File Index Out of Bound"));
          break;
        case FileMismatch:
          Serial.println(F("Cannot Find File"));
          break;
        case Advertise:
          Serial.println(F("In Advertise"));
          break;
        default:
          break;
      }
      break;
    default:
      break;
```

}}.