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Fursight: A Fully Integrated Solution for Pet Monitoring via CPS and IoT

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Introductions

Personal Information

My name is Vítor Cavaleiro
I am from Porto, Portugal

Some Background

FEUP student in Informatics and Computation Engineering
Completing Master's thesis
Research Grant holder at Inesc Tec

Research Interests

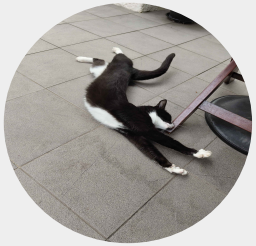
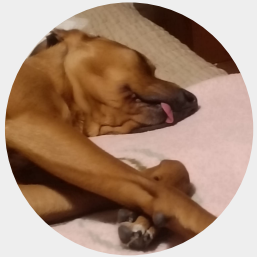
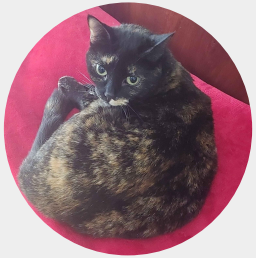
IoT and cyber-physical systems
Interoperable systems
Virtual Choreographies

Presentation Overview

- Context
- Goal
- Related Work
- Solution
- Architecture
- Evaluation, Proof of Concept, and Results
- Discussion, Limitations, and Future Work
- Conclusion

Context

Taking care of a pet is a significant responsibility, demanding attention to various factors impacting their health and well-being.





Context

Pet owners may…

- suffer from **busy** & **irregular** schedules, which **keeps them outside**
- be **unaware** of their **pet's (abnormal) activity**
- need to be **tracking** their **pet's health constantly**

…or even come home to find their pet has **run away** in the **middle of the day!**

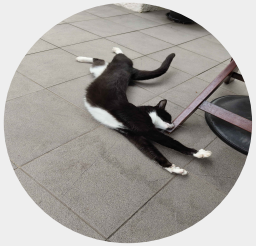
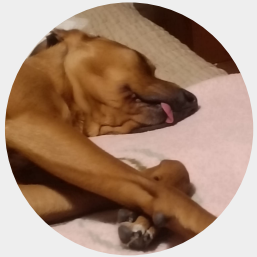
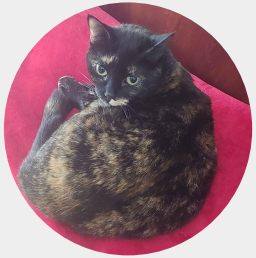
Context

CPS/IoT Systems...

- enable **real-time monitoring** and **data collection**
- integrate **seamlessly** into **smart home environments**
- enhance **automation**

Goal

Using CPS/IoT to provide multimodal pet monitoring data for better and more responsible pet care.





Related Work

Wearables: Continuous vitals and geolocation monitoring[1].

…Potential discomfort and obtrusiveness for pets[2].

Capturing Technologies: Remote pet supervision via cameras.

…High storage demands and security risks due to IoT device limitations[3].

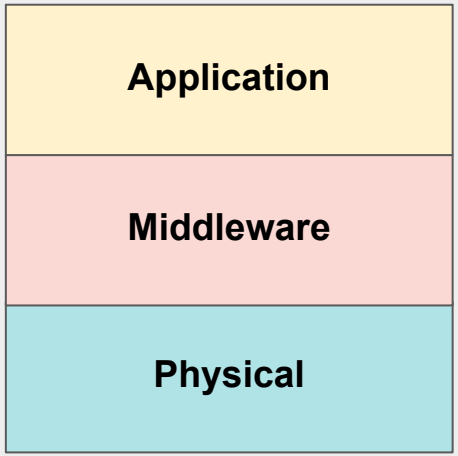
Software-based Solutions: Support pet monitoring and care as a complementary tool or standalone service.

…Reliance on mobile apps and the forced addition of social features can cause technological anxiety[4].

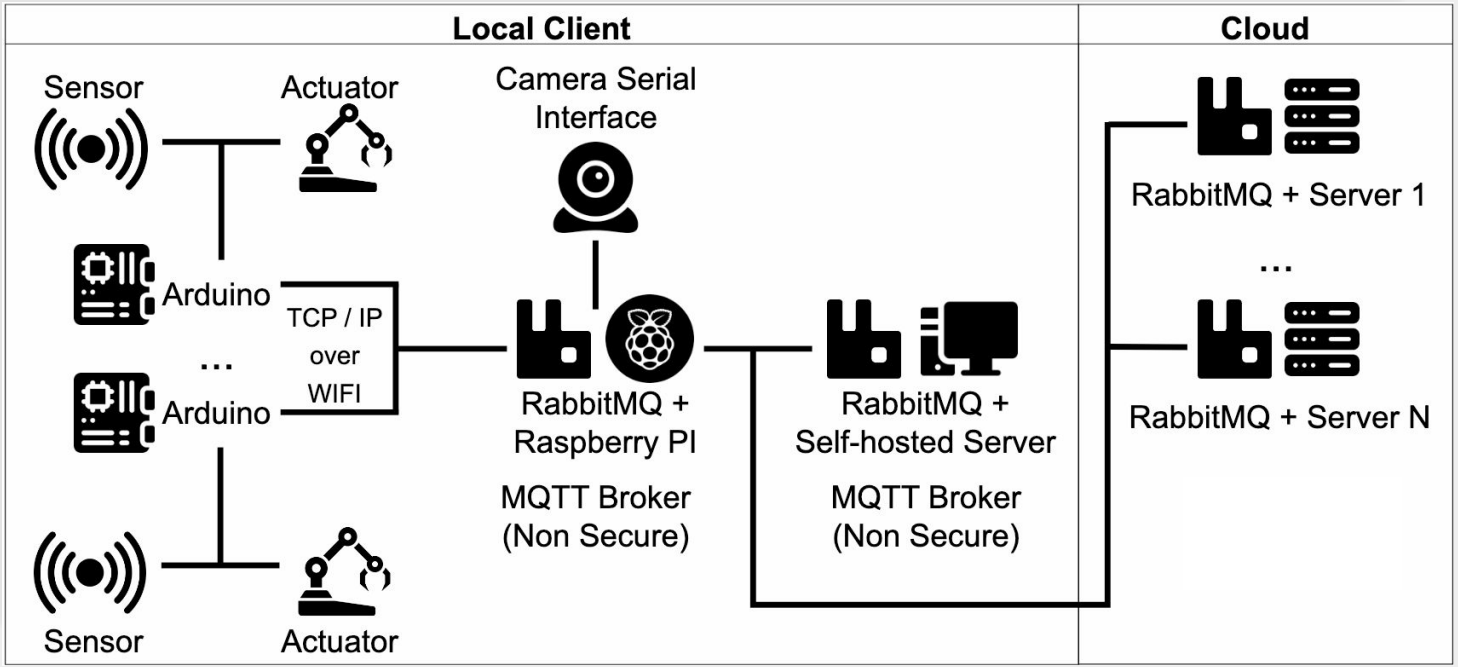
Solution

Fursight provides...

- **Integrated**, **Private**, and **Customizable** Pet Monitoring
- **Modular Design** for Flexibility
- **Scalable** & **Reliable** Architecture



Architecture



Architecture

Physical Layer

Local Setup consisting of ***Submodules***

Centralized Processing and Communication through a Raspberry Pi

Data Collection and Physical Interaction through Sensors and Actuators

Middleware Layer

Local Centralized Hub for complex client setups

Communication through RabbitMQ

Data Processing through Node-Red pipeline and Python scripting

Possible Cloud or Local implementations

Application Layer

Supabase as **Backend-as-a-Service** for secure data storage, authentication, edge functions…

REST API endpoints for CRUD and authentication

Next.JS & Typescript Frontend for fetching and displaying data to the end user

Architecture - Physical Layer

Local Setup
consisting of ***Submodules***

Centralized Processing and Communication between submodules through a Raspberry Pi

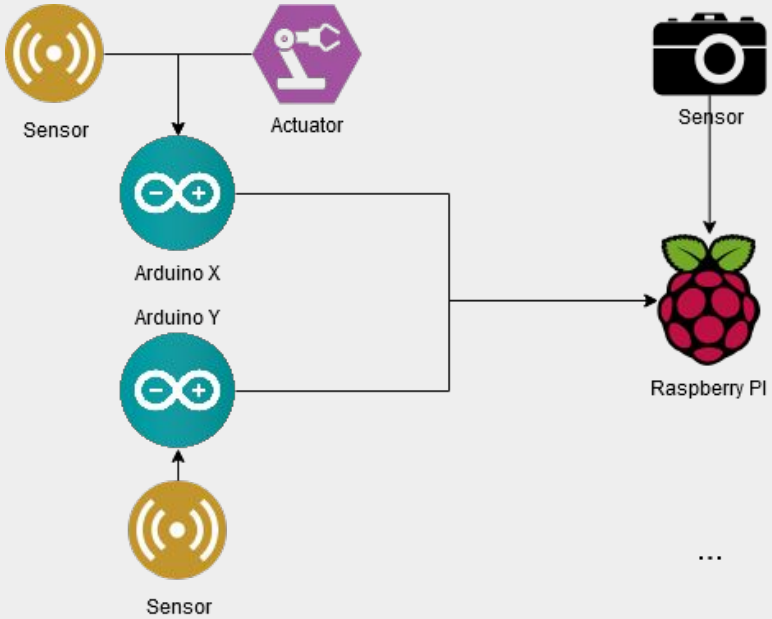
Data Collection and Physical Interaction through Sensors and Actuators

- **Submodules:**
  - Sensors/Actuators connected to Arduinos
  - SPI and UART Protocols
- **The hub:**
  - **Local network hotspot** using DHCP
  - Can hold secure **TCP/IP** connections to servers
  - Communicates through RabbitMQ's **message topics**
- **Advanced sensors** (e.g. camera) are **connected to the central hub** and are not inside a submodule

With the right devices, **new features can be added with ease** by just inserting a new submodule or adding a sensor to an already existing one, making it adaptable to any home environment.

Track litter box activity through a moisture sensor, monitor sound to be alert for distress calls, surveil a room with a camera if need be…

Architecture - Physical



Architecture - Middleware Layer

Local Centralized Hub for complex client setups

- Handles the **full scope of the local installation** transmitted by the physical hubs
  - Multiple physical setups, like multiple rooms, transmit to here

Communication through RabbitMQ

- **Topic-based communication:**
  - ensures the partitioning of our data settled by the Physical Layer stays consistent
  - makes data routing trajectories transparent at all times

Data Processing through Node-Red pipeline and Python scripting

- **Node-RED** provides a **low-code, browser-based platform**, to easily **integrate and transform** data from various sources, including performing data transformations like moving averages.
- Configurations are made **simple and adaptable** through the use of **easily exchangeable** JSON files..
- **Python** is employed for its strong relevance in data science and its comprehensive support of related libraries.

Architecture - Middleware Layer

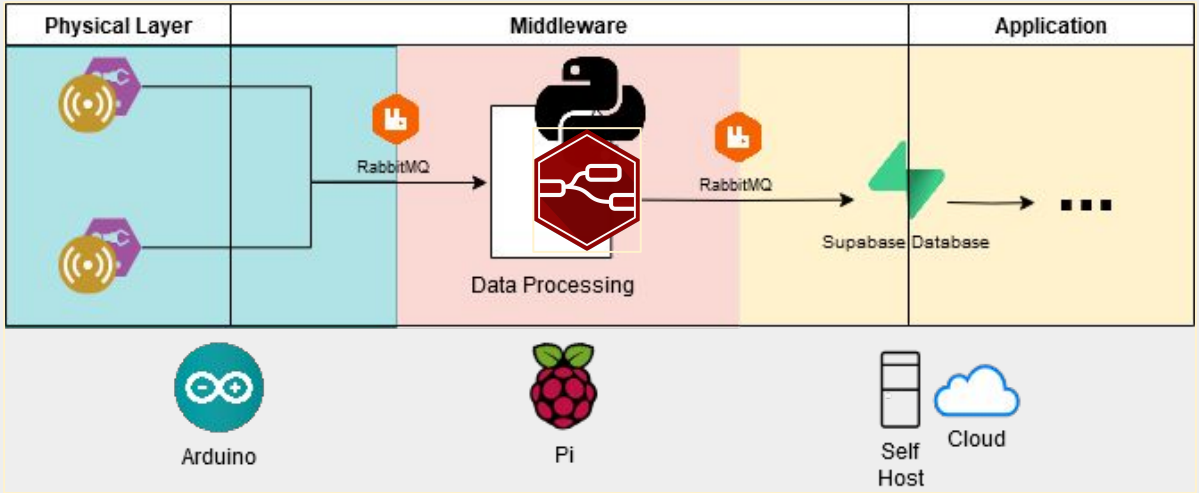
Local, self-hosted database implementations:

- More private alternative
- **Fast and lightweight**, although not very secure (not problematic since this is an isolated environment)

Cloud server implementations:

- Always available solution
- Data redundancy with replicas, load distribution with different servers
- Secure communication via transport protocols like Secure Sockets Layer (SSL) and Transport Layer Security (TCL)

Architecture - Middleware Layer



Architecture - Application Layer

Supabase as
Backend-as-a-Service
for data storage

- **Supabase handles the** storing of **all sensor data,** as well as important metadata like the **location of each service's deployment**, **hardware specifications** and **full local configurations** for each user
- A **relational and time-series database** is essential!

REST API endpoints for
CRUD and authentication
(from **Supabase**)

- **Several REST API endpoints** bridge frontend and backend by managing and transmitting storage access **securely**

Next.JS & Typescript Frontend
for fetching and displaying data to
the end user

- **Frontend application** delivers a consistent and clear understanding of the system through data visualization and insight
- **User authentication** (login and registering) is done through an **authentication portal**

Evaluation

- Used prototypes and scale models to simulate real-life conditions.
- Focused on cat monitoring, covering various aspects of cat care.
- Tested across multiple use cases to assess real-world applicability.
- Evaluate system behavior under different scenarios.

Proof of Concept

Pet Detection System

- Pressure sensor usage allows for a possible on-demand feeding module.

Litter Box Tracking

- Monitors litter box activity through a soil moisture sensor, utilizing a camera module to ensure more accurate tracking.

Pet Environment Monitor

- Provides real-time audio for pet monitoring.
- Tracks room temperature and humidity to ensure a comfortable environment, as well as carbon monoxide levels.

Results

Fursight:

- Displays environmental & sound activity with time-series graphs.
- Registers touch activity in the feeder and represent it in time-series graphs.
- Tracks soil moisture and litter box usage, displaying the data in time-series graphs, even with repeated use.
- Monitors presence in the litter box as an alternative to tracking soil humidity.

Discussion

- Modular design allows flexible deployment in various settings.
- Successful scale model tests suggest feasibility for full-scale implementation.
- Potential applications in pet hotels & veterinary clinics, even with complex setups.
- Non-invasive—no need for pet-worn devices.

Limitations

- Experimental limitations restricted real-world accuracy.
- Strict physical setup requirements were necessary for proper function.
- Prototype sensor issues, e.g., pressure sensor misfires on non-pet activity.
- It is not yet commercially viable despite demonstrating practical value.

Future Work

- Integration of more complex submodules.
- In a commercial context:
  - Develop a more straightforward setup process with a standalone integrated service.
  - Create a more robust, sellable physical package with key components and modular expansions for additional functionality.

Conclusion

Fursight came to be a **non-invasive way to track a pet's activity** using a CPS and IoT framework. This modular approach was able to **integrate several edge devices** into a monitoring system comprised of **physical, middleware and application** layers in **an adaptable manner**, edging the promise of **easy deployment on various home configurations**.

Despite the several limitations, the developed proof-of-concept sparked an understanding of how to better attain our initial idea through the development of a **simpler, integrated standalone service** and a **more robust physical package of key collection and actuating devices**.

Thank You!

Any Questions?

References

[1] S. Nithin Wilfred Reyu and J. Pearly Princess, “IoT based Pet Health Monitoring System for Sick Pets,” in 2024 3rd International Conference on Applied Artificial Intelligence and Computing (ICAAIC), Jun. 2024, pp. 1648–1652. DOI: 10 . 1109/ICAAIC60222.2024.10574965.
[2] Y. Shenoda, M. P. Ward, D. McKeegan, and A. Fawcett, “The cone of shame: welfare implications of Elizabethan collar use on dogs and cats as reported by their owners,” Animals, vol. 10, no. 2, p. 333, 2020.
[3] I. Rozlomii, A. Yarmilko, and S. Naumenko, “Data security of IoT devices with limited resources: challenges and potential solutions.,” in doors, 2024, pp. 85–96.
[4] J.-W. Kang and Y. Namkung, “The role of personalization on continuance intention in food service mobile apps: A privacy calculus perspective,” International Journal of Contemporary Hospitality Management, vol. 31, no. 2, pp. 734–752, 2019.