Designing, Implementing, and Testing AI-Oriented Smart Home Applications: Challenges and Best Practices

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Agenda

- Context and Motivation
- Research Questions (RQs)
- Methodology
- Results
- Final Remarks

Context and Motivation

- what is a smart home?

Context and Motivation

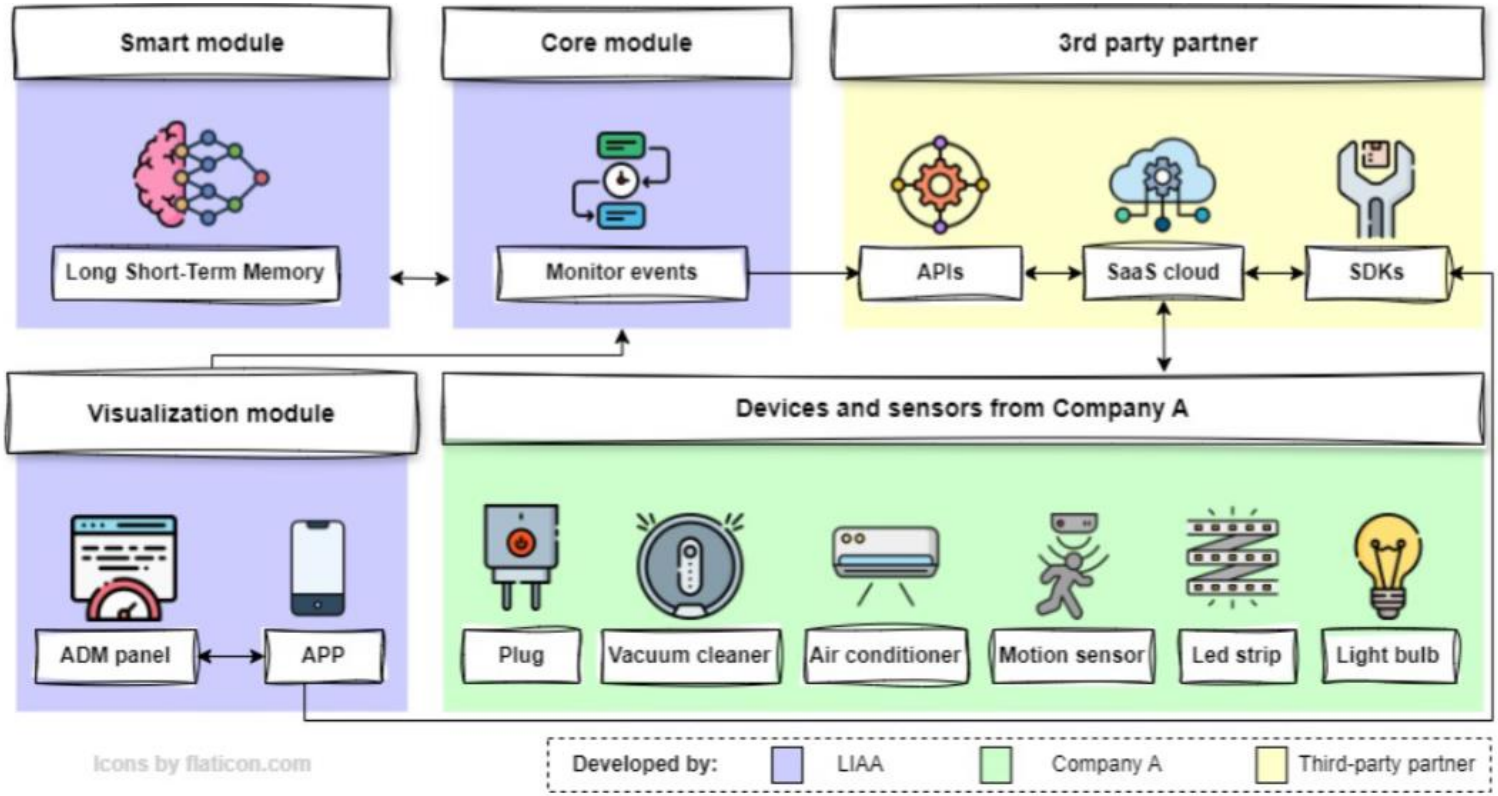
- **AI-Oriented Smart Home**
  - The decision-making process of **device actions** should **lean towards Artificial Intelligence (AI)** rather **than human intervention** to create a completely **autonomous smart home** (Sikder et. al 2019)[1].
  - An AI-oriented smart home dynamically **adapts to residents' behavior** patterns.
  - However, **smart homes** with such a **level of automation** are still **rare**.

1 Sikder, A.K., Babun, L., Aksu, H., Uluagac, A.S.: Aegis: ***A context-aware security framework for smart home systems*** . In: Proceedings of the 35th Annual Computer Security Applications Conference. ACSAC '19, Association for computing Machinery, New York, NY, USA (2019).

Context and Motivation

- A **collaboration** between a **Company A** and **practitioners** from the Applied Artificial Intelligence Laboratory (LIAA).
- Practitioners **implemented** an **AI-oriented smart home** that utilizes AI to suggest actions for devices based on inferred user living habits.

Smart Home Architecture



Problem statement

There is a need for **more evidence** in the literature on the **difficulties practitioners face** and the **best practices** they employ in **constructing smart homes** focused on **using AI** without human intervention.

Goal

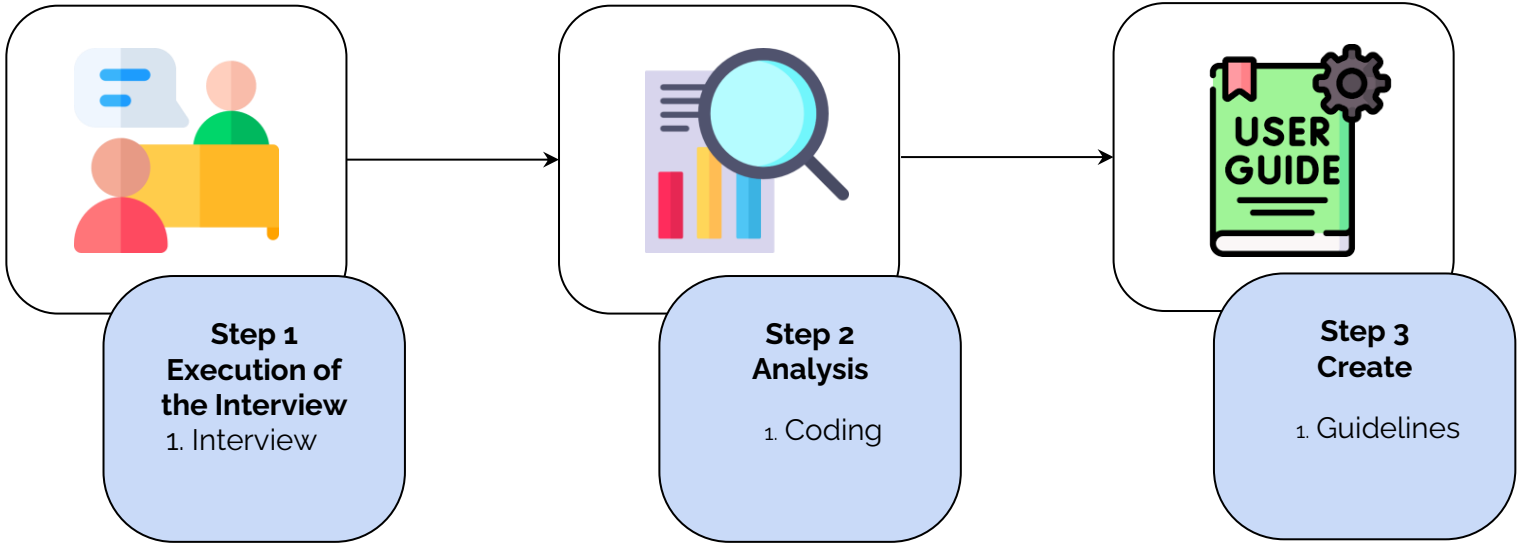
Our aims to identify the **challenges** practitioners face and the **practices** they **adopt** when **developing a smart home**.

Research Questions (RQs)

RQ1. What are the **challenges** practitioners face in developing a smart home solutions?

RQ2. What are the **best practices** adopted by practitioners for developing a smart home solution?

Methodology



Results - Challenges & Best Practices - CORE (CO)

- **Challenge CO1**
  - Distributed system saving memory and processor without adding **network delay.** The system was developed to work in a distributed way to isolate processes in different nodes.

- **Best Practice CO1.**
  - Practitioners use their experiences and search for **industry-academia experiences** over **real-time systems** to design the system.

Results - Challenges & Best Practices - CORE (CO)

- **Challenge CO2.**
  - The **algorithms' processing time might increase with the potential growth of devices being used in the smart home.** Practitioners develop machine learning models that are not always in memory, and **we also select algorithms based on time and precision.**

- **Best Practice CO2.**
  - **Implement bit counting.** The bit count **contributes to processing efficiency,** and the **data size count makes it possible to evaluate space allocation savings.** Practitioners observe data repetition and code variables in memory. Practitioners preprocess the dataset to reduce the amount of data in memory and load code in memory to process the data.

Results - Challenges & Best Practices - Smart Module (SM)

- **Challenge SM1.**
  - Data classification on the inputs and outputs of the connections between the Smart Module and the communications (COM) was a crucial point. Throughout the system, **data is typed, but in the Smart Module part, it is formatted in JavaScript Object Notation (json).** This entails certain specifications, **such as transforming numbers into strings and Booleans into strings.** This json behavior requires constantly checking the types of data received and sent.

- **Best Practice SM1.**
  - Save the typing used for transformation when returning the data..

Results - Challenges & Best Practices - Smart Module (SM)

- **Challenge SM2.**
  - Ensuring that the **interaction** and **communication** among **AI models** have a satisfactory **result is complex.**

- **Best Practice SM2.**
  - **Brainstorming meetings** to **analyze** the domain and **develop idea**s of what **could be implemented.** Then, **test the best ideas and choose the one which has the best result.**

Results - Challenges & Best Practices - Third-Party Partner (TPP)

- **Challenge TPP1.1**

1. One of the project's most **significant problems was that the third-party platform message queue service needed to be updated, and the changes often interrupted communication with the project's devices.**

- **Best Practice TPP1.1**
  - **Create an intermediate class** to **make** the necessary **adaptations to the communication library with the API** when **there is an update** and send it to the core after the update.

Results - Challenges & Best Practices - Third-Party Partner (TPP)

- **Challenge TPP2.1**
  - **Difficulty with the devices because we needed to have the devices directly from company A.**
    - **Each device** has its **specific functionalities**.

- **Best Practice TPP2.1**
  - **Buy** the **devices** from **company A**, and study each of the characteristics found in company A devices.

Results - Challenges & Best Practices - Visualization (APP)

- **Challenge APP1.1**
  - During the phases of defining the **technologies to be used,** there was a **communication gap** between practitioners, project managers, and company A regarding the choice of technologies to be adopted.

- **Best Practice APP1.1**
  - **Establish regular meetings** to **ensure** continuous **alignment** on the **use of technologies**.
  - The company A team proactively **shared comprehensive documents** about the technologies employed in mobile application development.
  - The **management team facilitated** seamless **communication** between **company A** and the **practitioners' teams**, addressing queries related to the project's technological aspects.

Results - Challenges & Best Practices - Visualization (APP)

- **Challenge APP2.1**
  - **Integration and implementation of the project.**
  - The communication between the **mobile application** and the **core module** was managed through a third-party API instead of conventional requests.

- **Best Practice APP2.1**
  - A **good practice was to conduct** a feasibility **study with virtual devices** and **datasets.**
  - Practitioners could have **simulated** the **requests** more similarly to the **third-party API** to ease the translation from study to the real-world application.

Results - Challenges & Best Practices - DevOps (DV)

- **Challenge DV1**
  - **Kubernetes documentation.**
  - The documentation **provided** needed to **be more precise** and **provide** a solution to the problems faced.
  - The practitioners encountered **limitations** with **online** and **cloud storage.**

- **Best Practice DV1**
  - **Practitioners explore** through **trial** and **error**, **looking** for **answers on QA platforms** such as **GitHub** and **online forums.**

Results - Challenges & Best Practices - DevOps (DV)

- **Challenge DV2**
  - The first contact of practitioners with **Kubernetes** and **docker may not be that difficult,** but **implementing a complete distributed system and integrating all modules with just a two-member group** and **limited expertise** can indeed be quite challenging.
- **Best Practice DV2**
  - Searching for **forums** and **real examples helped us to understand how Kubernetes and docker work in a real development environment.**

Conclusion

- **Final Remarks**
  - This study investigated the **challenges** and **practices** for developing smart homes.
  - The **practitioners' different backgrounds** allowed us to identify challenges and good practices for **different modules** of a smart home application.
  - The **challenges have provided insights** into **practices** that can **serve as lessons for future projects.**

- **Future work**
  - we will **explore partnerships** with third parties to **integrate innovative devices** and **additional functionalities** into the existing system.
  - In addition, we will **validate the good practices proposed** in this paper.

Thank you!

Any questions?

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