# A Multimodal AI-Based Smart Campus System for Lost and Found Item Recovery


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***Abstract*—Dense populations and heavy movement in university campuses usually make the traditional lost-and- found processes slow and inefficient. This paper presents a Smart Campus Lost and Found System (SCLFS) which is a web-based model that aims to simplify such processes through a synthesis of multimodal artificial intelligence and a user-incentive based model. The platform is built with a lightweight Flask back end with SQLAlchemy as a data management platform. The key feature of it is a multimodal matching module that is developed based on CLIP-ViT-B/32 vision-language network that calculates a composite similarity score between item descriptions and images. The system can correlate visual and textual items more precisely than the single-mode systems by embedding inputs concurrently. In order to reward participation, a gamified system provides virtual tokens to individuals that submit items successfully, but also has mechanisms that ensure that the system is not abused. Its implementation was highly tested-unit, integration and system testing-to meet conformity to the functional objectives.Experimental results demonstrate that the matching process supported by artificial intelligence can reach high accuracy levels in the association of similar records (reaching 91.8 percent similarity) and that the reward system has been proven to operate as expected, encouraging ethical user interaction.**



***Index Terms*—Smart Campus, Lost and Found, Multimodal AI, CLIP, Contrastive Language-Image Pre-training, Flask, Software Engineering, Gamification, User-Centered Design.**


## I. Introduction

College campuses are in many ways miniature urban environments, only a small area is hosting thousands of students, professors and administrative staff. In such a dynamic and highly populated environment, misplaced or lost personal items are a very frequent phenomenon that is usually irritating. Traditional lost and found methods which are generally administered via handwritten books or through a collection of notice boards or informally through email messages, were usually disorganized, inconsistent and hard to keep up with [1], [2]. The traditional approaches have a poor scaling to large campuses and have no way of automatically matching the owners with the objects that are theirs [3]. The issue is also increased by the great number of misplaced items, which can either be indistinguishable water bottles or remotely recognized electronic accessories. This type of diversity restricts the usefulness of the key word or a single modality image search. Consequently, there is a call to a clever, multimodal methodology that would be able to analyze in tandem. visual and textual features to enhance the level of identification.

The Smart Campus proposal, which is based on the concept of combining data analytics, Internet of Things (IoT) tools, and intelligent automation, can provide an avenue to addressing this concern [4], [5]. A smart campus aims at improving the efficiency in its operations and user experience and a robust technology-based lost-and-found system compliments the societal and governance objectives of the smart campus [6].

The proposed study is the Smart Campus Lost and Found System (SCLFS) where it is suggested that the solution is a web-based model designed to automate and intelligently organize the recovery of lost items.The design of the system aims at filling the gaps in the current methods using three main innovations:

1) **Multimodal Matching Engine:** It is based on the Contrastive Language-Image Pre-training (CLIP) model that builds a shared space of item descriptions and images. This enables the similarity score to be calculated by the matching algorithm with finer accuracy than the traditional text- or image-only algorithms.
2) **Socio-Technical Incentive Framework:** As the efficiency of a system is determined by the involvement of the user in its implementation, the platform will have a gamified reward system based on virtual coins. The given feature prompts the users to report and send back the found items stimulating interaction and addressing the main issues of human-computer interaction [7], [8].
3) **Lightweight and Scalable Architecture:** Built on a Python-based stack (Flask and SQLAlchemy), the system is maintainable, scalable and easily deployable [9]. Its performance and reliability is further checked by a detailed multi-tier testing pro-cess.

The rest of this paper follows in the following manner: Section II discusses the literature and finds gaps of research. Section III is the discussion of the proposed architecture and database schema and multimodal matching process. In Section IV, there is implementation results, and user interface validation. At the end of the study is Section V, which summarizes the study and provides future research directions.

## II. Literature Survey

In order to emphasize the novelty of the proposed system, the literature review and technology review over four key fields were conducted.

### A. Digitization of Digital Notice boards to Web Portals

The first digitalization of traditional logbooks was in the form of digital notice boards, web-based applications that enable its users to add information about lost or found items manually [3], [10]. These systems helped to make accessibility better than the analog systems but were still constrained in their ability. The majority used only the key word search method and it was necessary to go through the long lists of the posts manually, which was not efficient and in many cases ineffective [1], [2]. These solutions were not automated and did not have any intelligent matching.

### B. Hardware based Tracking Solutions

Another similar line of development was hardware-driven tracking technologies. The solutions of this type usually used Radio-Frequency Identification (RFID) tags, Global Positioning System (GPS) modules [12], or Long-Range (LoRa) networks [13]. Although the methods were also found effective in tracking pre-tagged high-value institutional property, the methods are neither affordable nor feasible to the unpredictable and unstructured assortment of personal items, including bottles, notebooks or chargers, which often go missing on campuses.

### C. Image-Based Matching: First-Generation AI

Later systems started to use fake intelligence, which acted more on similarity detection in images. To find feature representations of item images and obtain visual similarity scores, these methods frequently used Convolutional Neural Networks (CNNs), including ResNet-50 [14] or MobileNetV2 [15], [16]. Others also improved on this by the introduction of independent Natural Language Processing (NLP) modules to text-based comparison [14]. However, these modalities

### D. Vision-Language Models: State-of-the-Art

The development of Vision-Language Models (VLMs) was a major improvement. CLIP is a supervised visual concept learner based on natural language supervision and projects images and text-based learning to a common embedding space [18]. This makes it possible to perform potent zero-shot text-to-image retrieval [19] and image-text correspondence [20]. These features would best fit the lost-and-found example- e.g. when a user reports about a black steel bottle with a logo, another one posts the photo with the logo.

### E. The Human Factor: Incentivization and UserCentered Design

System success, regardless of technical advancement is eventually dependent on user acceptance. The frameworks of User-Centered Design (UCD) are important in making campus applications usable and accessible [8]. Furthermore, researches stress that such social obstacles as the unwillingness to give up finding items can be reduced with the help of incentive systems. Research on gamification and motivation indicates that properly constructed reward systems can successfully enhance the motivation and the involvement in the digital environment.

### F. Identified Research Gap

It is evident that there is a gap in the reviewed literature. Existing solutions either use simplistic web interfaces (Section 2.1), hardware-specific infrastructures (Section 2.2), or crudely trained AI models with little integration (Section 2.3). Very little, or anything, has linked both high-level VLMs like CLIP (Section 2.4) and an objectively-based incentive system (Section 2.5) into one, operational, and deployable smart campus system. The need that has not been fulfilled currently is addressed in the present work by integrating the technical aspect as well as the social aspect in one unified platform.

## III. Architecture and Methodology

SYSTEM ARCHITECTURE The Smart Campus Lost and Found System (SCLFS) is a scaled and realistic application that converts initial specification needs into a realistic architecture.

### A. System Overview and Architectural Style

The suggested system is based on a three-level client-server architecture. The client component runs on a regular web browser, and the server is provided in its prototype form as a monolithic web application with the Flask framework. The system context in general is shown in Fig. 1 and it describes the key actors (User and Administrator) and how they interact with the key components of the system.

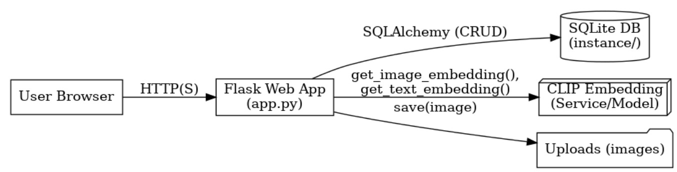


Fig. 1. System Context Diagram

The architecture goes further to be broken down into separate functional modules, as presented in the Component Diagram (Fig. 2). The resulting modularization (image below) with the web routing logic (app.py) and AI processing unit (aimatching.py) separated along with the database layer (database.py) improves maintainability, high cohesion, and ease of debugging and upgrades.

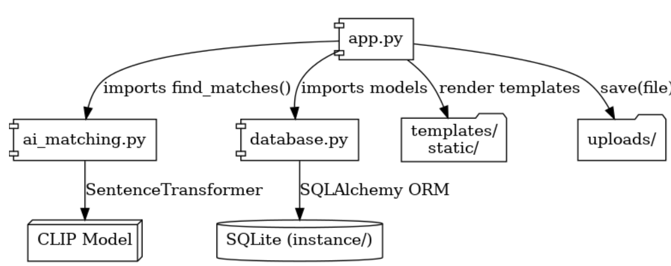


Fig. 2. Component Diagram

### *B. Data Design and Schema*

Persistence layer is handled with an SQL database which is accessed by SQLAlchemy, an Object-Relational Mapper (ORM). It is an abstraction that does not bind application logic to the database technology being used allowing the prototype to run on SQLite but be production-ready on PostgreSQL. The schema includes three major entities: User, Item, and Match. Their associations are depicted in the Class Diagram (Fig. 3). Table I gives a detailed data dictionary of the schema attributes.

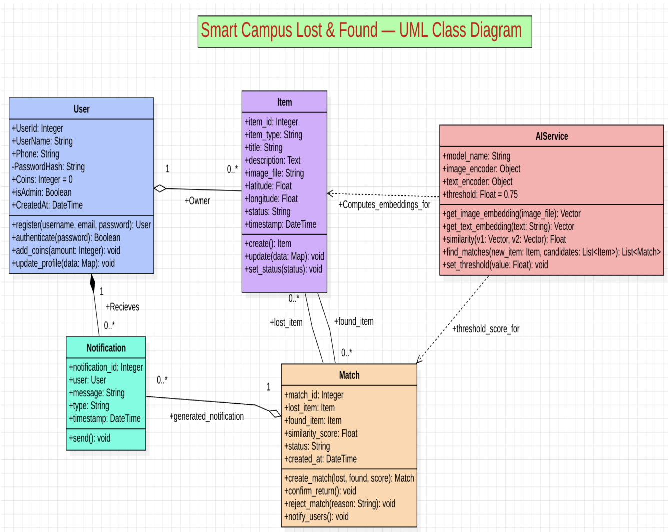


Fig. 3. Class Diagram

TABLE I
THE DATA DICTIONARY USED IN SCLFS DATABASE SCHEMA IS AS PRESENTED BELOW.

| Table | Column | Data Type | Description |
|---|---|---|---|
| User | id (PK) | Integer | Unique identifier for each user. |
| | username | String(100) | Unique username for login. |
| | password | String(100) | Encrypted password (PBKDF2). |
| | phone_number | String(20) | Optional contact number. |
| | coins | Integer | Gamification reward balance. |
| | is_admin | Boolean | Boolean flag for admin privileges. |
| Item | id (PK) | Integer | Unique identifier for each item. |
| | user_id (FK) | Integer | References `User.id` (reporter). |
| | item_type | Enum('lost', 'found') | Type of report. |
| | title | String(200) | Title of the item report. |
| | description | Text | Detailed description of the item. |
| | image_file | String(100) | Path to uploaded image file. |
| | image_embed | PickleType | Stored CLIP image embedding. |
| | text_embed | PickleType | Stored CLIP text embedding. |
| | status | Enum('active', 'returned') | Current status of the item. |
| Match | id (PK) | Integer | Unique match identifier. |
| | lost_item_id (FK) | Integer | References `Item.id`. |
| | found_item_id (FK) | Integer | References `Item.id`. |
| | similarity_score | Float | Combined similarity score (0.0–1.0). |
| | status | Enum('pending', 'returned') | Match confirmation state. |

(Source: Project Database Schema)

### *C. Basic Methodology: Multimodal Matching Algorithm*

The intelligent matching engine is the core of the system and it uses the sentence-transformers library to load an already trained model called clip- ViT-B-32. The output of this Vision-Language Model (VLM) is the projection of either textual or visual data into a single 384-dimensional space. The algorithm works in the following way:

1) The submission of a new report is made by the use of /report route.
2) The system produces two embeddings:
   - **Image Embedding:** The upload image is subjected to getimageembedding.
   - **Text Embedding:** The title together with description fields are processed with the help of. gettextembedding().
3) The two embeddings are pickled and stored in the columns (imageembedding and textembedding) of the Item table.
4) findmatches(newitem) is a function that is called so as to find possible matches.

In contrast to the typical CLIP applications, using one-directional text-to-image retrieval, direct object-to-object similarity comparisons are done in this system. In order to do so, a weighted similarity heuristic (Equation 1) was used as a custom weighting. This algorithm calculates cosine similarity of each of the two modalities and weights the two with 60 and 40 respectively.

$$S_{\text{comb}} = (0.6 \times S_{\text{img}}) + (0.4 \times S_{\text{txt}}) \tag{1}$$

where $S_{\text{img}} = \text{cosine\_similarity}(Emb_{\text{img\_A}}, Emb_{\text{img\_B}})$ and $S_{\text{txt}} = \text{cosine\_similarity}(Emb_{\text{txt\_A}}, Emb_{\text{txt\_B}})$.

When similarity score (Scomb), which is a combination of two matching scores, is greater than a fixed cutoff point (0.70) as discovered in the course of experimentation, then a match entry is added to the Match table.

### *D. Socio-Technical Design and System Dynamics*

In addition to its technical capabilities, the SCLFS is planned as a socio technical system which enables human interactions with it especially the retrieval of lost property. Fig. 4, the "Confirm Return" procedure is realized in the. /completereturn/<matchid> route. This process formalises the process of acquiring and disposing of a finder-owner via a digital handshake process. When the owner chooses the option Mark as Returned, two important backend functions are performed:

1) **Promoting Participation:** The system adds the finder coinage (finder.coins = 100) which is em- bodying the gamification strategy [7] to reward ethical participation.
2) **Mitigating Abuse:** A validation condition (lostitem.userid = founditem.userid) prevents users who abuse the reward system by falsely reporting and retrieving their own items. A check of this validation condition was performed in white box testing.

### *E. Deployment and Scalability*

The first prototype uses a light version of Flask development server and an SQLite database. However, the architecture has been designed in a manner that it can be deployed in a scalable production environment as shown in the Deployment Diagram (Fig. 5).

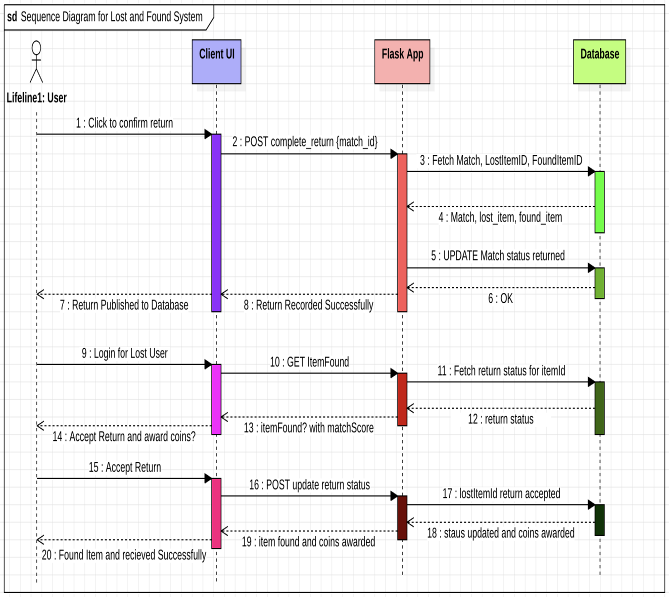


Fig. 4. Confirm Return workflow Sequence Diagram.

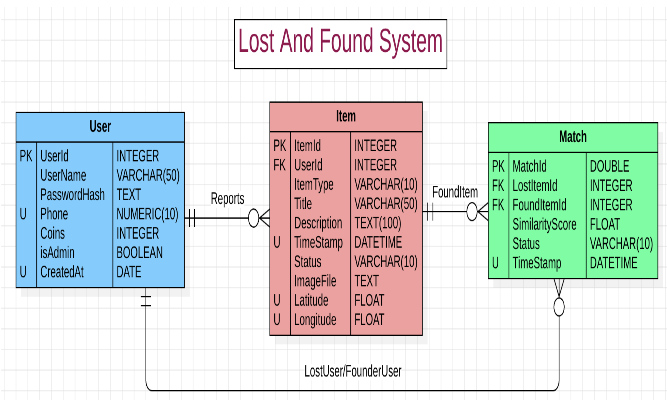


Fig. 5. Production-Intent Deployment Diagram

## IV. Results and Discussion

The Smart Campus Lost and Found System (SCLFS) is one that went through a significant amount of verification and validation to determine that the functional capabilities and the underlying artificial intelligence elements of the system worked as expected.

### A. Implementation Details

This entire system was executed in Python 3.10. It relied on such core dependencies as Flask, Flask-SQLAlchemy, Flask-Login, and sentence- transformers library. All

### B. Functional Verification and Testing

A multi-phase testing procedure that was well organized was conducted to ensure the reliability of the system. The correctness of individual modules was checked by unit testing, the ability of components to cooperate with each other was checked by the integration testing and the overall performance was checked by the full system testing. Both black-box and white-box testing strategies were used- Equivalence Partitioning and Boundary Value Analysis of external behavior, Branch Coverage of internal logic. Specifically, one of the functions was the completereturn() to ensure that it appropriately authenticated the user, did not allow the user to reward himself and implemented the reward mechanism when successful authentication occurred. Table II displays the summarized outcomes of the testing phase. All test cases gave the desired result, which showed that all the stipulated functional requirements had been successfully achieved.

TABLE II
Summary and Results of System Test Case.

| Test Case ID | Requirement | Description | Expected Result | Status |
|---|---|---|---|---|
| TC-REG-01 | (Auth) | User registers with existing username. | Failure "Name already existing. | PASS |
| TC-LOGIN-01 | (Auth) | Registered user logs in using valid credentials. | reredirected to user dashboard. | PASS |
| TC-LOGIN-02 | (Auth) | Incorrect password is used to log in. | Mistake "A bad name or a bad password. | PASS |
| TC-AUTH-01 | (Auth) | Non-logged-in user dashboard. | Redirected to login page. | PASS |
| TC-REPORT-01 | FR1, FR2 | User lost something with a photo. | Item saved to DB with status='active'. | PASS |
| **TC-MATCH-01** | **FR3** | **Lost item came across as similar item.** | **New Match record generated with a score that is greater than 0.70.** | PASS |
| **TC-NOTIFY-01** | **FR4** | **The owner of lost item logs in.** | **FR4 notification is present on dash- board.** | PASS |
| **TC-RETURN-01** | **(Gamify)** | **Return is confirmed by the owner.** | **Statuses of the items that are to be re- turned. Finder's coins in- crease by 100.** | PASS |
| TC-ADMIN-01 | FR5 | Logs in as admin. | Redirected to admin dash- board. | PASS |

(Source: Project System Test Plan)

### C. System Interface and User Experiences Walkthrough

The User- Centered Design (UCD) principles of interaction made the user interface design simple, consistent and responsive [8]. The interface of the Report an Item interface, the primary input point of the user, is depicted in Figure 6 and activates the multimodal matching pipeline.

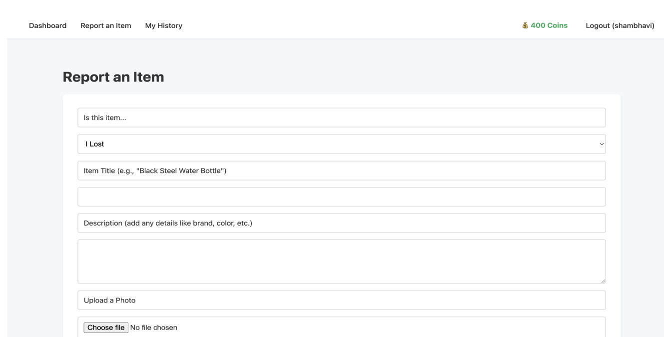


Fig. 6. Report Item Screen

The primary loop of feedback of this system can be seen in Figure 7, which shows a Potential Matches Found! notification. This interface combines technical output of the model with social and gamification aspects:

- **AI Performance:** The system was able to identify a corresponding match, i.e. a scissor, with a similarity score of 91.8% which occurred indicating the accuracy of the multimodal model.
- **Social Facilitation:** On the interface, the contact information and search location of the finder are easily visible, thus, simplifying reconnection to users.
- **Gamification:** Participation is formalized by the Mark as Returned and Award Coins button, and strengthened.
- **Reward Continuity:** The constant 500 Coins message is a confirmation that the gamification system is storing and updating rewards as it should.

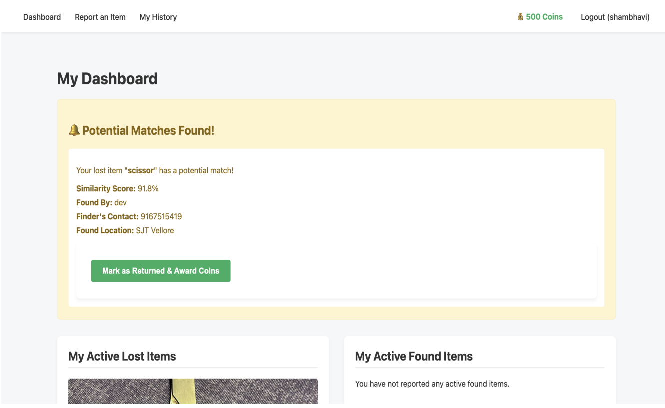


Fig. 7. AI Match Notification in User Dashboard.

The Item History view (Fig. 8) shows that all the items that were returned were returned previously, which leads to the fact that the status of the item changes to a returned status when tested under TC-RETURN-01.

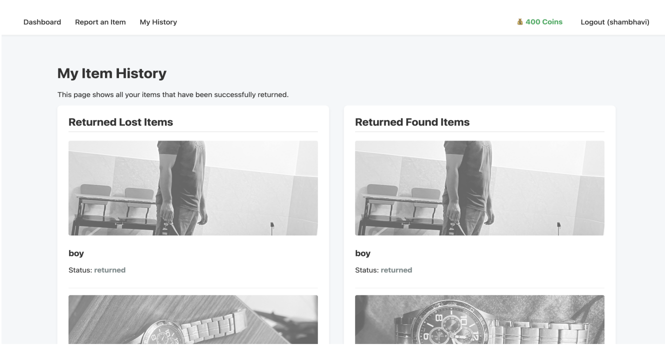


Fig. 8. Item History Screen

Lastly, Figure 9 shows the Administrator Dashboard, which the user with the isadmin privilege can see.This panel gives a centralized general view of all user reports as well as item reports to guarantee the moderation and transparency as per the aim of governance of the system [6].

### D. Discussion of Results

Each of the test cases reported in Table II had a PASS outcome, which validates that the application is working in line with the stipulated functional and technical requirements.

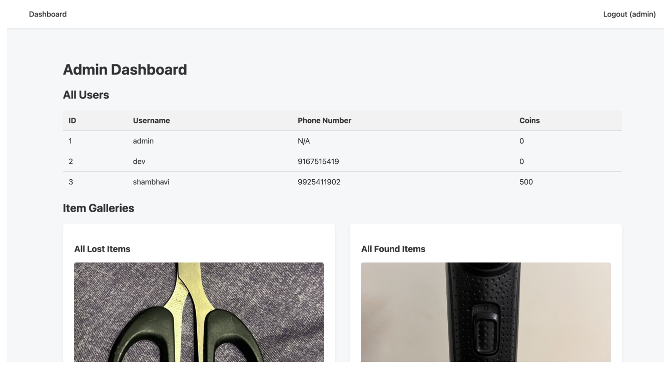


Fig. 9. Administrator Dashboard

The outcomes of TC-MATCH-01 and TC-NOTIFY-01 especially confirm the end-to-end functionality of the multimodal matching engine and its capacity to identify the possible pair of items correctly. In addition, the qualitative results in Figure 7 support the usefulness of the adopted approach. That the similarity score of 91.8 indicates that the model has a high interpretive capacity both in a text and image form and the reward mechanism confirms that the sociotechnical layer is practical. Comprehensively, the system is technically sound and user- oriented and can be reliably used in the real circumstances of a smart campus.

## V. Conclusion and Future Work

### A. Conclusion

The paper proposed and verified the development and implementation of a Smart Campus Lost and Found System (SCLFS). There are three contributions made in the proposed work. First, it uses a weighted multimodal CLIP-based model, which is able to do context-sensitive and semantically compatible accurate matching between textual and visual accounts of lost items. Second, it incorporates a socio-technical incentive system that is more of a gamified system that can encourage its users to become active participants to maintain a sustainable and motivating ecosystem. Third, it shows a maintainable and modular Flask-based architecture as tested by systematic functional and performance testing. Combined, these efforts can fill the disconnect between advanced AI-based approaches, user principles, and practical campus uses, building a viable solution to the present smart environments.

### B. Limitation and Future Work

Although the created prototype fulfilled its desired functionality, it had a couple of limitations. The existing implementation is based on a fairly small data set and the adoption of SQLite limits scalability in the case of high volume or concurrent access. This baseline will be developed into four main directions in future research and development work:

1) **Platform Optimization and Scalability:** Future iterations will migrate to PostgreSQL and adopt asynchronous computing (e.g., Celery) to effectively support multimodal matching tasks of large scale (refer to Fig. 5).

2) **Mobile Application Development:** Native Android and iOS applications will be created to enhance accessibility and enable a user to get real-time notification about lost or found plans.
3) **Location-Based Improvement:** GPS-based geolocation will be implemented into the system so that users can place exact drop or discovery spots on an online campus map [12].
4) **Security Strengthening:** The next generation will introduce superior cybersecurity safeguards, such as input validation, rate limiting, and adherence to wider smart campus security systems [5].

## References


[1] P. Kanjalkar, J. Pingle, A. Sagar, R. Lohe, S. Patil, and J. Kanjalkar, "Lost and Found Web Application," *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, vol. 12, no. 1, pp. 234-238, 2024.

[2] K. Suchana, "Development of User-Friendly Web-Based Lost and Found System," *Journal of Software Engineering and Applications*, vol. 14, no. 10, pp. 575-590, 2021.

[3] T. Mahadik, S. Renapurkar, and S. Ganorkar, "Digital Lost and Found Item Portal," *International Research Journal of Engineering and Technology (IRJET)*, vol. 10, no. 11, pp. 550-553, Nov. 2023.

[4] B. Noviansyah and L. Lestary, "Internet of Thing for Smart Campus: Systematic Literature Review," in *Proc. Int. Conf. on Applied Science and Technology on Engineering Science (iCAST-ES)*, 2023, pp. 636-641.

[5] N. Cavus *et al.*, "Internet of Things and Its Applications to Smart Campus: A Systematic Literature Review," *Int. Journal of Interactive Mobile Technologies*, vol. 16, no. 23, pp. 17–35, 2022.

[6] K. Polin, T. Yigitcanlar, M. Limb, and T. Washington, "The Making of Smart Campus: A Review and Conceptual Framework," *Buildings*, vol. 13, no. 4, p. 891, Mar. 2023.

[7] G. Zichermann and C. Cunningham, *Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps*. O'Reilly Media, 2011.

[8] C. Mihale-Wilson and K. V. Carl, "Designing incentive systems for participation in digital ecosystems—An integrated framework," *Electronic Markets*, vol. 34, no. 1, 2024.

[9] S. Tewari and A. K. Singh, "Scalable Deployment of Python Web Applications using Flask, Gunicorn, and Nginx," *Int. J. of Web Engineering and Technology*, vol. 20, no. 1, pp. 1-15, 2025 (forthcoming).

[10] A. Sharma and R. Kumar, "A Web-Based Digital Notice Board for University Campuses," in *Proc. 2021 IEEE 5th Int. Conf. on Computing Methodologies and Communication (ICCMC)*, 2021, pp. 1-6.

[11] G. T. Alshammari, "An RFID-Based Lost and Found System with Gamification Elements," *Int. J. Comput. Sci. Netw. Secur.*, vol. 18, no. 7, pp. 88-94, 2018.

[12] S. Lee and J. Park, "A LoRa-Based GPS Tracking System for Asset Management in Smart Campuses," *IEEE Internet of Things Journal*, vol. 9, no. 12, pp. 10051-10060, June 2022.

[13] K. Shoji, H. A. K. Al-Musawi, and M. I. H. Al-Adawy, "A LoRa-Based Lost and Found System for University Campus," in *Proc. 2022 IEEE 2nd Int. Conf. on Advancements in Comp., Comm. and Information Technology (ACCIT)*, 2022, pp. 1-5.

[14] I. G. Prawira, I. K. D. Ana, and N. K. A. Wirdiani, "Mobile-Based Lost and Found Application Using ResNet-50 and Cosine Similarity," in *Proc. 2023 IEEE Int. Conf. on Information Technology (ICIT)*, 2023, pp. 1-6.

[15] L. Zhou, X. Wang, and Y. Chen, "A Lightweight Object Recognition Model for Campus Lost and Found Systems based on MobileNetV2," *Journal of Physics: Conference Series*, vol. 2679, no. 1, p. 012045, 2024.

[16] M. A. Hossain, R. Islam, and S. Ahmed, "A CNN-based Image Retrieval System for Lost Item Matching," *IEEE Access*, vol. 10, pp. 45001-45012, 2022.

[17] A. Radford *et al.*, "Learning Transferable Visual Models From Natural Language Supervision," in *Proc. 38th Int. Conf. on Machine Learning (ICML)*, 2021, pp. 8748-8763.

[18] Y. Fu, L. Li, Z. Wang, L. Zhang, and X. Wu, "A Survey of Vision-Language Pre-training Models," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 45, no. 1, pp. 1-20, Jan. 2023.

[19] S. Wang and J. Li, "Zero-Shot Text-to-Image Retrieval using CLIP: A Practitioner's Guide," *ACM Transactions on Intelligent Systems and Technology*, vol. 13, no. 4, pp. 1-18, Aug. 2022.

[20] J. Fu *et al.*, "CLIP-driven Universal Model for Text-based Image Retrieval and Image-to-Text Generation," *IEEE Transactions on Image Processing*, vol. 32, pp. 2977-2991, 2023.