Utilizing advanced human-machine interaction technologies for remote patient supporting and improving quality of life

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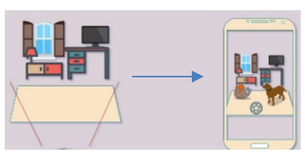
Abstract

Latest advancements in human-machine interaction technologies, which arise from the evolution of edge and mobile devices, in both software and hardware level, introduce new possibilities for research and innovation, especially in the tele-health and improving quality of life fields. The present thesis emanates from the ever-increasing capabilities of mobile devices and microprocessors which offer the ability of executing even more sophisticated machine learning tasks. The environmental understanding capabilities of commodity mobile devices are examined and tested to evaluate how they can satisfy the thesis goals. Hence, algorithms and prototypes are developed which utilize mobile Computer Vision, Augmented Reality, IoT and Cloud / Edge computing for remote health monitoring, exergames, navigation, accessibility for impaired and education.



Motivation

Primary obstacles of remote patient supporting and general improving quality of life are divided into two categories: **practical** and **mental**.

Practical obstacles:

- Static hardware installation
- Use of different equipment and cost of equipment
- Bureaucracy

Mental obstacles

- Lack of users' motivation for performing important for their health actions
- Unfamiliarity and skepticism of technology

These obstacles act as the base of the thesis motivation. Advanced human-machine interaction technologies:

- Can run on commodity devices
- Offer hardware independence, cost elimination, ease of use, and accessibility

The idea is to utilize only devices that a user already owns for:

- Improving quality of life
- Monitoring physical and mental activity
- Educating
- Helping users with disabilities for everyday actions
- Increasing accessibility.

Methods

The utilized technologies which serve the thesis purpose are Computer Vision, Augmented Reality, IoT, Machine Learning and Cloud Computing.

- **Augmented Reality**, an extension of **Computer Vision**, is the ability of understanding the environment and interacting with the frontal space by inserting virtual content. It offers
  a. Ease of use
  b. Hardware independence and
  c. Mobility
  It has no operational cost and can be executed in most mobile devices and operating systems. The AR's Simultaneous Localization And Mapping - SLAM ability displays common AR content between different devices.
- **IoT** sensors are small edge devices which are programmed to execute certain tasks and, in our case, record user health related data (biosignals).
- **Cloud Computing** offers data manipulation, storage and remote task execution.
- **Machine Learning** is utilized to identify patterns and recognize certain sequences. Although it is the base of the AR functionality, it is also used in combination with AR to supplement the research progress.

Results

Various prototypes have been developed to support the hypothesis and proposed methods of the thesis. The utilization of Mobile Augmented Reality – MAR is the common denominator of the prototypes but is used in combination with different technologies for different purposes and scenarios.

MAR Exergames: The challenges of developing a MAR exergame have been studied in combination with health data retrieval from wearable IoT sensors. Results have shown great user engagement and positive health impact.
Key contribution: combining MAR exergame with IoT for remote patient exercise motivation and monitoring

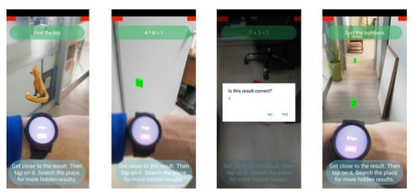


Fig 1: AR IoT Exergame system in practice

Gamification & NBS: The utilization of MAR's SLAM ability in combination with gamification techniques (Badges, Leaderboards) increases the user motivation to exercise in the concept of a Nature Based Solution.
Key contribution: The use of AR badges and leaderboards for motivating NBS visitors to visit the site and perform exercises

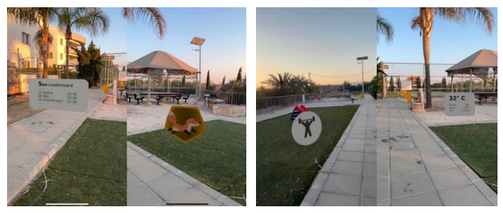


Fig 2: AR Badges, Leaderboards in NBS

Deaf accessibility in exhibitions: With the use of MAR, the overall experience of a mild vision or oral impaired can be enhanced.

- Multi-Tenant AR Cloud platform
- Exhibition elements to AR Point of Interests – PoIs
- PoI recognition with the least model training effort

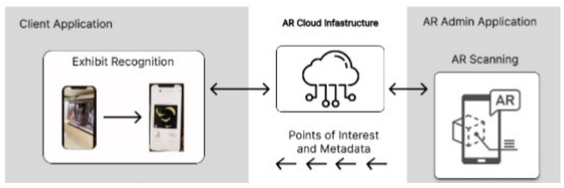


Fig 3: Multi-tenant AR cloud platform

Indoor Navigation

- Solving the indoor localization and navigation problem
- SLAM and AR Cloud Anchor capabilities for remote guidance without the use of geolocation

Methods:

- training the AR system to recognize an indoor area
- storing certain PoIs in the cloud and sharing them with the visitor users

Implementation:

- Algorithms for visualizing the guidance
- Identification of the current interior location using key-anchor techniques
- Optimization of indoor area training to offer the fastest response

The prototype application-called UNIPI: AR Experience-is in the final phase of development and is available to download. It enhances the visitor's experience at the university by offering several UNIPI destinations and general AR content.

Key contribution: The development and deployment of MAR and Cloud system to offer AR indoor localization and navigation.

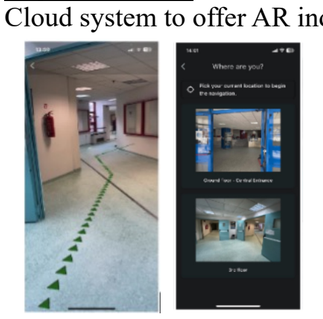


Fig 4: AR Navigation system

Table 1. Session hosting

Device	Duration(s)	Displacement(cm)	Hosting session
iPhone SE 2020	4.32	22.6	Individual
Huawei H20 Pro	6.01	30.1	Individual
iPhone SE 2020	2.99	12.4	Same
Huawei H20 Pro	4.24	21.9	Same

Table 2. Success rate per missed anchors

Anchors missed	Tests performed	Destination reached
0	58	100% (58)
1	24	83.3% (20)
2	8	25% (6)
3	6	50% (1)
4+	4	0% (0)

Pharmaceutical Education

- MAR and Computer Vision - CV
- Medicine box recognition
- Molecular information retrieval
- Compound augmentation-visualization

Key contribution: AR and CV for enhancing Education by visualizing molecular compounds of identified medicine.

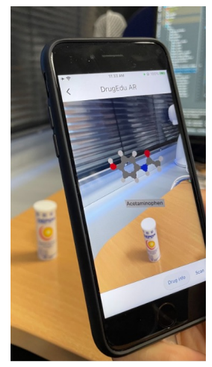


Fig 5: CV & MAR system

Future Work

Future extensions of the present thesis are affecting not only the MAR context of the project but the utilization of lower-level machine learning techniques to enhance the thesis goal.

Concerning the MAR:

- Visually impaired support in combination with the already developed AR systems
- Health education and medical procedures incorporation for immersive and more tangible results
- MAR for providing instructions on how to use sophisticated (medical) equipment for the elders
- Remote training and recording areas and PoIs

Concerning more generic machine learning capabilities:

- An object detection system for mobile devices to support impaired and provide directions towards the objects. In this example, MAR can be helpful after the object identification.
- The use of a mobile device's camera and microphone for domain generalization: to recognize an area for a person that is not able to (e.g. a restaurant).
- The use of external machine learning algorithms to supplement indoor localization before executing the MAR navigation.

Other fields:

- Optimize human-machine interaction for recording symptoms and health-related events

References

- Koulouris, Dionysios, Andreas Menychtas, and Ilias Maglogiannis. "An IoT-Enabled Platform for the Assessment of Physical and Mental Activities Utilizing Augmented Reality Exergaming." *Sensors* 22.9 (2022): 3181.
- Koulouris, Dionysios, Andreas Menychtas, and Ilias Maglogiannis. "On the development of augmented reality based exergames for assessing human activity and cognition on mobile devices." *The 14th PErvasive Technologies Related to Assistive Environments Conference*. 2021.
- Koulouris, Dionysios, et al. "Exploiting Augmented Reality and Computer Vision for Healthcare Education: The Case of Pharmaceutical Substances Visualization and Information Retrieval." *Digital Professionalism in Health and Care: Developing the Workforce, Building the Future*. IOS Press, 2022. 87-91.
- Koulouris, Dionysios, et al. "Integrating AR and IoT Services into mHealth Applications for Promoting Wellbeing." *2022 18th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob)*. IEEE, 2022.

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