Faculty of organizational sciences
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A DISTRIBUTED IOT SYSTEM FOR MODELLING DYNAMICS IN SMART ENVIRONMENTS

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INTRODUCTION

Introduction

- Smart environments need to be able to dynamically and in real-time adjust their structure, parameters and control actions to the ever-changing external conditions and user requests

- These requirements are implemented both on the level of individual IoT devices, and on the system as a whole, using appropriate methods, tools and techniques.

- Complex smart systems are composed of numerous subsystems and individual devices, and require complex models and methods for managing the smart environments on different levels of hierarchy.

Introduction

- The main goal of this paper is to design an approach for modelling the dynamics of smart environments on different levels of hierarchy.

- The specific goal of the paper is to propose the application of such an approach for the case of noise pollution modelling and management in a smart city.

THEORETICAL BACKGROUND

Smart environment simulation and digital twins

- Application scenarios in various smart environments require high availability and low latency.

- This can be achieved by careful system design and intelligent placement of hardware and software elements across the IoT nodes, edge and cloud services.

- This ecosystem is extended with the concept of the digital twin - an integrated probabilistic simulation of a real system that uses the available models and data to mirror the life of a physical system.

Data assimilation from smart environments

- The state of many variables in the smart environment changes in time, so the communication with the digital twin must be continuous.

- The synchronization of variables should be done at small time intervals.

- The process of incorporating observation data into a simulation model with the goal of improving estimates of state variables is called data assimilation.

- The estimations are based on real-time measurements from the sensors in a smart environment.

Data assimilation from smart environments

- The simulation starts with dynamically estimated initial states, but new sensor data can be integrated into the simulation model at any time.

- Data assimilation relies on several elements:
  - sensors that collect data from smart environments in real-time
  - simulation model of the system dynamics
  - data assimilation algorithms for the state estimation
    - ✓ Kalman filtering and its variations
    - ✓ interpolation techniques
    - ✓ particle filters
    - ✓ machine learning algorithms.

Modelling dynamics of smart environments

- Approaches used for modelling dynamics of smart environments:
  - Analogue Resistor Inductance Capacitor (RLC) models
  - Machine learning algorithms (ensemble learning, subspace methods, etc.)
  - Semi-physical modelling
  - Mathematical modelling

- Limitations of existing approaches:
  - Focus on state estimation and not on the model structure
  - Mainly based on a unidirectional data flow – from the physical system to the simulation model.

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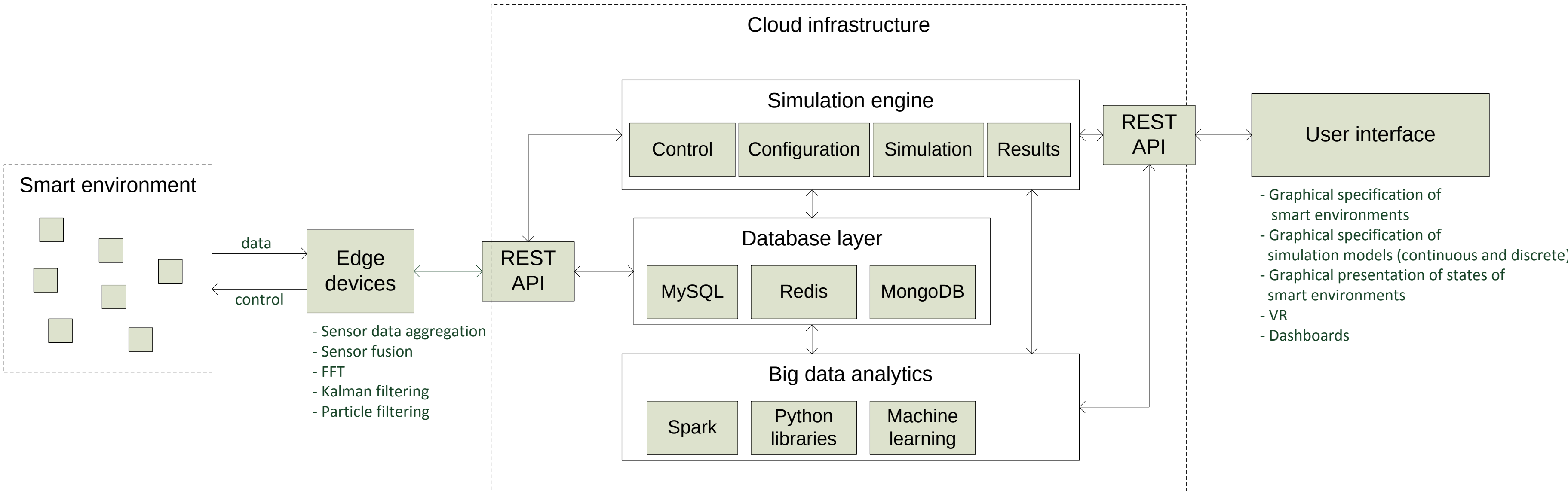
Research goal

- The main goal of this paper is to design an approach for modelling the dynamics of smart environments on different levels of hierarchy, in order to provide a fully symbiotic simulation system:
  - using real data from smart environments as inputs for simulation models, and
  - using simulation results for effective real-time management of smart environments.

- To achieve this goal, we have defined a uniform formal model applicable to any smart environment whose mathematical representation can be mapped to its implementation as one-to-one correspondence.
  - Infrastructure
  - Methodology and application scenarios

Infrastructure



Infrastructure
- smart environment -

- A smart environment consists of sensors, actuators, and devices interconnected into a system that can be adaptable to users' needs.

- The proposed model does not pose any restrictions regarding the smart environment design, as long as it can be integrated with the cloud infrastructure through a REST API.

- Typical tasks done on the edge devices include sensor data aggregation and fusion, Fast Fourier transformations, Kalman filtering, particle filtering, and others.

Infrastructure
- cloud services -

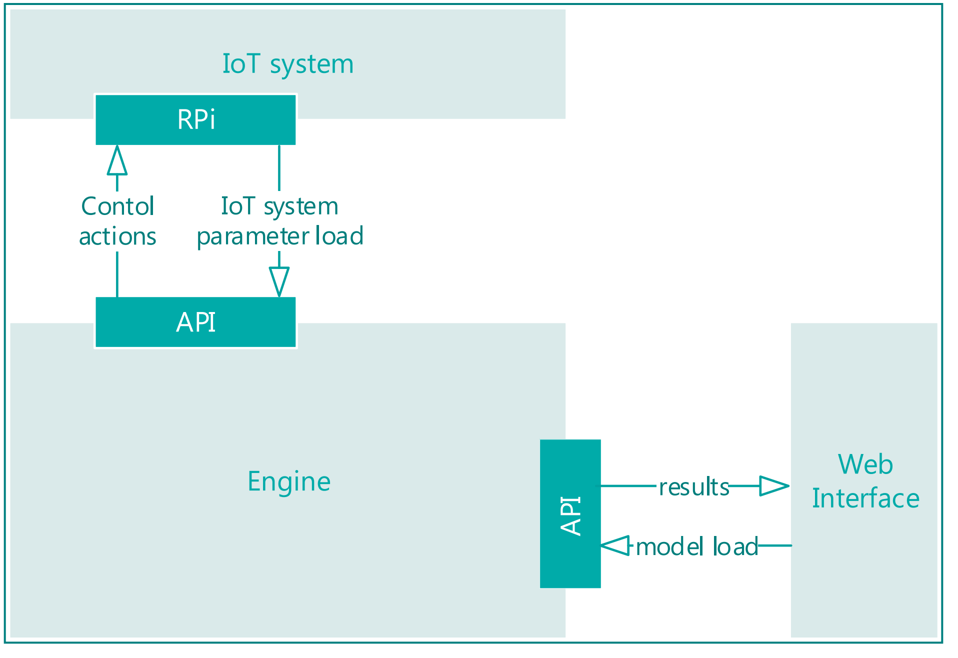
- Cloud services have proven to be adequate for providing distributed, scalable, reliable and secure services in IoT contexts.

- Components:
  - Simulation engine - controls the simulation process and enables the configuration of simulation models and processes.
  - Database layer - provides different types of data stores, relational and non-relational.
  - Big data analytics layer - tools for storing and analyzing big data to support decision making.
  - REST API - interaction between the system components.

Infrastructure
- simulation engine -

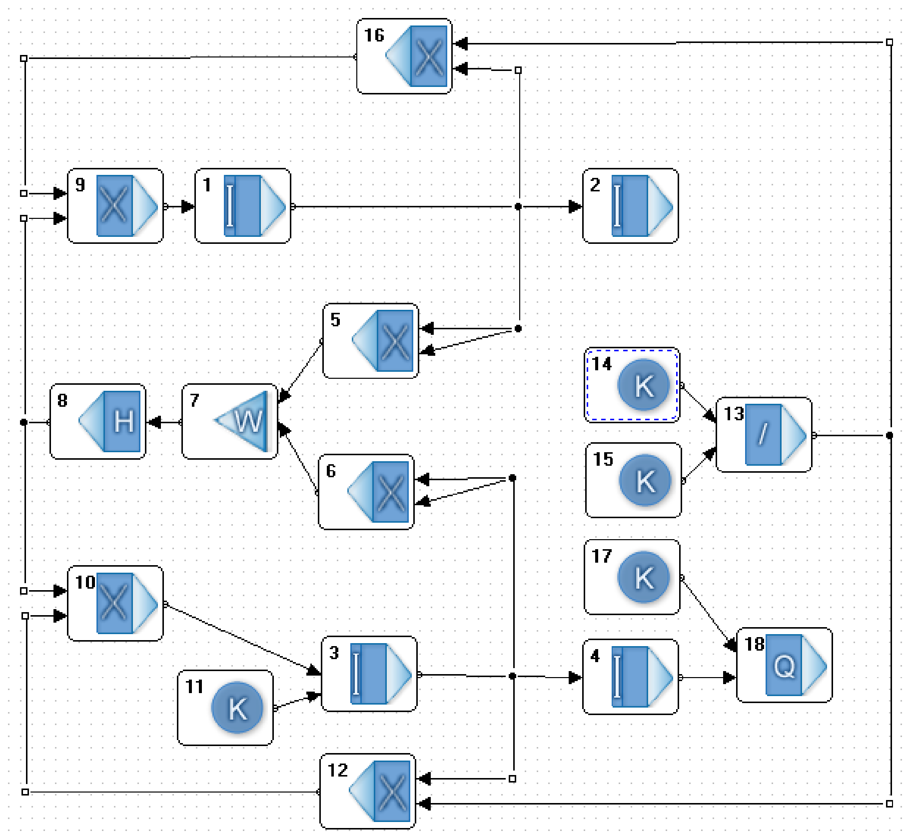
- The simulation engine is based on the CSMP simulation language.

- The implementation is based on the concepts of concurrent and distributed programming in order to achieve scalability and speed of execution.



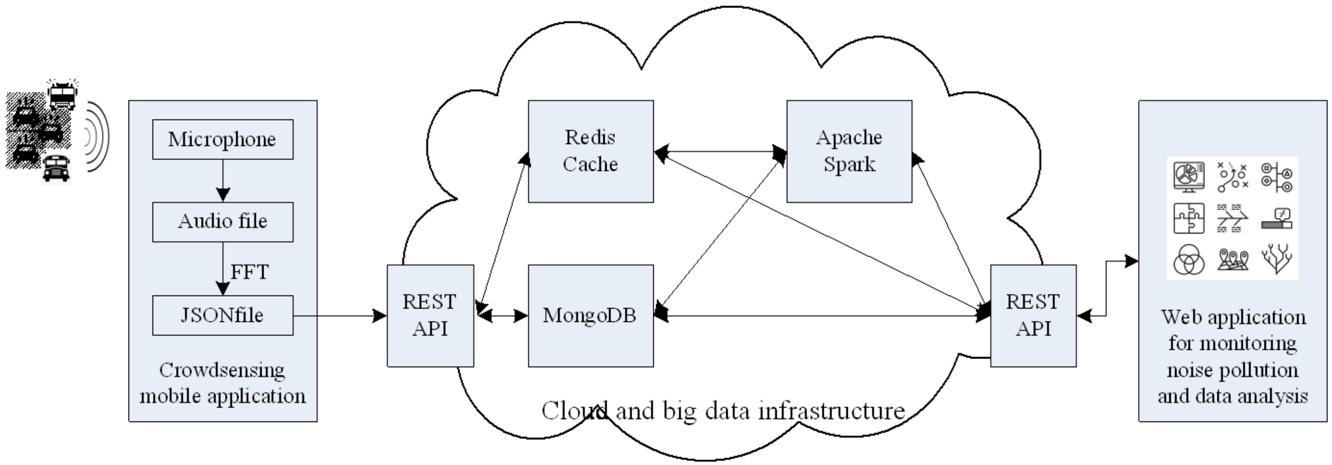
Infrastructure
- GUI -

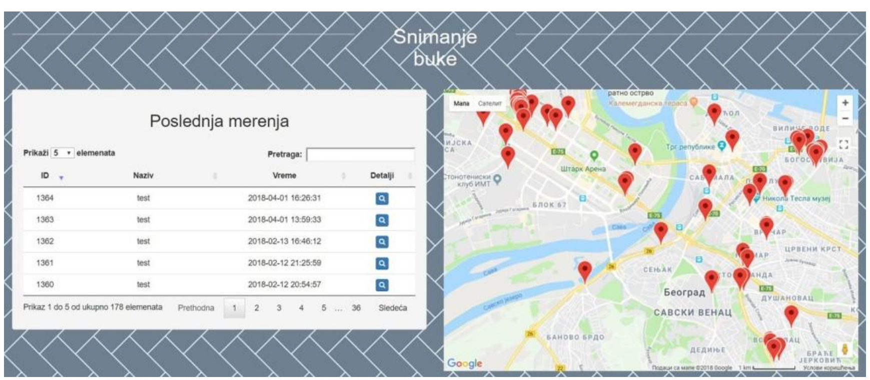
- The user interface enables users to specify simulation models using a predefined set of building blocks for performing mathematical operations and connecting them into complex models.

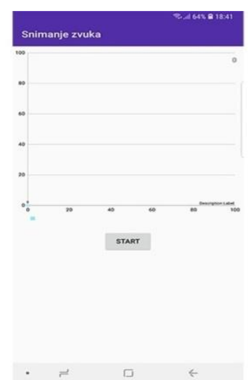


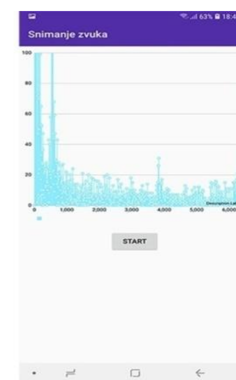
APPLICATION SCENARIOS

Application context
Noise pollution monitoring system

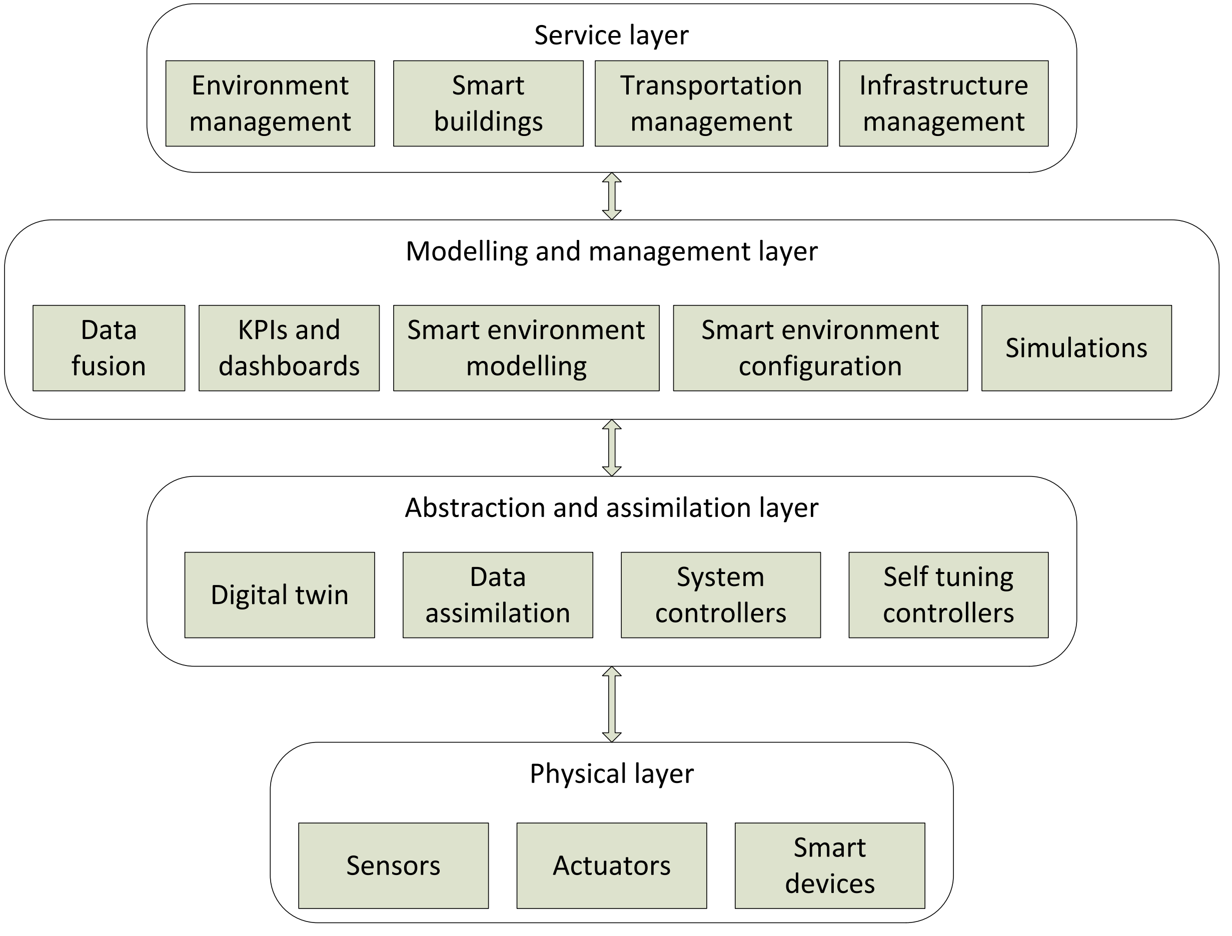








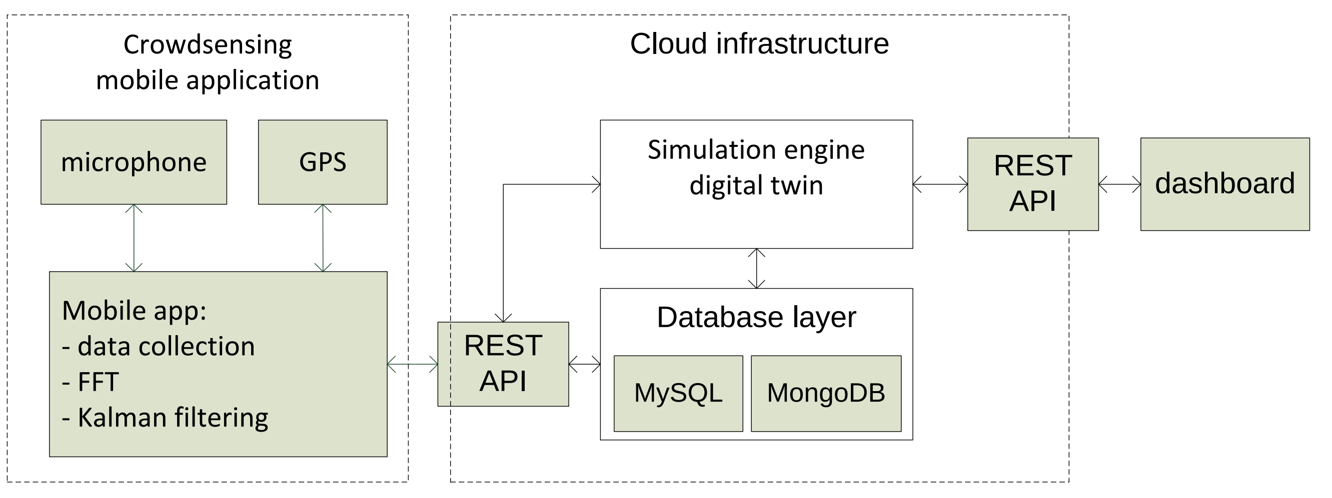
Layers of noise pollution monitoring system in a smart city



Application scenario: Digital twin

- This scenario enables a physical IoT device to be replaced with its digital twin. The digital twin can assume the function of the physical device in cases when the physical device is not available.

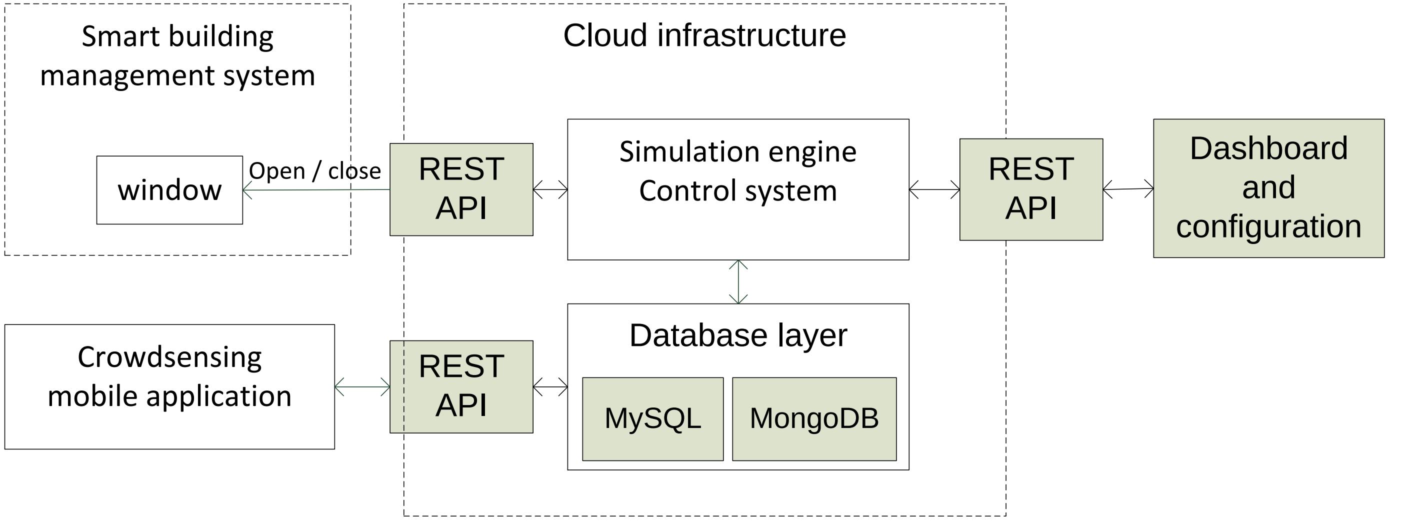
- Scenario: When a user submits a query or analyzes the dashboard data, they will get the requested information even if the mobile application is not active in real-time.



Application scenario: Control system for regulation of local parameters

- This scenario enables the development of applications for control of parameters of smart environments with simple automation models.

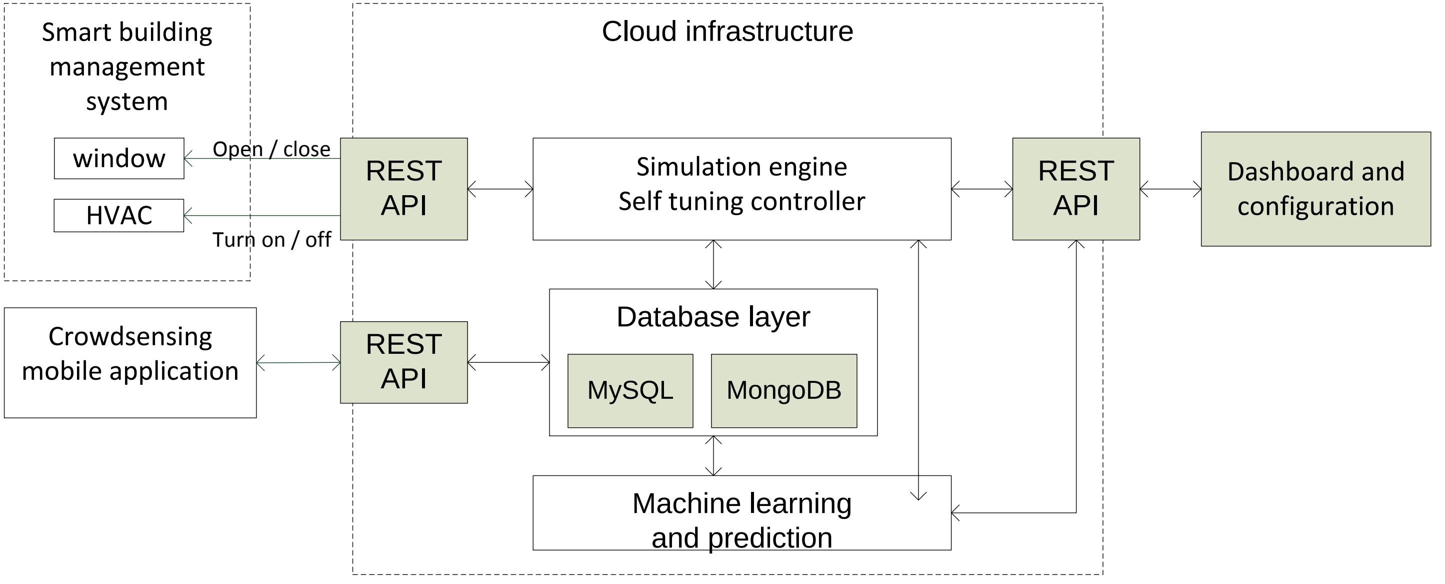
- Scenario: in a system for smart building management, a user can monitor the values of noise at a microlocation and create templates for automatic window opening and closing depending on the outside noise.



Application scenario: Advanced analytics and self-tuning controllers

- This scenario includes features such as predicting system behaviour, intelligent sensor data aggregation and similar. Typically, this scenario assumes that some of the computing tasks are deployed on edge devices.

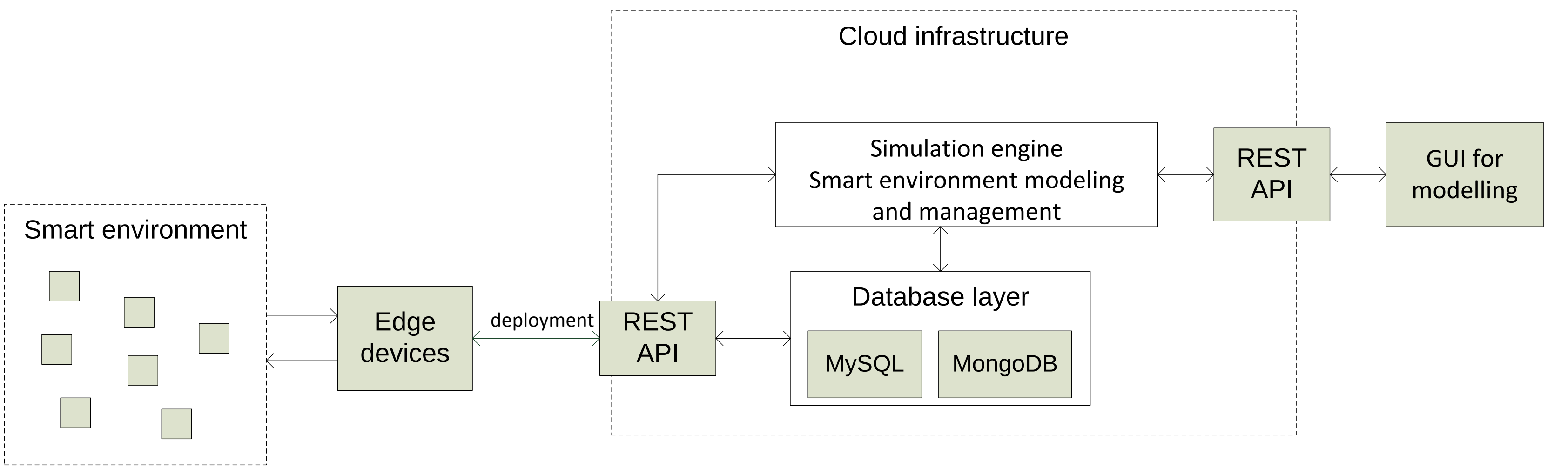
- Scenario: if an increased noise level is predicted, the smart building on the microlocation could initiate closing windows and turning the air conditioning system on, so to avoid noise from the outside to affect people inside.



Application scenario: Smart environment modelling and management

- This scenario enables users to model smart environments using adequate GUIs.

- Scenario: a user designs a smart environment using a graphical model or differential equations and then deploys the model to a smart environment through the cloud platform. The scenario enables automatic activation of a chosen set of mobile devices that participate in the opportunistic crowdsensing, so that the gathered data would best suit the needs of the designed experiment.



EXPERIMENTAL DESIGN
AND ANALYSIS OF RESULTS

Goals and procedure

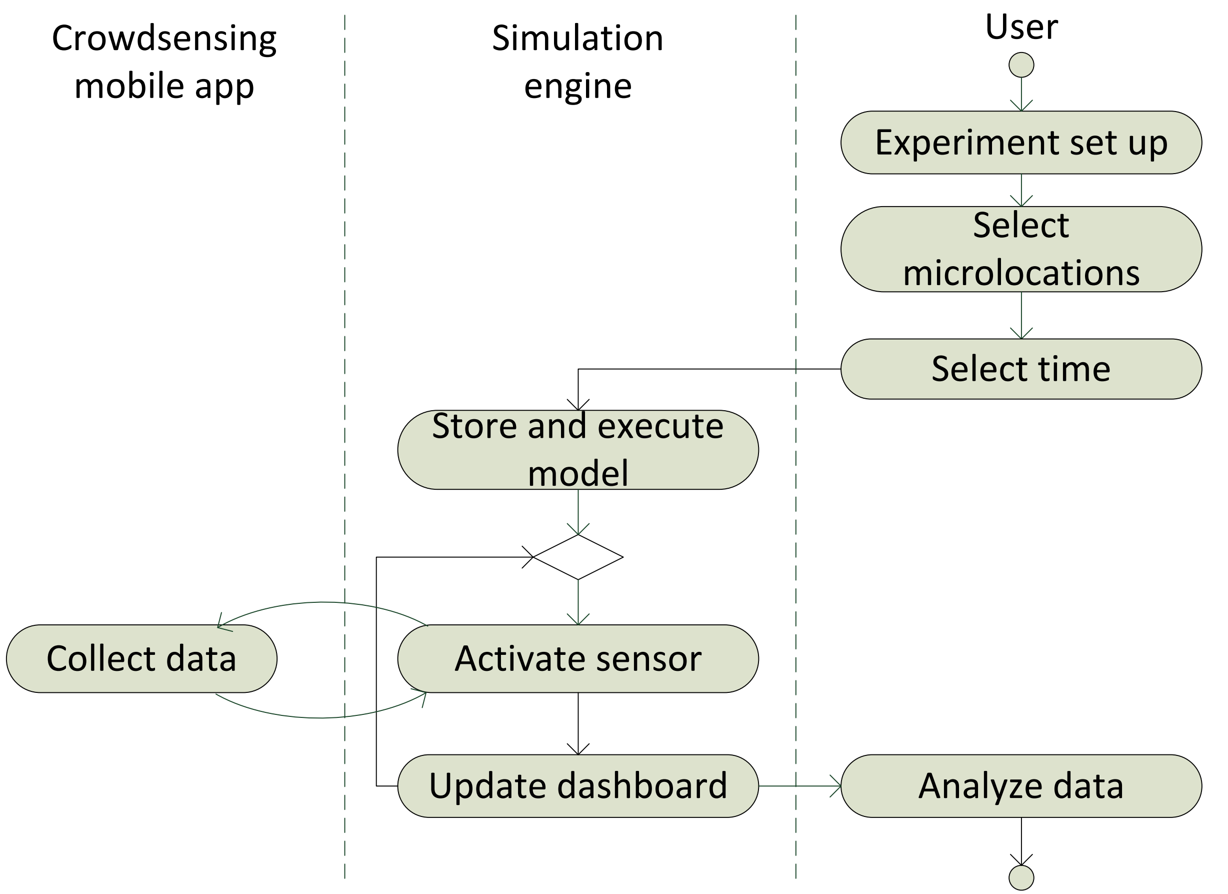
- The goal of the experiment is to collect noise data on a selected microlocation at a selected time.

- The location and the time can be chosen by a user when the experiment is being set up.

- The smartphones perform the measurements, transform audio data to the frequency spectrum, and perform Kalman filter for correcting the sensor errors. Then, the data is sent to the cloud database for further analysis and the presentation at the dashboard.

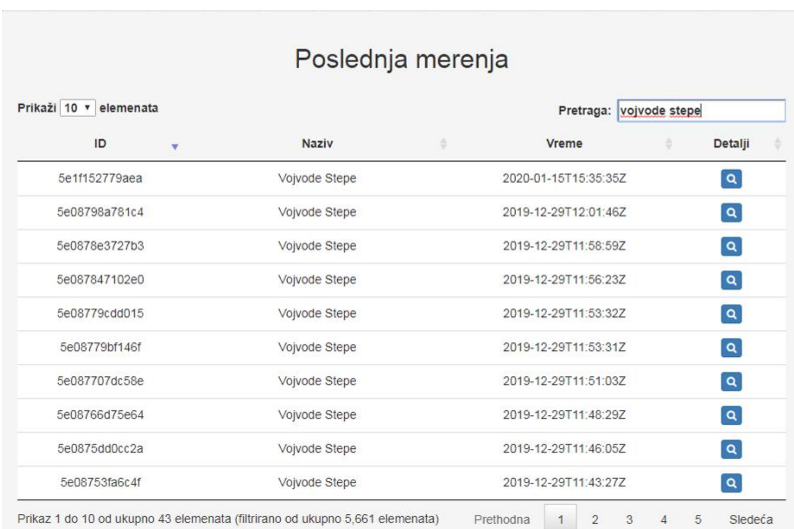
- The precondition for the realization of the experiment is that there is a number of citizens who participate in the opportunistic crowdsensing and who have the mobile application for noise measuring installed on their phones.

Flowchart of the noise measuring experiment



Analysis of results

- The first results of the application of the described system for gathering noise data in the city of Belgrade are presented to the user via a dashboard, using tables or maps.
- The data in the tables and maps can be updated with new measurements in real-time, or shown for a selected point in time.



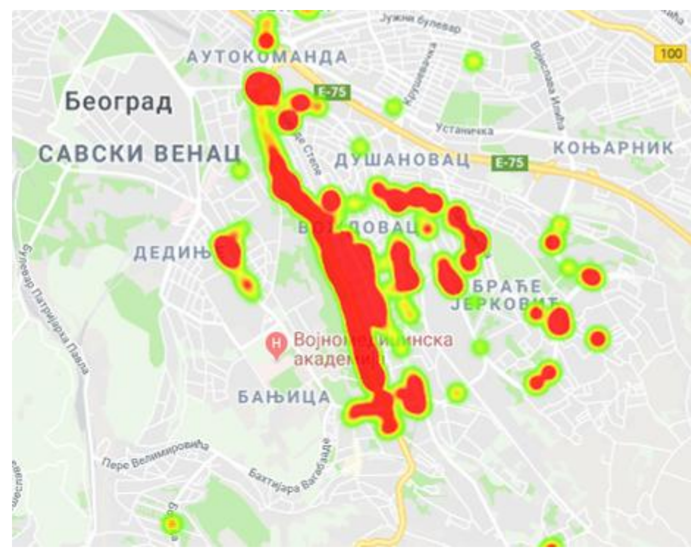
Poslednja merenja

Prikaži 10 elemenata

Pretraga: vojvode stepe

ID	Naziv	Vreme	Detalji
5e1f152779aea	Vojvode Stepe	2020-01-15T15:35:35Z	
5e08798a781c4	Vojvode Stepe	2019-12-29T12:01:46Z	
5e0878e3727b3	Vojvode Stepe	2019-12-29T11:58:59Z	
5e087847102e0	Vojvode Stepe	2019-12-29T11:56:23Z	
5e08779cdd015	Vojvode Stepe	2019-12-29T11:53:32Z	
5e08779bf146f	Vojvode Stepe	2019-12-29T11:53:31Z	
5e087707dc58e	Vojvode Stepe	2019-12-29T11:51:03Z	
5e08766d75e64	Vojvode Stepe	2019-12-29T11:48:29Z	
5e0875dd0cc2a	Vojvode Stepe	2019-12-29T11:46:05Z	
5e08753fa6c4f	Vojvode Stepe	2019-12-29T11:43:27Z	

Prikaz 1 do 10 od ukupno 43 elemenata (filtrirano od ukupno 5,661 elemenata) Prethodna 1 2 3 4 5 Sledeća



Conclusion

- We have presented an approach for designing a distributed IoT system for modelling dynamics in smart environments, and a set of possible applications in the context of noise pollution measuring and monitoring in a smart city.

- The presented approach relies on the integration of IoT, cloud, computer simulation and machine learning technologies and methods, and can be applied in various contexts and settings.

- Future work will be directed to the improvement of all the componenets and the evaluation in various contexts, such as smart agriculture, smart healthcare, smart classrooms and others.

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