MagSafe accessory classification using magnetometer

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***Abstract*—With the integration of MagSafe into the iPhone, attaching various accessories to the back of the device has become possible. In this work, we explore the feasibility of MagSafe accessory classification with IMU sensors available on commercial smartphones. Especially, we use the magnetic features, extracted when MagSafe accessories are attached, as the main feature for the classification. Our experiments achieve high classification accuracy across a variety of accessories.**

***Index Terms*—IMU, Magnetometer**

I. Introduction

Starting with the iPhone 12, Apple has incorporated a circular-shaped magnet, called MagSafe [1], to support wireless charging. Unlike Qi wireless charging, this magnet supports the precise alignment between the charger and device, enabling efficient power transfer. Note that it has been recently announced that the new wireless charging standard Qi2 will include the MagSafe technology. This indicates that the technology will be adopted by more diverse devices regardless of manufacturer and form factor.

The MagSafe technology also encourages the emergence of a new class of smartphone accessories, called MagSafe accessories. They include a circular magnet like a MagSafe-enabled smartphone but with an opposite direction, thus allowing them to be attached to the smartphone. Thanks to such high usability, many accessory vendors including both official and third-party ones have introduced a variety of MagSafe accessories, such as MagSafe wallets, stands, and battery packs. In this work, we aim to introduce a novel way to interact with these MagSafe accessories. Imagine someone starting a car. Before driving the car, she might first put her smartphone on a MagSafe car mount to launch a navigation application. At this time, she would be much happy if the smartphone recognizes her need and automatically opens the navigation application.

The key technique to realize this user experience is to identify what a MagSafe accessory is attached to a smartphone. Interestingly, MagSafe-enabled smartphones already support this functionality for official MagSafe accessories using NFC (Near Field Communication) [2]. For example, these accessories are equipped with an NFC tag and broadcast their encoded ID via NFC when they are attached to a MagSafe-enabled smartphone. However, the NFC-based accessory identification cannot be applied to third-party MagSafe accessories, which are the mainstream in the market, due to the absence of NFC tags.

In this paper, we overcome the limitation of the existing method by exploring the feasibility of identifying MagSafe accessories using only IMU (Intertial Measurement Unit) sensors available on most commercial smartphones, i.e., without requiring additional hardware on both smartphones and accessories. More specifically, when an accessory is attached to a smartphone, we detect a sudden variation in magnetometer readings caused by the magnet present in the accessory. We then extract magnetic features from the readings and finally classify the accessory using the features.

II. Related works

Similarly to our proposed method, several studies have attempted to introduce new mobile applications by leveraging magnetic variations as their key feature. For example, MagHacker [3] infers letters using the 3D trajectories of magnetometer readings. MagTouch [4] utilizes both the touch position and the magnetic field measured from a smartwatch to determine which finger is touching the smartwatch. However, we use the magnetic fluctuations to introduce another class of applications, i.e., MagSafe accessory identification. Note that to the best of our knowledge, this is the first attempt to distinguish MagSafe accessories using the magnetic features.

III. System Design

Figure 1 illustrates the overall procedures of our MagSafe accessory identification system that consists of two phases; *training* and *identification* phases. In the training phase, a user initially collects a set of templates for each MagSafe accessory by repeatedly attaching it to her smartphone and constructs a classification model using the sensor data obtained from the built-in IMU sensors. After the training (i.e., in the identification phase), whenever the accessory is attached to the smartphone, it is identified using the pre-built model.

A. Background: Hard-iron effect

Such a design is based on the phenomenon called a hard-iron effect that is generated by permanent magnets and causes a 3D offset in magnetometer readings. In particular, when a MagSafe accessory is attached to a smartphone, the hard-iron effect also occurs due to its built-in permanent magnet. That

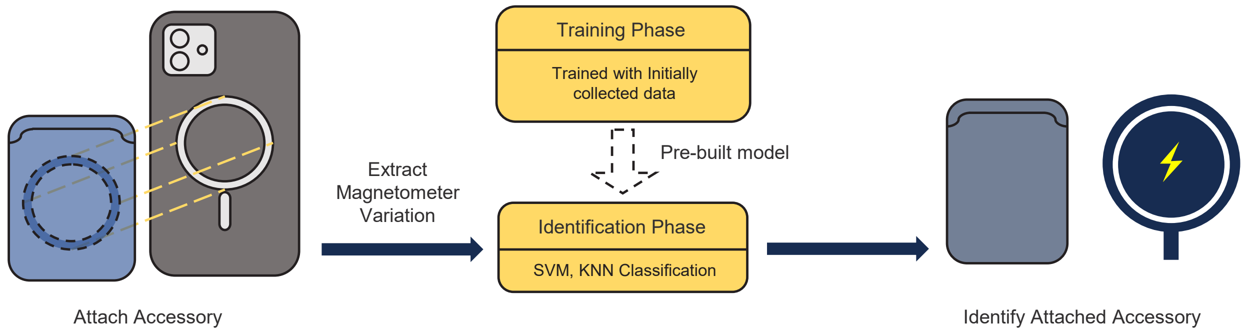

Fig. 1: System Overview.

Fig. 2: Third-party MagSafe accessories used in our experiments.

is, magnetometer values are biased by the accessory. Furthermore, the amount of the bias becomes different depending on the accessory because each accessory incorporates a circular magnet with different magnetic properties.

B. Accessory classification

To classify MagSafe accessories, we first detect the moments when the accessories are attached and detached. Towards this, we detect the time instant at which *i*) a sudden increase or decrease in magnetometer values, i.e., the accessory-induced bias, occurs and *ii*) accelerometer recordings show transient fluctuations (caused by the attachment or detachment of the accessories). Once detected at time t, we extract a magnetic feature computed as $B(t+2s) - B(t-1s)$, where $B(t)$ is the three-axis magnetometer value obtained at time t and eventually classify the accessory using the extracted features and classification model constructed in the training phase.

IV. Experiment

We asked a single user to attach/detach MagSafe accessories to/from an Apple iPhone 12 smartphone, while collecting motion and magnetic data using the built-in accelerometer, gyroscope, and magnetometer with a sampling rate of 100 Hz. In particular, we leveraged twelve third-party accessories each of which has different form factors (see Figure 2) and repeated the data collection (i.e., attachment and detachment) 50 times for each accessory. We then measured the classification accuracy of our proposed system via a 2-fold cross validation.

	Support Vector Machine	K-Nearest Neighbor
Accuracy	99.1%	99.7%

TABLE I: Classification Accuracy

Table I shows that our proposed system can precisely identify MagSafe accessories regardless of classification model. We achieved an average classification accuracy of 99.1% and 99.7% with Support Vector Machine and K-nearest neighbor methods, respectively. This high accuracy is because each accessory has unique magnetic characteristics, leading to the ease of classification. However, we also observed that our propose method fails to accurately identify accessories in the presence of a user's movement, e.g., walking. Our future works include to improve robustness against such behavioral noise.

V. Conclusion

In this study, we investigated the feasibility of identifying MagSafe accessories based on variations in magnetometer readings. This work is based on the magnetic phenomenon, called hard-iron effect, which occurs when magnetic materials, e.g., MagSafe accessories, are closely placed. By collecting data from a sufficient number of accessories across a wide range of applications, we have demonstrated the practicality of this identification method. In conclusion, our work presents a promising pathway for a novel method of accessory identification, offering potential applications in enhancing user experience.

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