PURRtentio: Implementing a Smart Litter Box for Feline Urinalysis with Electrochemical Biosensors

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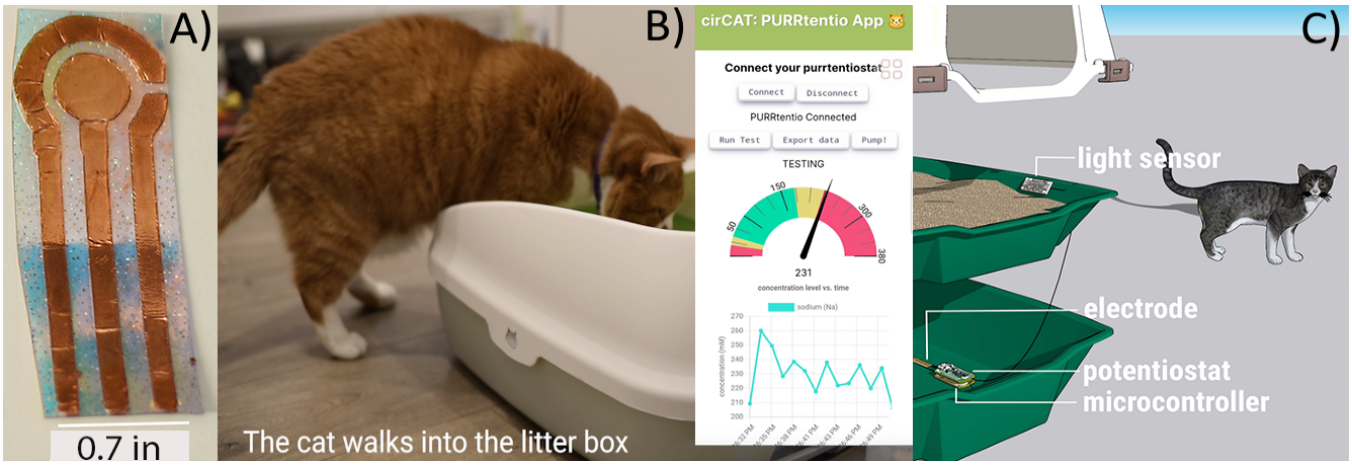

Figure 1: PURRtentio a) DIY electrochemical biosensor b) Litter Box System and mobile application readouts. c) Components.

ABSTRACT

Traditional collection and analysis of feline urine samples for health monitoring are invasive, expensive, and infrequent. This paper introduces PURRtentio, a novel litter box system utilizing an electrochemical biosensor to monitor analytes in feline urine. The system comprises a DIY biosensor, potentiostat, microcontroller, distance sensor, and mobile application. Performance validation compared PURRtentio with an industry-grade potentiostat. PURRtentio presents an innovative and non-invasive approach for consistent monitoring of chemistry elements in feline urine, enabling early detection and management of cat's health conditions. This technology has the potential to revolutionize feline health monitoring, providing a solution for veterinarians and pet owners.

CCS CONCEPTS

• **Human-centered computing** → **Interactive systems and tools**; **Interaction devices**; • **Applied computing** → **Life and medical sciences**.

UIST '23 Adjunct, October 29-November 01, 2023, San Francisco, CA, USA

ACM ISBN 979-8-4007-0096-5/23/10.
https://doi.org/10.1145/3586182.3615820

KEYWORDS

biosensor, electrochemistry, potentiostat, urinalysis

ACM Reference Format:
Shuyi Sun, Gabriela Vega, Erkin Şeker, Krystle Reagan, and Katia Vega. 2023. PURRtentio: Implementing a Smart Litter Box for Feline Urinalysis with Electrochemical Biosensors. In *The 36th Annual ACM Symposium on User Interface Software and Technology (UIST '23 Adjunct), October 29-November 01, 2023, San Francisco, CA, USA.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3586182.3615820

1 INTRODUCTION AND RELATED WORKS

Electrochemical biosensors are devices that detect and measure specific analytes, such as glucose, sodium, pH, and metal ions, by utilizing electrochemical reactions at electrodes. Typically, they consist of a working electrode, a counter electrode, and a reference electrode, with a potentiostat controlling the electrical potential and current between them. These biosensors have shown promise in health monitoring applications, from diabetes management to drug efficacy assessment [2, 25, 26].

Feline urine analysis is crucial for assessing the health status of cats, providing insights into hydration levels, kidney function, and metabolic disorders [3, 5, 18]. Sodium, potassium, glucose, and pH are common analytes in cat urine and serve as indicators of underlying health conditions [4, 10, 22, 23]. As a proof of concept, we focus on sodium levels due to they can a) vary significantly by dietary intake, making it easy to detect fluctuations even in

healthy cats [4], b) be an indicative marker of feline health [14, 16], and c) be more useful as a marker when assessed in combination with other anayltes, which follows our project goal of multiple analytes analysis in the future. Previous research explored colorimetric biosensors and visual chemical indicators in cat litter for detection purposes [5, 10, 23]. However, colorimetric sensors have limitations in lifespan and reversibility compared to electrochemical biosensors, making them impractical for continuous use [1, 13, 15].

This project introduces PURRtentio, a litter box system that integrates electrochemical biosensors for unobtrusive and continuous monitoring of feline health. We developed a cost-effective solution using DIY electrodes and a low-cost potentiostat to promote hardware and software replicability. Our focus is on detecting sodium levels in cat urine as an initial step towards comprehensive health monitoring. By enabling continuous monitoring of feline's health, PURRtentio facilitates early detection of health issues and personalized care without costly and time-consuming lab tests [17, 18].

2 IMPLEMENTATION

We modified a two-layer litter box to house the hardware. The bottom layer includes the potentiostat system (Adafruit Feather M4 Express board, Adafruit Bluefruit LE SPI Friend module, and 1000uA Rodeostat Featherwing V0.3 R1) and a pee pad for fluid absorption. The biosensor receives fluids through a sift surface topped with non-absorbent cat litter. A second funnel layer ensures all liquids are directed to an opening to the biosensor. The upper layer incorporates VL53L0X Distance sensor (ToF) that triggers the system upon detecting the cat's presence and departure. See Figure 1b. The system operates with Open Circuit Potential (OCP). OCP refers to the voltage present when a circuit's terminals are disconnected. The form factor is designed to facilitate urine flow, allowing sufficient biosensor stabilization time before testing.

The electrochemical biosensor is made using antioxidant-free, oxidation-resistant copper tape with an insulating adhesive, ensuring resistance to oxidation and corrosion [7, 12]. This material choice provides a cost-effective alternative to traditional materials for biosensors [8, 9, 11, 20]. Fabrication involves cutting the copper tape with a home-crafter cutting machine to create electrodes with dimensions of 0.7 inches wide by 2 inches long (Fig. 1a), selected based on fluid flow areas, flexibility, and testing requirements. The working electrode undergoes treatment with a sodium activation solution, making it sodium ion-selective and preventing interference from other elements [19]. An insulating barrier solution is applied to the exposed areas of the electrodes, not on the biosensor section, ensuring precise measurements and prevent contamination.

The system operates asynchronously with optimized sampling rate to accommodate biosensor behavior and BLE communication with the application. Utilizing the p5ble.js library, the application establishes a connection with the device, enabling real-time data visualization through live graphs and concentration level gauges.

3 TECHNICAL EVALUATION

In choosing biosensor material, we compared our potentiostat in PURRtentio with the industry-grade potentiostat EmStat. Sodium test solutions were prepared using preferred electrochemical techniques [6, 21] at concentrations based on feline urine levels [4, 14, 24]: 43.48, 97.83, 156.52, 195.65, 234.8, and 391.3 mM. We prepared

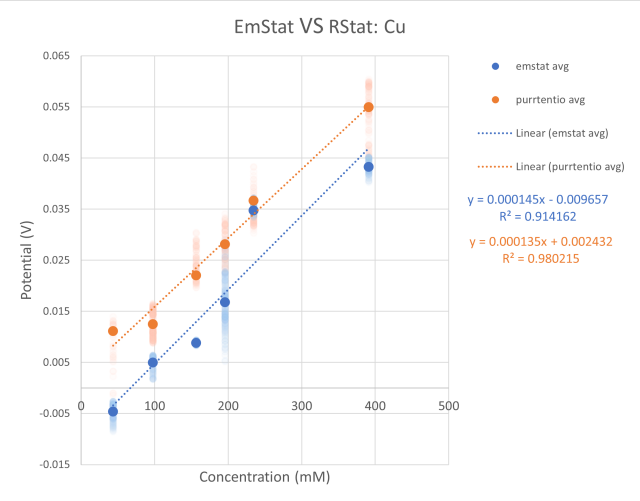

Figure 2: Comparision of EmStat and RodeoStat

them through dilution of a highly concentrated of sodium solution with known tested value in deionized water. Solutions were mixed by machine controlling speed, time, temperature, and amount [21].

We conducted a technical evaluation to validate the performance of the DIY biosensor and the PURRtentio system by comparing them against EmStat using OCP with prepared test solutions. Our system show similar trends for either system used. This is evident from the trendline analyses and the r-squared values (shown in Figure 2), with slope values similar to the ten thousandth place and r-squared values <0.1 apart, which indicate the strength of the correlation between the measured values and the expected values.

4 CONCLUSION AND FUTURE WORKS

Our study presents PURRtentio, an innovative method for continuous and non-invasive monitoring of feline health using electrochemical biosensors. By developing a DIY biosensor and low-cost potentiostat, we accurately measure sodium levels in feline urine. Our evaluation shows that PURRtentio performs comparably to an industry-grade potentiostat, providing reliable measurements for different sodium concentrations.

Future work includes developing a rinsing system to prolong biosensor lifespan, conducting tests with various analytes and feline urine, interviewing veterinarians, and performing user studies in real-world settings. Integrating PURRtentio with IoT devices like smart feeders and activity trackers enhances functionality for comprehensive feline health monitoring. Exploring other analytes such as glucose for feline diabetes and simultaneous detection of multiple analytes holds great potential.

PURRtentio revolutionizes feline health monitoring, improving veterinary care and cat well-being. With further advancements and IoT integration, this technology has broader applications in animal and human health monitoring and beyond.

ACKNOWLEDGMENTS

This material is based upon work partially supported by the National Science Foundation under Grant No 2146461.

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