# Drawing Attention: A Field Study of Sketch-Based Penguin Identification for Aquarium Visitor Engagement

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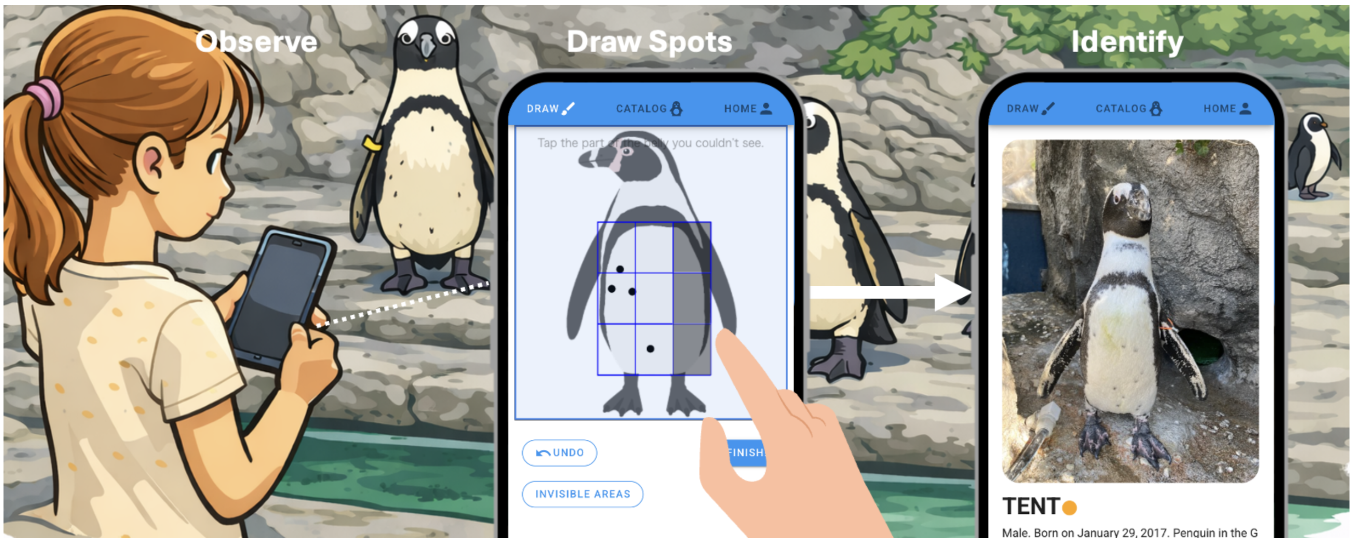


**Figure 1: Illustration of visitors using the drawing-based system at a penguin exhibit. By sketching the unique belly spot patterns, they can search for and recognize individual penguins, fostering active observation, personal connection, and meaningful learning experiences in zoos and aquariums.**

## Abstract

Zoos and aquariums often house animals in groups, making it difficult for visitors to recognize individuals. Penguins exemplify this challenge, even though identifying individuals can foster empathy and engagement. We addressed the following research questions: (RQ1) How do zoos and aquariums currently provide individual identification and what challenges remain? (RQ2) How does a sketch-based identification system affect visitor behavior and awareness in a real-world setting? To answer these questions, we (1) surveyed 25 facilities and clarified the limitations of existing practices, (2) refined a drawing-based retrieval algorithm to handle partial observations, (3) implemented a practical interactive system, and (4) validated it in a field study with 167 visitor groups (270 individuals). Results showed that the system encouraged name-based conversations, enhanced recognition of individual penguins, and increased dwell time. These findings suggest that sketch-based retrieval can enrich visitor experiences by promoting active observation and deeper engagement.


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## CCS Concepts

• **Human-centered computing** → *Field studies.*

## Keywords

Penguin, Drawing, Retrieval, Observation support, Aquarium, Identification, Field study

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## 1 Introduction

Zoos and aquariums are not only leisure spaces but also important venues for education, research, and the promotion of conservation awareness [44, 71]. Prior studies [1, 4, 10, 20] have shown that observation experiences in these settings can enhance visitors' motivation to learn, raise environmental awareness, and strengthen connections with animals. Yet, actual on-site experiences often remain at the level of "watching the group as a whole," with little attention paid to the characteristics or behaviors of individual animals. As a result, memory and attachment related to exhibited animals are not sufficiently formed, limiting both the educational impact and willingness to revisit. Penguins, a particularly popular species, exemplify this issue: dozens of individuals are displayed together, and visitors tend to observe the flock vaguely, without developing memory or affection toward specific individuals.

If visitors could instead identify "this one penguin" on the spot, link it to a name, and remember it, the observation would become a more active and engaging experience, enhancing learning, interest, and motivation to revisit. Research on dolphins has shown that the ability to identify individuals increases empathy and strengthens conservation intentions toward the species [67], suggesting that similar effects may apply to other animals as well. Current penguin identification methods, however, rely heavily on flipper bands, which are small, difficult to see, and often obscured. During our on-site survey, individual lists were often placed on walls or at a distance from the exhibit, requiring visitors to repeatedly shift their gaze between the animals and the panel. Because these lists typically present dozens of names without identifiable markings, visitors had difficulty retaining enough information to perform real-time matching. In several cases, visitors attempted to identify individuals by flipper-band color but were unable to distinguish similar hues such as green and light green, making on-site matching particularly challenging. Moreover, previous research has indicated that such informational signage is often overlooked by visitors [9, 62], suggesting a gap between the provision of information and visitors' actual observation practices.

To address this, we proposed a drawing-based observation support method that allowed visitors to sketch the unique abdominal spot patterns of penguins on a smartphone and immediately retrieve the corresponding individual by name [49, 50]. Controlled experiments suggested that the act of drawing and searching could increase visitors' interest in and memory of individual penguins. These evaluations, however, were limited in participant numbers and restricted to controlled settings, without verification in real aquarium environments with general visitors.

Building on this work, three key gaps remain:

- Existing literature lacks a consolidated understanding of how penguins are exhibited and how individual identification is presented to visitors, leaving the practical context necessary for designing and situating the approach insufficiently articulated.
- They did not take into account the fact that penguins move, and that their abdominal patterns cannot always be fully observed due to orientation or occlusion.
- They did not clarify how aquarium visitors would behave when using the system.

To fill these gaps, we first visited zoos and aquariums that keep and exhibit penguins to examine how names and individual identification are presented, and to clarify visitor needs and establish the significance of this research. Next, we focused on the fact that penguins move and that their abdominal patterns cannot always be fully observed due to orientation or occlusion, and we refined the algorithm to accommodate such partial observations. Finally, based on this improved algorithm, we implemented a system suitable for practical use in aquariums and zoos, and through user studies with visitors, we investigated how the system was actually utilized.

To guide our investigation, we addressed the following research questions. **RQ1:** How do zoos and aquariums currently provide individual identification and information about animals, and what challenges remain for enhancing visitor experiences? **RQ2:** How does a sketch-based identification system influence visitor behaviors, conversations, and awareness of individual penguins in a real-world aquarium setting?

The contributions of this research are as follows:

- **Empirical survey:** We conducted field investigations at 25 zoos and aquariums that keep and exhibit penguins, and clarified the limitations of existing exhibition practices and the challenges of applying our method in real settings.
- **Refined retrieval method:** Unlike prior work [43], our algorithm explicitly handles partial observations by allowing users to specify unseen areas, significantly improving retrieval accuracy in realistic exhibition settings
- **System implementation:** We implemented a practical system suitable for use in aquariums and zoos, integrating the refined algorithm into an interactive platform.
- **Field study validation:** We conducted a field study with 167 visitor groups (270 individuals) at an urban aquarium, demonstrating the usefulness of the proposed approach while also identifying challenges for real-world deployment.

In this way, our work not only enhances the quality of visitor experiences but also introduces a new direction for observation support through drawing in the HCI field. The next section reviews related research on observation support, individual identification, drawing, and visitor studies. We then report on our survey of zoo and aquarium exhibitions, describe the system design, and present the methodology and results of our aquarium field study. Finally, we discuss implications for observation experience design, education and outreach, and animal welfare, and outline limitations and future directions, including long-term deployment, expansion to other facilities, and extensions of algorithms and user experience.

## 2 Related Work

### 2.1 Roles of Zoos and Aquariums

Zoos and aquariums have evolved from leisure facilities into institutions with multiple roles, including education, research, and conservation awareness [23, 44, 68, 71]. Today, they are generally operated with four primary purposes: leisure, education, conservation, and research [17], and discussions have emerged about positioning well-being as a potential fifth pillar [27]. In addition, leisure is increasingly framed not as passive entertainment but as an opportunity to cultivate empathy and meaningful engagement with animals [61].

The impacts of visiting such facilities are well documented. Visits can enhance conservation knowledge, increase self-efficacy, and encourage pro-conservation behaviors [14, 41]. Research has also demonstrated positive effects on adult visitors' attitudes and understanding of conservation [20]. Jensen et al. [29] found that biodiversity learning outcomes acquired during visits can persist over time. Furthermore, studies have suggested that zoo experiences foster a sense of connectedness with nature and animals [10, 28, 65], and that visits to zoos and aquariums can enhance visitors' positive emotions and empathetic responses toward animals [36, 48].

However, some studies have pointed out that such educational effects and attitudinal changes may diminish over time or fail to translate into actual behavioral change [1]. Malamud et al. [38] argued that there is insufficient evidence to conclude that zoo visits lead to significant shifts in attitudes or conservation engagement. This suggests the need for interaction designs that sustain attention and learning beyond the immediate visit.

Building on this body of work, our study advances the discussion by examining how individual-level engagement, rather than species-level framing, can sustain attention and deepen connections in zoo and aquarium contexts.

## 2.2 Studies on Zoo and Aquarium Visitors

Visitors come to zoos and aquariums not only for recreation and relaxation [3, 13, 45], but also to seek educational experiences [4, 60, 72]. Davey [18] reported that major motivations for visiting include education and the opportunity to observe unusual animals, and that visitors tend to hold more positive perceptions of zoos and captive animals compared to the general public. Packer [54] further noted that even visitors who do not explicitly intend to learn may nonetheless become engaged in learning experiences.

Participatory exhibitions and naturalistic displays have been shown to increase visitors' dwell time and interest [21, 42]. Moreover, combining exhibits with educational interventions contributes to knowledge acquisition and deeper understanding [15, 74]. Other studies have pointed out that positive perceptions of animals and exhibitions can support motivation for further learning, and that interactive experiences with animals enhance educational outcomes [16, 26]. Skibins et al. [65] suggested that innovative exhibit designs and strategic messaging can increase visitors' attention to and appreciation of less prominent animal species. In addition, Ballantyne et al. [3] showed that visitors place high value on information such as animal names and species, underscoring the importance of effective information provision. Also, empathy toward animals has been suggested to contribute not only to conservation behaviors but also to promoting welfare awareness [13, 43, 78].

Thus, in order to strengthen learning and conservation awareness in zoos and aquariums, it is important to design exhibits and educational interventions that cultivate interest in and empathy toward animals. Luebke et al. [37] demonstrated that visitors' emotional reactions while observing animals are strongly associated with their sense of enjoyment. Similarly, Lucardie [35] showed that enjoyment and joy enhance memory retention and learning outcomes, emphasizing the importance of creating mechanisms that draw out visitors' enjoyment while also deepening their engagement and learning.

## 2.3 Research on Individual Animal Identification

Individual identification of animals has been explored for purposes such as population monitoring and wildlife management. Burghardt et al. [11] developed a prototype system that identifies individual African penguins in real time based on abdominal spot patterns captured on video. In addition, methods that combine RGB-based detection of penguins with hyperspectral image-based individual identification have been proposed for recognizing individuals within a colony [51].

Beyond penguins, individual identification has also been studied for other species. For example, techniques using scars on flippers have been developed for identifying sea lions in behavioral studies [40], and depth-image based methods have been proposed for recognizing individual chickens [79]. Duyck et al. [19] developed an image retrieval system for individual animal identification to support ecological monitoring and conservation.

Most existing approaches prioritize scientific accuracy and are intended for researchers rather than visitors. In contrast, our study shifts the focus to visitor-centered interaction by enabling lay users to identify individual penguins themselves. Through sketch-based retrieval, we demonstrate how individual identification can move beyond automated recognition and become a meaningful public experience, robust even to the variation inherent in human drawings.

## 2.4 Research on Support in Zoos and Aquariums

A growing body of research has explored how digital technologies and interactive methods can support observation and learning in zoos and aquariums. Lindemann-Matthies et al. [34] demonstrated that interactive educational approaches such as touch tables improved long-term knowledge retention compared to static labels. Bellotti et al. [5] found that handheld hypermedia guides enhanced visitor satisfaction and engagement more effectively than traditional signage. Similarly, Ohashi et al. [52] showed that mobile devices encouraged children's active participation in animal observation. At the same time, Allen [2] emphasized that effective exhibit design requires stimulating intrinsic motivation while avoiding excessive cognitive load or overly complex interactivity.

Research on augmented reality has also demonstrated its potential for enhancing zoo and aquarium experiences [31, 56, 69]. For example, Karlsson et al. [30] developed an AR-based system that enabled visitors to identify animals and access related information, thereby supporting observation. Reh et al. [59] noted that while AR effectively enhances engagement, clear educational objectives are essential to ensure meaningful learning outcomes.

Taken together, these studies show that interactive technologies can complement direct observation, but they also highlight the risk of distracting visitors from the animals themselves. Our contribution is to integrate a lightweight sketch-based system directly into on-site observation, balancing technological support with authentic engagement.

## 2.5 Technology-Mediated Human-Animal Relationships in ACI

General zoo research indicates that observing active animal behaviors is a key factor in fostering positive visitor perceptions and emotional connections [33]. Building on this understanding within Animal Computer Interaction (ACI), researchers have examined how interactive technologies can mediate the relationships between zoo animals and visitors. Carter et al. [12] argue that technologies which make animals' cognitive abilities and agency visible can bridge psychological distance between humans and animals, fostering respect and a deeper sense of connection. For example, Webber et al. [76] showed that when visitors observe orangutans using an interactive system, they often attribute intentionality, curiosity, and even human-like qualities to the animals, which can enhance empathy and emotional connection. This work demonstrates how technology can reshape visitors' interpretations of animals by foregrounding individual behaviors and cognitive engagement.

Other ACI work has introduced interactive systems that make animals' behaviors, preferences, or choices more visible to visitors. For example, Wang et al. [75] created a multisensory installation for lemurs that revealed which visual, auditory, or olfactory stimuli they preferred. Martin et al. [39] designed cognitive enrichment devices for great apes, allowing visitors to observe how apes solve tasks rather than simply viewing static exhibits. Pons et al. [58] examined how children imagine and design playful interactions with animals, highlighting the role of interactive technologies in shaping visitors' interpretations of animal abilities and agency. These studies illustrate how technology can help visitors gain a richer understanding of animals by foregrounding their behaviors, choices, and cognitive engagement.

Research has also explored how digital systems affect both animal welfare and visitor attitudes. Perdue et al. [55] investigated a touchscreen installation for orangutans at Zoo Atlanta and found that the system did not increase aggression or distress, nor did it negatively impact visitor experience; instead, visitors expressed broadly positive attitudes toward the role of technology in enhancing welfare and engagement. Complementing this, French et al. [24] proposed technology-supported hunting experiences to recreate naturalistic behavioral challenges, illustrating how interactive systems can enrich animals' lives while deepening visitor understanding of species-specific behaviors.

Our work aligns with this line of research but differs in its emphasis. While previous ACI systems highlight animals' agency or multimodal interaction, they rarely support visitors in recognizing and following specific individuals. In contrast, our sketch-based system makes the individual distinctiveness of each penguin directly perceivable and usable in real time. By enabling visitors to identify and repeatedly observe the same individual, our approach offers a complementary, visitor-centered mechanism for deepening human-animal relationships in zoo environments.

# 3 Survey of Penguin Exhibition Practices at Zoos and Aquariums

## 3.1 Purpose

Previous work [49, 50] introduced a drawing-based observation support method for identifying individual penguins. While controlled studies suggested its potential to enhance visitors' interest and memory, they did not examine how penguins are actually exhibited in aquariums, how individual information is presented, or how these practices affect visitors' observation and memory. Because existing literature also provides limited consolidated descriptions of these exhibition practices, it was first necessary to clarify this practical context as a motivation and foundation for our research. To address this gap and to ground our system in real-world contexts, we conducted field investigations at zoos and aquariums. The purpose was to capture the current state of penguin exhibitions, clarify challenges in existing identification methods, and consider how our approach might be applied in practice.

## 3.2 Method

Between June 1, 2022 and September 10, 2025, we visited 25 zoos and aquariums that keep and exhibit penguins, including 17 facilities in Japan and 8 overseas (Europe, Asia, and Oceania). At each site, we systematically observed and recorded the following aspects, which are summarized in Table 1:

- **Facility and country** (name of the zoo or aquarium and its location)
- **Penguin count and year** (number of penguins kept at the time of observation, with year of reference)
- **Identification methods** (e.g., flipper bands, bead combinations, leg bands, name boards)
- **On-site availability of names or IDs** (whether visitors could access name or ID information directly)
- **Individual-focused exhibition practices** (e.g., panels, posters, catalogs, or digital systems introducing each penguin's traits, relationships, or stories)
- **Exhibit style** (indoor, outdoor, or both)

For each facility, either the first or the second author personally visited the site and documented the exhibition environment in detail. This included taking comprehensive photographs of the enclosures, signage, and all materials related to individual identification, as well as noting the approximate number of penguins on display (confirmed with staff when necessary). We additionally recorded how individual identification was implemented in practice and whether visitors had accessible means to obtain that information (e.g., visibility and placement of name lists, posters, or digital displays). Based on these materials, we compiled a comparative summary across facilities and conducted a descriptive analysis to identify common patterns and differences in exhibition practices.

## 3.3 Findings

Table 1 summarizes the survey results of 25 facilities. Almost all facilities (24/25) relied on flipper bands for husbandry management and individual identification (Figure 2). Some facilities displayed posters or lists linking band colors to individuals (Figure 3), and a few assigned ID numbers based on color codes rather than names (Figure 4).

However, from the perspective of visitors, these methods often provide little support for recognizing and remembering "this particular penguin." While most facilities displayed species-level information, only 12 presented individual-focused panels with names, personalities, or life histories (Figure 5). Notable cases include the web-based *Pentagon* system at the Sumida and Kyoto aquariums, which allows visitors to search for individuals by band color. Kyoto further introduced abdominal spot patterns as an additional cue (Figure 6).

Overall, our on-site survey indicates that only a minority of facilities provide individual-level information, and even when such materials are available, they offer limited support for real-time matching during observation. In several facilities, individual lists were positioned at a distance from the exhibit or displayed without distinctive

**Table 1: Surveyed zoos and aquariums (25 facilities) and their approaches to penguin individual identification and exhibition.**

| Facility (Country) | Penguin Count (Year) | Identification Method | On-site Name/ID | On-site Individual-focused Exhibition Practices | Exhibit Style |
|---|---|---|---|---|---|
| Asahiyama Zoo (Japan) | 40 (2024) | Colored bands and beads | | None | Both |
| Otaru Aquarium (Japan) | 33 (2022) | Flipper bands with names | ✓ | Introduces penguin pairs with names and photos; penguin shows with names | Outdoor |
| AOAO SAPPORO (Japan) | 22 (2024) | 12 colored bands | ✓ | Posters listing all penguins' names, photos, sex, personalities | Indoor |
| Aqua World Ibaraki Prefecture Oarai Aquarium (Japan) | 36 (2023) | 34 colored bands | | None | Both |
| Sunshine Aquarium (Japan) | 47 (2025) | 12 colored bands | | Posters introducing how to identify penguins by band colors | Outdoor |
| Sumida Aquarium (Japan) | 56 (2024) | 13 colored bands | ✓ | Correlation chart of all penguins with faces and bands; "Pentagon" system; spot-based identification posters; "favorite penguin" diagnosis site | Indoor |
| Kamogawa Sea World (Japan) | N/A | Colored bands | | None | Both |
| Enoshima Aquarium (Japan) | 27 (2024) | Colored bands | ✓ | Correlation chart of all penguins; individual introduction panels with names | Indoor |
| Kakegawa Kachoen (Japan) | 33 (2025) | 12 colored bands | ✓ | Correlation chart of all penguins; encyclopedia-style panels with individual information | Outdoor |
| Hamamatsu Zoological Gardens (Japan) | 11 (2023) | 12 colored bands | | None | Outdoor |
| Toyohashi Zoo & Botanical Park (Japan) | ≈70 (2025) | Colored bands | | Poster encouraging visitors to find their favorite penguin via band colors | Both |
| Port of Nagoya Public Aquarium (Japan) | ≈170 (2014) | 4 colored beads on bands | | Poster explaining identification via band and bead colors | Both |
| Minami-Chita Beach Land (Japan) | 63 (2024) | 2 colored bands | ✓ | Encyclopedia-style panels showing all individuals | Both |
| Toba Aquarium (Japan) | 51 (2025) | 12 colored bands | | None | Outdoor |
| Kyoto Aquarium (Japan) | 50 (2025) | 12 colored beads on bands | ✓ | Correlation chart; "Pentagon" system; spot-based identification posters | Indoor |
| NIFREL (Japan) | 10 (2023) | 3 colored beads on bands | | None | Indoor |
| Osaka Aquarium Kaiyukan (Japan) | 81 (2025) | 4 colored beads on bands | | None | Both |
| átoa (Japan) | 7 (2024) | Not specified | | None | Outdoor |
| Nagasaki Penguin Aquarium (Japan) | ≈180 (2023) | 2 colored bands | | Poster explaining identification via band colors | Both |
| DMM Kariyushi Aquarium (Japan) | 7 (2023) | 2 colored bands | ✓ | Correlation chart; posters encouraging name recall via bands | Indoor |
| Sea Life Sydney Aquarium (Australia) | 45 (2024) | 1 colored band | ✓ | Boards listing individuals with names, ages, sex, partners, traits | Indoor |
| National Zoo & Aquarium (Australia) | 16 (2025) | 1 colored band | | None | Outdoor |
| Copenhagen Zoo (Denmark) | 39 (2022) | Colored beads on bands | | None | Outdoor |
| Aquarium of Genoa (Italy) | ≈30 (2022) | Colored bands | | None | Indoor |
| L'Aquàrium de Barcelona (Spain) | 21 (2018) | Colored beads on bands | | None | Indoor |

visual cues, requiring visitors to repeatedly shift their gaze between the animals and the panel while attempting to retain information about dozens of similarly presented individuals. Visitors also frequently struggled to distinguish flipper-band colors—particularly similar hues such as green and light green—making it difficult to reliably identify specific penguins in real time.

Findings from prior research further contextualize these challenges. Static informational panels generally attract limited visitor attention and are often glanced at only briefly [9, 32, 62, 70]. Other work has shown that interactive or immersive exhibit elements hold attention more effectively and support deeper learning compared with static signage alone [6, 34, 47, 64, 66, 73, 77]. Based on these insights, static individual-information displays in penguin exhibits may not provide sufficient support for sustained engagement or moment-to-moment matching during observation, making visitor interaction more likely to remain passive.

These practical constraints suggest that existing identification practices provide insufficient support for helping visitors recognize and form attachments to particular individuals, underscoring the need for alternative approaches such as drawing-based methods that more directly link observation to identity.

## 3.4 Challenges

From these observations, several challenges became evident:


**Figure 2: Examples of penguin identification bands used in different aquariums and zoos. From top left: color-band combinations at Sunshine Aquarium; three-band combinations on both flippers at Sumida Aquarium; bands with names explicitly written at Otaru Aquarium; four-bead color combinations on bands at Osaka Aquarium Kaiyukan; striped color-band combinations at Copenhagen Zoo; and single-color bands attached to legs at the National Zoo & Aquarium.**


**Figure 3: Example of an exhibition board at Sea Life Sydney, displaying each penguin's name, age, partner, personality traits, sex, and flipper band color in a tabular format.**


**Figure 4: Examples of exhibition panels explaining how to identify penguins by deriving their individual ID numbers from flipper band codes (Left: Port of Nagoya Public Aquarium; Right: Nagasaki Penguin Aquarium). On the left, bead colors are assigned digits as follows: black = 0, red = 1, blue = 2, yellow = 3, green = 4, and white = 5. From the back toward the belly, the first bead represents the hundreds place, the second the tens place, and the third and fourth beads are summed to determine the ones place, thereby generating each penguin's unique number. If the base color of the band is white, 50 is added to the number. On the right, band colors are mapped to digits, and two bands are used: one representing the tens place and the other the ones place, together determining each penguin's ID number.**

- **Visibility issues**: Flipper bands are small, hard to distinguish in dim lighting or underwater, and often overlap in color.
- **Difficulty linking information to individuals**: Even when lists or charts are provided, visitors struggle to match them with specific, moving penguins.
- **Limited information depth**: Most facilities provide species-level explanations, with few opportunities to highlight unique traits of individuals.
- **Limited visitor agency**: As suggested in prior research on zoo signage [32, 62], static displays tend to attract limited attention and support only short viewing durations, which can restrict opportunities for active engagement with individual animals.
- **Animal welfare concerns**: Studies [8, 25, 57] suggest that bands may negatively impact wild penguins' survival and reproduction, raising ethical concerns even in captivity.

In addition to these exhibition-related issues, our observations across multiple zoos and aquariums revealed several practical challenges for applying our method in the wild:

- Penguins were sometimes partially obscured by other penguins, making it impossible to observe the entire abdominal pattern.
- In some facilities, rocks or pillars blocked the view, which also prevented full observation of the abdominal pattern.
- As penguins moved or swam around, it occasionally became difficult to determine which penguin was being observed.

Since our method assumes that the entire pattern can be observed and drawn, these findings indicate that directly applying the method in real settings poses difficulties for retrieval.

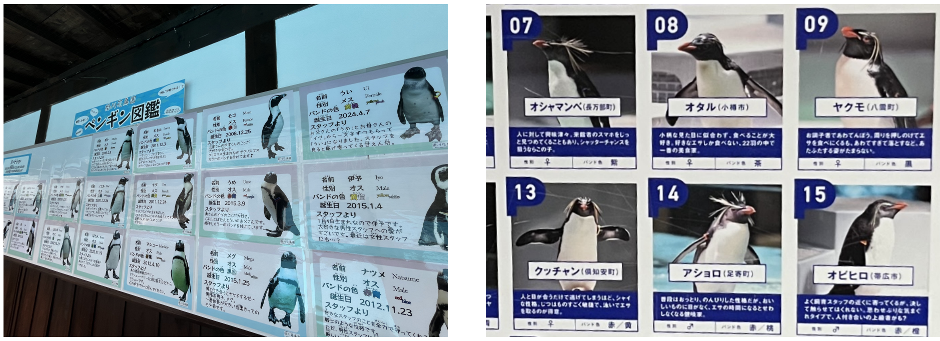

**Figure 5: Examples of catalog-style exhibition panels displaying comprehensive individual information for all penguins (Left: Kakegawa Kachoen; Right: AOAO SAPPORO). Kakegawa Kachoen provides each penguin's name, gender, band color, birthday, personality traits, and a photograph. AOAO SAPPORO provides the name, gender, band color, personality traits, and photographs.**


**Figure 6: Example of a poster encouraging visitors to distinguish penguins by abdominal spot patterns (Kyoto Aquarium). Each penguin's name is shown along with its distinctive spots (e.g., concentrated on the right chest, spreading vertically like a constellation, concentrated on the upper body).**


**Figure 7: Examples of penguin relationship correlation charts showing pairings and family connections (Left: Kakegawa Kachoen; Right: Sumida Aquarium). In addition to pairings and parentchild relationships, the charts also display information such as close friendships, rivalries, unrequited love, and breakups.**

These observations clarified the practical challenges of applying the drawing-based method in real-world exhibition environments. The next section discusses how these findings informed the design of our system.

# 4 System Design

## 4.1 Implications from the Survey

The survey of 25 zoos and aquariums highlighted several limitations of existing identification practices. Visitors often found it difficult to distinguish band colors, particularly under dim lighting or when similar colors were used. Information displays tended to be limited in depth and were not directly linked to the penguins being observed. Moreover, many visitors engaged in passive viewing, and individual differences were rarely noticed or discussed. In addition, real exhibition environments presented practical constraints, such as obstructed views and moving animals, which often resulted in only partial visibility of abdominal spot patterns. These findings informed the design of our revised system.

The drawing-based method for searching penguins by their abdominal spot patterns is valuable in that it encourages active observation while reducing the cognitive load of identification. Also, when combined with existing methods such as flipper bands and information panels, this approach can support multifaceted connections between individuals and their information, thereby facilitating more memorable and engaging observation experiences.

Based on these implications and survey findings, we derived the following design requirements for our system.

## 4.2 Design Requirements

The goal of this study is to support visitors in achieving a more active and enriched observation experience by encouraging them to focus on the differences among individual penguins, rather than merely observing the flock as a whole. To this end, we implemented a drawing-based observation support system that enables visitors to observe penguins in the exhibition, draw the abdominal spot patterns of a specific individual on their own smartphones, and retrieve the corresponding individual information based on the drawn data.

Our previous work [50] examined the use of a prototype system in controlled laboratory settings with university students. For broader application, it was necessary to revise the system so that it could be used by general visitors of diverse age groups in actual aquarium environments. Prior research has also shown that visitors value not only consuming content but also collecting and retaining it as part of their experience, which can enrich engagement [53]. Therefore, the design of our system also needed to incorporate features that motivate visitors to engage in and preserve their own observations. Furthermore, the earlier prototype [50] covered only a limited number of individuals, which meant that some penguins could not be retrieved at all. Based on these identified issues, we defined the following design requirements for the system:

- **Need for individual identification during observation:** At Sunshine Aquarium, where our field study was conducted, visitors had no direct means to confirm the names of the penguins they were observing, making it difficult to connect individuals with their information. To address this, the system centers on a function that allows visitors to draw abdominal spot patterns as input and immediately retrieve the corresponding individual, thus supporting on-site identification.
- **Accessibility for diverse visitors:** Considering a wider range of visitors, including young children, the drawing interface and button labels employ simple hiragana notation to ensure intuitive use.
- **Ensuring comprehensive retrieval:** Earlier studies reported that the prototype system was limited to a subset of individuals, leaving some penguins unsearchable. In this study, we incorporated information on all 47 Cape penguins provided by the aquarium, thereby ensuring complete coverage of searchable individuals.
- **Handling partially unobservable situations:** As revealed in the survey, real aquarium environments do not guarantee a full frontal view of each penguin. Movement, viewing angles, and occlusion by other penguins or objects frequently result in only partial visibility of the abdomen. To address this issue, the system incorporates a function that allows users to specify "invisible areas" of the abdomen, which are then excluded from the similarity calculation during retrieval. This feature directly responds to the challenges identified in the survey and enables reliable identification even when observations are incomplete.
- **Access to individual information:** To accommodate visitors who may find drawing difficult, the system also provides a catalog view of all penguins. This includes individuals housed across the three areas of Sunshine Aquarium: "Grassland", "Sky", and "Backyard". In this way, even penguins not visible in the exhibition can be browsed.
- **Use beyond the visit:** To meet the needs of visitors who wish to engage with penguin information outside the aquarium, we implemented an album function. Logged-in users can save the drawings, corresponding individual information, and search history, allowing them to revisit their past observations and enjoy them as memorable experiences.

The fundamental drawing interface and similarity-based retrieval algorithm were designed and refined based on our previous work [50].

## 4.3 Construction of the Retrieval Dataset

For the purpose of conducting our field study at Sunshine Aquarium, an urban aquarium located in Ikebukuro, Tokyo, we constructed a drawing dataset covering all 47 Cape penguins kept at the facility.

Since visitor drawings naturally include individual differences and variations, it was necessary to create template data for each individual penguin to serve as a reference when calculating similarity with user input during retrieval. To this end, we conducted a drawing task with 30 participants (21 male and 9 female university and graduate students, aged 20-24). In this task, a frontal photograph of each penguin, in which the abdominal spot pattern was clearly visible, was projected on a screen together with the individual's name. Participants accessed the system on their own smartphones and freely drew the abdominal patterns based on the presented image. No time limit was imposed, and the session proceeded to the next penguin only after all participants had completed their drawings.

The collected drawing data were processed following the method described in our previous work [50]. Specifically, the abdominal area was divided into a $3 \times 3$ grid, and the distribution of drawn spots within each region was vectorized. For each penguin, average vectors were computed across multiple participant drawings to generate template data for retrieval. In this way, we prepared searchable template data for all 47 Cape penguins, which were subsequently used to calculate similarity with user-generated sketches.

## 4.4 Handling Invisible Areas and Range-Selection Algorithm

This system is designed to be used by visitors while observing penguins that move freely within the aquarium. However, as revealed in our survey, parts of the penguins' abdomens are often obscured due to their movement, the viewing angle, or obstruction by other penguins or visitors. Therefore, it is important to provide a way for visitors to avoid having to draw portions they cannot actually observe.

To address this, we added an "Invisible Area" button to the drawing screen, which switches the interface into a mode where visitors can mark unseen regions (Fig. 8). In this mode, a 3×3 grid is overlaid on the penguin's abdominal outline, and visitors can tap to specify areas they were unable to view. The marked regions are then excluded from the similarity calculation during retrieval.

We adopted a 3×3 grid for marking invisible regions for two practical reasons. First, the retrieval method used in our system builds directly on the algorithm proposed in our previous work [50] , which divides the drawing space into 3×3 subregions and compares the number of painted points in each cell. Aligning the invisible-area interface with this algorithm ensured conceptual and computational consistency and avoided mismatches between what users specify and what the recognition model can utilize. Second, because sketching abdominal spot patterns naturally introduces variability across users, finer grids would be more sensitive to small inconsistencies and could reduce robustness. They would also increase cognitive load and slow interaction, particularly for casual visitors and children. Although a more granular grid or an adjustable option may improve accuracy in some cases, such flexibility introduces a usability trade-off. We therefore selected a simple 3×3 design for this

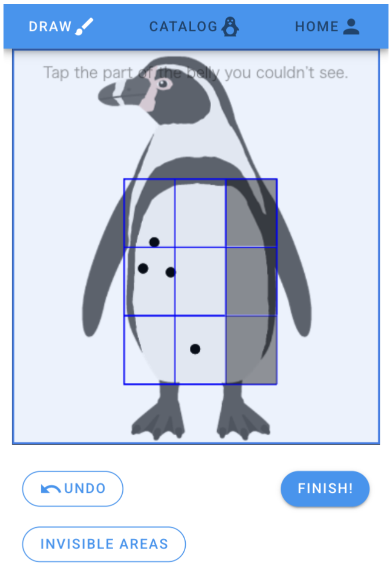


**Figure 8: Example of the *Invisible Area* function: when part of a penguin's abdomen (e.g., the right side) cannot be observed due to movement or occlusion, visitors can tap the corresponding grid cell to mark it as "not visible." The marked region is then excluded from the similarity calculation during retrieval.**

deployment as a balanced choice for in-situ use, while exploring alternative granularities remains an avenue for future work.

To evaluate the effectiveness of this feature, we conducted a preliminary field study with 6 university students at the aquarium. Participants observed penguins on display and drew their abdominal spot patterns using the system, after which retrieval was performed both with and without the invisible-area specification function. In total, 12 drawings were collected and analyzed. The results showed that retrieval accuracy improved when unseen regions were excluded compared to when they were not (Table 2). Specifically, the proportion of correct identifications appearing within the top five ranked candidates increased from 33.3% without the function to 50.0% with it. These findings demonstrate that the invisible-area specification effectively addresses partial information loss that commonly occurs in real-world observation scenarios.

With this mechanism, retrieval can be conducted using only the visible portions of the penguin's body, enabling flexible individual identification that adapts to the constraints of on-site observation. This function represents a novel extension of the baseline similarity calculation method described in our previous work [50], tailored to the realities of exhibition environments.

### 4.5 System Overview

Based on the design requirements described in Section 4.2, we implemented the proposed drawing-based observation support system. The system is composed of multiple screens that allow visitors to identify individual penguins and access related information during their observation in the exhibition. The main screens are as follows:

- **Home Screen**: Visitors can choose to log in or use the system as a guest. From this screen, they can start drawing by tapping the "Drawing" button. Logging in enables access to the album function (Fig. 9, top left).
- **Drawing Screen**: Visitors observe penguins in the exhibition and draw the abdominal spot patterns. If some parts of the abdomen are not visible due to obstacles or penguin movement, they can mark those regions as "invisible area," which are then excluded from similarity calculations during retrieval. After completing the sketch and pressing the "Finish" button, the system transitions to the search results screen (Fig. 9, top right).
- **Search Results Screen**: Once the drawing is submitted, the system presents candidate penguins ranked by similarity between the input drawing and the template data (Fig. 9, center left).
- **Individual Detail Screen**: When a specific penguin is selected from the search results, the system displays detailed information such as the penguin's image, name, band color, and profile. If the identified penguin matches the one observed, the visitor can press the "This is the one!" button. The drawing data is then sent to the database and stored in the visitor's personal album (Fig. 9, center right).
- **Catalog Screen**: Visitors can browse a list of all penguins kept at Sunshine Aquarium. By clicking on a penguin's face image, a modal window opens to show detailed information, including the individual's photo, name, band color, and profile (Fig. 9, bottom left). This catalog includes not only the penguins on display but also those housed in the "Grassland," "Sky," and "Backyard" areas.
- **Album Screen**: Logged-in visitors can view and manage a personal album containing the drawings they created, the corresponding penguin images, and the dates of their searches. This feature allows them to revisit and reflect on past observations, and to enjoy the records as personal memories (Fig. 9, bottom right).

In addition, visitors can freely navigate between the Home, Drawing, and Catalog screens through a header navigation menu. The system was implemented with the Vue.js framework for the frontend, PHP for the backend, and MySQL as the database.

## 5 Field Study

### 5.1 Study Overview

To examine how sketch-based retrieval of penguin abdominal spot patterns influences visitors' observation behaviors, we conducted a field study at Sunshine Aquarium in Tokyo. The study was carried out over six days between October 15 (Tuesday) and October 21 (Monday), 2024, excluding October 19 (Saturday). The experiment took place in two exhibition areas: the "Grassland" and "Sky" zones. To enable natural access to the system, signage was installed in front of each exhibit with a brief explanation and a QR code (Fig. 10, Fig. 11). The signage remained on display throughout the study period, allowing visitors to access the system on their own smartphones by scanning the QR code. The system was accessed

**Table 2: Comparison of retrieval accuracy with and without the range-selection function (Top-$k$ accuracy)**

| Condition | With Invisible-area Specification | Without Invisible-area Specification |
|---|---|---|
| Top 1 ($k$=1) | 25.0% | 16.7% |
| Top 3 ($k$=3) | 41.7% | 33.3% |
| Top 5 ($k$=5) | 50.0% | 33.3% |

exclusively through visitors' own smartphones by scanning the QR code on the signage. No devices were provided by the researchers, and the system operated as a web-based application that required no installation. Thus, all usage occurred in a naturalistic manner on visitors' personal devices, reflecting typical on-site interaction conditions. When necessary, experimenters provided brief verbal explanations of the system to visitors who showed interest by reading the signage.

This study was conducted in a public setting at an aquarium to examine how a sketch-based interface influences visitors' individual recognition and engagement with penguins. No identifiable personal data, images, or audio recordings were collected, and all observations were conducted anonymously from a distance. In accordance with institutional guidelines and their interpretation for observational research in public settings, the study was regarded as low-risk, non-identifiable behavioral observation and therefore did not require prior approval from the institutional ethics board. The study procedure was reviewed and approved by the host aquarium's management as a local operational authorization, independent of institutional ethics review.

Participation in the system was entirely voluntary. Posters placed near the exhibits explained the purpose of the study, and users could access the system only by scanning the QR code printed on the poster. The initial screen of the application informed users that their anonymous usage data might be analyzed for research purposes and provided the option not to proceed. Questionnaire respondents were also informed about the study purpose and data handling. We did not conduct systematic post-interaction debriefings, as we sought to avoid interrupting visitors' spontaneous conversations; instead, study information was provided on the signage and the app's initial screen. No photos or videos of visitors were taken, and only anonymous behavioral patterns were documented in field notes. The only images included in this paper show users from behind in a way that prevents personal identification.

During the study, three experimenters were stationed near the exhibits from 10:00 to 16:00 each day to observe visitor behavior. They focused on recording visitors' interactions with the signage, their use of QR codes, and their engagement with the system.

To ensure consistency in data collection, the three experimenters followed a shared observational protocol. Experimenters were positioned several meters away from the exhibit—close enough for visitors to be aware of their presence, but far enough to avoid interfering with natural behavior. Each experimenter conducted observations independently while recording notes in a shared, collaboratively edited digital document using their smartphones.

The protocol specified the following:

- **What to observe:** interactions with the signage, QR-code scanning behavior, transitions between drawing, catalog browsing, and other system screens, visible reactions to retrieval results, and verbal utterances audible within a reasonable distance.
- **What not to record:** any identifiable personal information, including faces or clothing details, as well as conversations unrelated to the system.
- **How to classify visitor groups:** experimenters used observable cues such as height or the presence of a guardian to distinguish between "adults" and "children," without inferring more detailed demographic attributes.
- **How to document behaviors:** experimenters wrote short, time-stamped notes describing observable actions (e.g., "family of three scanning QR," "child drawing for a long time," "adult pointing to the name result").

After each observation session, the notes were briefly cross-checked among experimenters to reduce potential inconsistencies. During the analysis phase, the first author synthesized these collaboratively produced notes into higher-level behavioral categories (Section 5.3).

## 5.2 Visitor Demographics and Participation

Visitor attributes were inferred based on the observational protocol described above and were used only as broad indicators (e.g., distinguishing between adults and children), rather than precise demographic data.

After the field study, the first author organized and analyzed the behavioral field notes recorded during observations at the exhibition areas. The notes, totaling 13,222 Japanese characters, were used to summarize patterns of visitor behavior and verbal interactions. The number of system users was aggregated by day and usage type (Table 3).

Across the six-day period, many visitors were observed reading the signage and accessing the system by scanning the QR code. Within the range of recorded observations, a total of 167 groups comprising 270 individuals used the system. The most common usage pattern was multiple people sharing a single device, observed in 79 groups. Groups that appeared to include both adults and children were especially likely to engage in collaborative drawing using a shared smartphone. The number of users increased toward the weekend and the following Monday, coinciding with higher visitor turnout at the aquarium; on the final day alone, 55 groups used the system.

Overall, the system was used by a broad range of visitors, with particularly active engagement observed in groups that included children.

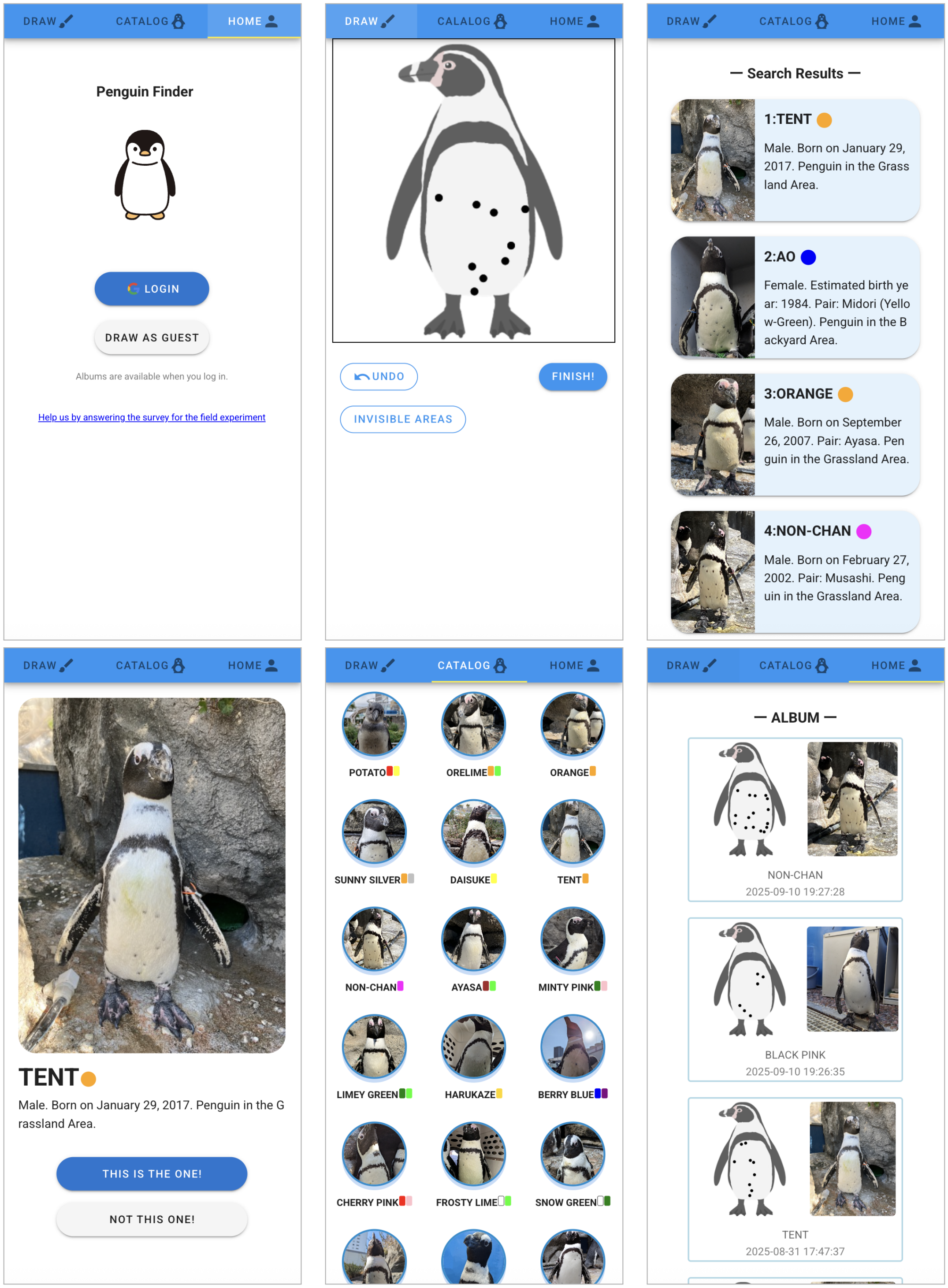


**Figure 9: Main screens of the system: Home, Drawing, Search Results, Individual Detail, Catalog, and Album. For clarity, the actual system employs simple Japanese hiragana notation to ensure accessibility for young children. In the figures presented in this paper, however, the labels have been translated into English both to make them understandable to international readers and to align with the requirements of submission to an international conference.**

**Table 3: Number of user groups by usage type and day (groups).**

| Usage type | Oct 15 (Tue) | Oct 16 (Wed) | Oct 17 (Thu) | Oct 18 (Fri) | Oct 20 (Sun) | Oct 21 (Mon) | Total |
|---|---|---|---|---|---|---|---|
| Single visitor | 5 | 4 | 5 | 2 | 9 | 8 | 33 |
| Multiple visitors, one device | 11 | 3 | 6 | 8 | 11 | 40 | 79 |
| Multiple visitors, multiple devices | 2 | 10 | 6 | 7 | 23 | 7 | 55 |
| Total | 18 | 17 | 17 | 17 | 43 | 55 | 167 |

**Figure 10: Examples of posters (left: Grassland area, right: Sky area)**

**Figure 11: Scene from the field experiment**

## 5.3 Analysis of Conversations and Observations

The conversations recorded during observation were broadly categorized into three types: (1) conversations mentioning penguin names, (2) utterances promoting individual-focused observation or communication, and (3) positive comments about the system and the experience. After using the retrieval function, many visitors made name-related remarks such as "Oh, that's Potato, so cute" or "It was Oimo! Born in 2023!?" During the drawing process, comments such as "This one has many spots," "I didn't know their patterns were different," and "It's interesting that they all have spots" were frequently observed, indicating that sketching encouraged visitors to notice and verbalize individual differences. Remarks such as "Isn't this the one?" or "I found the partner penguin too!" reflected attempts to identify individuals and recognize inter-individual relationships through observation and retrieval. Positive reactions toward the system were also documented, including comments such as "I'm happy because I could finally know their names."

As shown in Table 4, a total of 101 utterances were recorded, originating from 54 visitor groups comprising 148 individuals. By usage type, the largest number occurred when multiple people shared a single device (55 utterances), followed by multiple people using multiple devices (40 utterances), and individual use (6 utterances). The "multiple people-one device" condition yielded the highest number of name-related utterances (24) and observation- or communication-promoting utterances (24), suggesting that the system stimulated active conversations centered on penguin individuals. In the "multiple people-multiple devices" condition, visitors often compared drawings and verified names across devices (40 utterances), which supported collaborative observation and interaction. In contrast, individual use generated only six utterances in total, with no instances of name-related conversations.

Family groups were especially active in collaborative use. Parents were observed reading signage aloud to their children while encouraging them to draw, or lending a smartphone to their children to sketch while assisting with operations and checking results together. Siblings were also seen taking turns with the device, reinforcing cooperative engagement.

The system also appeared to extend dwell times at the exhibits. Utterances such as "Time flies while watching this" and repeated observations that children became deeply absorbed in drawing, sometimes to the extent that parents needed to prompt them to move on, indicated sustained engagement. Because dwell time was not measured quantitatively, these interpretations are based on qualitative impressions from field observations rather than precise time metrics. At the same time, some visitors reported difficulties such as "I can't see the pattern" or "It moved away," highlighting the influence of observation conditions. In addition, several visitors opted to use the catalog function directly to identify individuals without drawing or retrieval, suggesting that the system supported multiple modes of interaction depending on user preferences and situational constraints. Because the system stored no server-side logs of screen transitions, these observations rely solely on field notes and may not capture all cases of catalog-only use.

Furthermore, analysis of drawing data collected from the system revealed diverse patterns of use (Fig. 12). While many drawings followed the intended use of sketching abdominal spot patterns for retrieval, some visitors used the interface creatively by writing comments in blank areas to record impressions, observations, or

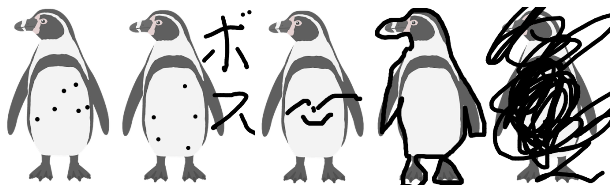


**Figure 12: Examples of drawings created during the field study: the leftmost shows a sketch of abdominal spots, the second from the left includes a comment written in the blank area, and the right three illustrate playful doodles by children.**

reflections. In contrast, especially among children, there were cases of unintended use such as doodling freely without observing the penguins. In addition, some visitors took screenshots of retrieval results or returned to the same penguin after visiting other exhibits to search for it again, indicating continued interest in specific individuals beyond a single interaction. These examples illustrate that the system affords a wide range of interactions, suggesting both opportunities for creative engagement and challenges when use diverges from the intended purpose.

## 5.4 Questionnaire Results

To better understand visitors' impressions after using the system, we placed a link to an optional open-ended questionnaire on the home screen. The questionnaire included the following items:

- Purpose of visiting Sunshine Aquarium (multiple choice)
- Visiting companions (multiple choice)
- Number of visits to Sunshine Aquarium (multiple choice)
- Degree of liking penguins (5-point Likert scale)
- Penguins remembered or favored through system use (open-ended)
- Frequency of zoo/aquarium visits (multiple choice)
- Total number of zoo/aquarium visits (multiple choice)
- Impressions or comments about the system (open-ended)

A total of 11 responses were collected. The most common purpose of visiting was "for my children," followed by "leisure," "education," and "relaxation." Regarding companions, "visiting alone" was most frequent (5/11), followed by "with family" (4/11), and "with partner" and "with friends" (each 1/11).

For the number of visits to Sunshine Aquarium, "10 times or more" accounted for 7/11, followed by "5–9 times" (2/11). "First visit" and "second visit" each accounted for 1/11, indicating that many respondents were repeat visitors. In terms of affinity toward penguins, seven participants selected "5 (like very much)," three selected "4," and one selected "3," suggesting an overall high level of interest in penguins.

For the open-ended item on "remembered or favored penguins," nine participants provided answers, frequently mentioning specific individual names such as "Potato" and "Musashi." This indicates that the system effectively supported individual recognition and facilitated the emergence of "favorite penguins."

Regarding the frequency of zoo and aquarium visits, "several times per month" was most common (6/11), followed by "once a month" (2/11) and "once every few months" (3/11). For lifetime visits, "20 times or more" was most frequent (7/11), followed by "10–20 times" (4/11). These results suggest that most respondents were highly engaged visitors with strong interest in zoos and aquariums.

The open-ended comments were predominantly positive. Examples included: "It was really great. I would be happy if this tool continues to be available as a way to enjoy the aquarium," "It was fun to observe while drawing and also to know the names. I am looking forward to the full deployment," and "I was surprised by the high accuracy. As a penguin fan, it was a very enjoyable experience." On the other hand, some respondents pointed out issues such as "I feel the accuracy is not very high (it sometimes did not match)," highlighting the need for further improvement in retrieval accuracy.

Because many respondents were already highly engaged visitors, their impressions likely reflect the perspectives of those who are intrinsically motivated to pay close attention to individual penguins. This sampling bias may have contributed to the generally positive evaluations, frequent mentions of specific penguin names, and the strong interest expressed in the open-ended responses. In contrast, casual or first-time visitors may show different patterns of use, levels of engagement, or willingness to draw. Therefore, the questionnaire results should be interpreted as reflecting a highly motivated subset of visitors rather than the broader aquarium audience.

# 6 Discussion

## 6.1 Individual Identification and Engagement

At Sunshine Aquarium, although each penguin has an individual name, visitors previously lacked a direct means to access this information during their visit. This often made it difficult for them to associate the penguins they observed with specific names or characteristics. By introducing our system, visitors were able to connect the individual they were observing with its corresponding profile through the combined process of drawing abdominal spot patterns and retrieving the matching name.

The drawing activity played a central role in shaping this engagement. As described in Section 5.3, visitors frequently verbalized fine-grained differences in abdominal spot patterns while sketching, indicating heightened attention to individual features. The retrieval results then provided immediate feedback, which supported name-based conversations and recognition of inter-individual relationships (e.g., identifying pairs or comparing similar patterns). These patterns suggest that integrating sketching with retrieval can shift observation from a broad, flock-level view toward more individualized and reflective engagement.

In addition, several spontaneous behaviors reported in Section 5.3 such as preserving results for later reference or revisiting the same individuals after observing other exhibits suggest that the system enabled emerging forms of personal attachment. Rather than a single interaction, some visitors began building short-term continuity in their observation by returning to their penguin or saving information to revisit later. Such behaviors point to the potential

**Table 4: Number of utterances by usage type and category (groups).**

| Usage type | Utterance category | Oct 15 (Tue) | Oct 16 (Wed) | Oct 17 (Thu) | Oct 18 (Fri) | Oct 20 (Sun) | Oct 21 (Mon) | Total |
|---|---|---|---|---|---|---|---|---|
| Single visitor | Mention of penguin names | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Observation / communication prompts | 1 | 0 | 0 | 0 | 3 | 0 | 4 |
| | Positive comments | 0 | 0 | 0 | 1 | 0 | 1 | 2 |
| Multiple visitors, one device | Mention of penguin names | 3 | 1 | 1 | 3 | 2 | 14 | 24 |
| | Observation / communication prompts | 2 | 1 | 4 | 3 | 2 | 12 | 24 |
| | Positive comments | 0 | 0 | 2 | 0 | 1 | 4 | 7 |
| Multiple visitors, multiple devices | Mention of penguin names | 0 | 5 | 0 | 2 | 7 | 1 | 15 |
| | Observation / communication prompts | 1 | 3 | 1 | 2 | 12 | 1 | 20 |
| | Positive comments | 0 | 2 | 1 | 1 | 1 | 0 | 5 |
| **Total** | – | 7 | 12 | 9 | 12 | 28 | 33 | 101 |

of the system to support the early stages of forming individualized connections with animals.

Taken together, these findings indicate that a sketch-based identification system can encourage closer attention to individual animals, facilitate immediate conversational engagement, and provide opportunities for visitors to construct more personal and meaningful relationships with the animals they encounter.

## 6.2 Collaborative and Family-centered Use

The field study showed that the system naturally invited collaborative forms of engagement, particularly when visitors shared a device or interacted in groups. Rather than using the system in isolation, many groups engaged in joint drawing, mutual explanation, and shared interpretation of the retrieval results. These behaviors indicate that the sketching and searching process provided a focal point around which companions could coordinate attention and conversation.

Family groups were especially notable in this regard. Caregivers often supported children by reading signage, clarifying band colors or spot differences, or assisting with operations, creating opportunities for guided learning. Such scaffolding suggests that the system can function as a conversational and educational resource within family interactions, helping younger visitors participate in focused observation that they might not undertake alone.

Even in cases where each person used their own smartphone, interactions frequently took the form of comparing drawings or discussing differences in identification results. This pattern implies that the iterative cycle of sketching and receiving feedback encouraged visitors to articulate their reasoning and negotiate interpretations together. Through this process, the system supported joint attention, peer learning, and the co-construction of understanding about individual penguins.

Overall, these collaborative dynamics demonstrate that sketch-based identification can extend beyond individual engagement to become a shared activity that strengthens social interaction and supports collective meaning-making during the visit.

## 6.3 Impact on Visitor Experience and Learning

Visitors who used the system appeared to spend longer periods in front of the penguin exhibits. During the field deployment, several utterances such as "Time flies while watching this" were documented, and children were frequently observed becoming deeply immersed in drawing. Although dwell time was not measured quantitatively, these qualitative observations suggest that the sketch-based interaction helped sustain visitors' attention at the exhibit. Since dwell time is widely regarded as an indicator of interest in zoo and aquarium contexts [7, 9, 46, 62, 63, 77], such impressions point to the potential of the system to promote deeper engagement. Because these observations are based solely on qualitative impressions rather than precise measurements, they should be interpreted with caution.

Survey results indicated that many respondents were highly interested and frequent visitors to the aquarium. Numerous positive comments were collected, suggesting that the system reinforced existing interest and supported learning-related engagement and intentions to revisit.

Access to individual profiles also encouraged visitors to relate the observed animals to themselves, as seen in comments such as noticing that a penguin's birthday was close to their own, which fostered personal familiarity and emotional connection. In line with previous research showing that zoo and aquarium visitors are often interested in information such as lifespans or unusual facts [22], these findings suggest that opportunities to engage with animals at the individual level can enhance visitors' interest and empathy, and may further support the cultivation of conservation awareness over time.

Taken together, these points suggest that sketch-based identification systems may support both cognitive and affective aspects of visitor experience by shifting passive looking toward more deliberate and personally meaningful observation.

## 6.4 System Usability

The field deployment highlighted several aspects of the system's usability that shaped how visitors engaged with individual identification. First, the sketch-based interface proved intuitive for many users, and the immediate feedback offered by the retrieval results appeared to support a smooth interaction flow. At the same time, the effectiveness of the system was strongly influenced by the physical observation environment. Factors such as penguin movement, occlusion, and dim lighting could limit the visibility of abdominal spots, which in turn constrained the reliability of the drawing-based interaction. These variations in observation conditions also help explain why some visitors perceived the system as highly accurate while others experienced inconsistent results. Because both the amount of visible information and the precision of sketches differed across situations and users, impressions of accuracy naturally varied. Although the system was designed to allow visitors to mark "invisible areas" and exclude them from the similarity calculation, these environmental constraints still posed a bottleneck for reliable identification. These environmental dependencies suggest that systems intended for in-situ wildlife observation must be designed with robustness to fluctuating visibility conditions.

The availability of multiple pathways for accessing penguin information also played an important role. The catalog function provided an alternative means of interaction for users who found drawing difficult or preferred a more direct approach. This coexistence of drawing-based and list-based exploration indicates that flexible access routes are essential for accommodating diverse visitor preferences and situational constraints. Moreover, some participants expanded their use of the system by taking screenshots of search results or writing their own observational comments in the blank space of the drawing screen. These behaviors highlight not only the flexibility of the system's usability but also the opportunities it provides for visitors to engage more actively in deep observation.

## 6.5 Implications

**For zoo and aquarium education:** The proposed approach complements band-based identification by offering a more accessible way to connect penguins with their names. Drawing-based retrieval overcomes limitations of band visibility (e.g., dim lighting, similar colors) and directly links observation to individual information. From an educational perspective, the drawing task encourages focused attention and active observation, while the retrieval results trigger immediate reflection and conversation, thereby supporting both knowledge retention and motivation. Moreover, the catalog and album functions allow visitors to revisit individual information after their trip, potentially encouraging repeat visits and sustaining long-term engagement. By including not only penguins in the main exhibition areas but also those in backstage enclosures, the catalog further extends visitor interest and attachment beyond the directly observable animals.

**For general visitors:** Our findings show that drawing-based identification makes penguin observation more personal and engaging. By calling penguins by name and discussing them with companions, visitors can transform a passive experience into an active one, which enhances memory formation, strengthens attachment, and increases motivation to revisit.

**For keepers and exhibition staff:** The system encourages visitors to pay attention to individual penguins, which helps highlight unique characteristics and personal stories. This not only increases the value of individual introductions but also contributes to educational outcomes and the creation of more meaningful visitor-animal interactions.

**For the HCI/CSCW/CHI research community:** This work provides a field case of a novel interaction design that integrates observation, drawing, and retrieval. It expands knowledge of how interactive systems can be designed to enhance engagement with animals in real-world environments, bridging human-animal interaction with traditional HCI concerns.

Although our study was conducted with penguins in a Japanese aquarium, the underlying principles are not limited to this context. The sketch-based identification approach can be extended to other species that are exhibited in groups—such as dolphins, pandas, or birds—by enabling visitors to link observable features (e.g., markings, scars, plumage variations) with individual profiles. More broadly, the method suggests how interactive systems can support individual-level recognition in cultural and educational settings worldwide. For example, in museums or botanical gardens, visitors could sketch shapes, colors, or textures to connect artifacts or plants with digital records, turning abstract information into personal encounters. These directions highlight how drawing-based retrieval can serve as a general design strategy to transform passive observation into active, individualized engagement across domains.

## 6.6 Limitations

Although the field study involved a wide range of visitors, many of those who responded to the post-experience questionnaire were frequent visitors with a strong pre-existing interest in penguins and in zoos and aquariums more broadly. This background suggests that the questionnaire results may primarily reflect the perspectives of highly motivated visitor segments. Therefore, caution is needed when generalizing these impressions to casual visitors or first-time audiences. We thus distinguish between the questionnaire data, which captured the perspectives of an enthusiastic subgroup, and the behavioral observations, which provide a more representative account of general visitor interactions. Casual visitors may not demonstrate the same depth of engagement or willingness to draw, and their experiences may differ accordingly.

In addition, two methodological considerations should be noted. First, because access to the system required visitors to voluntarily scan a QR code, the sample likely overrepresents those who were already motivated or curious enough to engage. To more accurately assess the degree of self-selection bias, future studies should compare system users with the total number of visitors who viewed the signage but chose not to participate, or conduct a brief survey of non-users to understand their reasons for not engaging. Such measures would help clarify how representative the observed behaviors are of the broader visitor population.

Second, although experimenters maintained distance and did not initiate interactions, their visible presence near the exhibits may have influenced visitor behavior. Experimenters wore neck badges labeled "under study," making their role clearly visible to visitors. This visibility may have increased visitors' awareness of being observed and shaped how confidently or attentively they used the system. Several visitors approached the researchers to ask about the study, further suggesting that the identifiable presence of experimenters could have influenced certain behaviors.

Furthermore, the present study focused primarily on short-term outcomes such as dwell time and immediate conversations, and did not examine long-term impacts on memory retention, revisit intentions, or attitudinal change. Moreover, although the refined algorithm addressed partial observations, practical factors such as dim lighting and occlusion by rocks or other penguins still affected the stability of recognition. Future studies should evaluate the system with more diverse participant groups, including those with little prior interest in penguins or limited zoo and aquarium experience, and under a wider range of exhibition environments.

Finally, the current system did not support iterative refinement of drawings. Even after viewing the retrieval results, when previously unseen portions of the penguin later became visible, users could not update or supplement their existing sketches without restarting the drawing process. As a result, some sketches remained incomplete or inconsistent. Designing mechanisms that allow users to iteratively refine their sketches based on changing visibility conditions represents an important direction for future development.

### 6.7 Future Work

In future work, we plan to refine the similarity calculation algorithm and reconsider the method for generating template data in order to improve retrieval accuracy. On the system side, we will develop multilingual support to accommodate international visitors and enhance the user interface for broader accessibility. In addition, by recording and analyzing logs of key operations such as drawing, retrieval, and browsing, we plan to conduct more detailed analyses of user behavior.

We also plan to explore optional photo-and video-assisted drawing features. Because penguins often move continuously, certain markings only become visible momentarily. Allowing users to capture a short video clip or still image and refer to it while sketching may support more accurate or complete drawings, especially when visibility fluctuates during observation.

Future studies will address the limitations of the current participant sample by recruiting more diverse visitors across different levels of prior interest, age groups, and cultural backgrounds. We further plan to conduct longitudinal and follow-up studies to evaluate long-term outcomes, including knowledge retention, revisit motivation, and conservation awareness. In particular, we plan to analyze revisit logs to examine whether visitors return to observe the same individuals across multiple visits. By collaborating with multiple aquariums and zoos, we will also investigate whether users who experience the system in one facility are able to transfer their knowledge and engagement when visiting other facilities.

Beyond penguins, we plan to extend the drawing-based method to other animal species with distinctive body patterns, such as spotted seals, giant pandas, and zebras, to explore its broader applicability across taxa. Moreover, while the present dataset of abdominal spot patterns was manually constructed, we plan to develop methods that automatically generate and update identification templates from images and videos. By leveraging data accumulated through real-world use, we plan to iteratively improve both the dataset and the retrieval algorithm, enabling the system to become more accurate and adaptive over time.

Finally, we plan to deploy the system as a permanent installation in collaboration with multiple aquariums. Such long-term deployments will allow us to investigate sustained engagement, knowledge retention, and conservation awareness in naturalistic settings. The outcomes of these longitudinal studies are beyond the scope of this paper, but represent an important direction for future research.

## 7 Conclusion

In this study, we investigated how drawing-based individual identification can enrich visitor experiences in zoos and aquariums. We first conducted a survey of 25 facilities that keep and exhibit penguins, which revealed the limitations of current flipper-band practices and the lack of effective mechanisms for supporting individual-level recognition. Based on these insights, we refined the retrieval algorithm proposed in our previous work [50] to handle partial observations of abdominal spot patterns and implemented a practical system for use in aquariums.

We then conducted a field study with 167 visitor groups at Sunshine Aquarium. The results showed that the system enabled visitors to identify specific penguins, call them by name, and engage in active conversations about spot patterns and relationships. Visitors also spent longer at the exhibit, took screenshots, annotated drawings, and returned to the same penguin, demonstrating the potential of the system to promote familiarity, attachment, and deeper engagement.

Addressing our research questions, **RQ1** reveals that while most facilities rely on flipper bands, they rarely provide accessible individual-level information, leaving visitors passive and disconnected from specific animals. **RQ2** shows that the sketch-based system promoted name-based identification, stimulated social interaction, and extended dwell times, thereby fostering stronger connections with individual penguins.

The contributions of this work are fourfold: (1) an empirical survey of penguin exhibition and identification practices across 25 facilities; (2) a refined retrieval method that accommodates partial observations; (3) a practical implementation suitable for zoos and aquariums; and (4) an in-situ validation showing the system's usefulness and challenges with real visitors.

Future work will further improve recognition accuracy, analyze detailed interaction logs, and conduct long-term and cross-facility deployments to examine sustained use. We also plan to extend the approach to other animal species and explore its integration with educational and welfare initiatives. These directions will advance the role of drawing-based support systems in enhancing visitor experiences while promoting empathy and conservation awareness.

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