Augmented Computing and Smart Cities Sustainability

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Abstract. Smart Cities promote a great improvement in urban environments in terms of sustainability, leveraged by the use of technologies that allow the optimization and monitoring of different systems, from waste management systems to public safety. There are several technologies that can play a key role in this process, highlighting augmented computing, augmented reality, virtual reality, artificial intelligence, and machine learning. In this context, smart cities collects and analyses, optimizing the various systems processes. There are many challenges that arise in order to have sustainable smart cities, challenges in terms of privacy and data security, but also in promoting inclusion and equity. It is important to adopt an inclusive and holistic approach that involves all stakeholders and takes into account the specific needs and objectives of a city. With this in mind, the adoption of augmented computing technologies facilitates the creation of more livable and also more sustainable urban environments. The main objective of this work is to explore the area of augmented computing in the context of smart cities sustainability.

Keywords: Augmented Computing · Smart City · Virtual and Augmented Reality · Machine Learning · Artificial Intelligence

1 Introduction

Sustainability is becoming a priority in all facets of society and urban environments around the world are recognizing its role in creating a sustainable future. With buildings consuming a significant proportion of global energy and therefore directly contributing to a city's overall environmental impact there is great momentum to improve this situation through the use of interconnected technologies (Aurigi & Odendaal, 2021).

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O. Gervasi et al. (Eds.): ICCSA 2023 Workshops, LNCS 14108, pp. 123–132, 2023.
https://doi.org/10.1007/978-3-031-37117-2_10

The perspective of sustainability applied to the urban environment, in order to achieve the necessary success to implement the related fundamental rights, gives rise to the concept of a sustainable city (Al Sharif & Pokharel, 2022), from an environmental point of view, corresponding to the optimization of the relationship between people and the environment, with a view to guaranteeing natural resources for future generations.

In a smart city, the environment, economy and society are necessarily intertwined and coexist in a single ecosystem. The connectivity infrastructure is fundamental in providing the services and processes offered (Allam, Sharifi, Bibri, Jones, & Krogstie, 2022).

Smart cities use technologies, programs, data and digital solutions with the aim of improving the quality of life of their inhabitants (Casini, 2017). In this context, augmented computing has a transformative potential in terms of the functioning of smart cities, making them more efficient, sustainable and also livable (Bibri & Krogstie, 2017).

Smart cities make use of various technologies, such as sensors, IoT devices, and monitoring solutions (Saleem, Zeebaree, Zeebaree, & Abdulazeez, 2020), which allow optimizing the various city systems, such as energy, waste, and transport, with the aim of improve the efficiency and sustainability of urban areas (Strielkowski, Veinbender, Tvaronavičienė, & Lace, 2020). As example we can have smart traffic lights can use real-time data to optimize traffic flow, thus reducing congestion and fuel consumption, and also smart buildings can use sensors to monitor energy consumption and thus optimize building systems, reducing the energy consumption. For example, smart waste management systems can use sensors to optimize waste collection, reducing the energy and fuel needed by garbage trucks. With intelligent transport systems is possible optimize the traffic flow and encourage citizens to use alternative transports (public transports, bicycle's, electrics, and others), and that can also help reducing carbon emissions (Meneguette, De Grande, & Loureiro, 2018).

The main objective of this work is to explore the area of cognitive computing in the context of smart cities sustainability, with the aim to have a perception of the challenges and impact of augmented computing (AC).

This work is organized in five sections. The second section provides an overview of augmented computing and the technologies used. The third is about the smart city and its sustainability, focusing on sustainable development. The fourth section explores the challenges of new technologies, specifically AC and its impact on the sustainability of smart cities. The last section presents the conclusions.

2 Augmented Computing

The first computational systems, and the first approaches to artificial intelligence, were registered at the beginning of the 20th century (Gershman, Horvitz, & Tenenbaum, 2015), being the beginning of the era of augmented computing, which evolved throughout the century, highlighting the appearance of the first systems of virtual reality, of intelligence artificial and machine learning (Xiong, Hsiang, He, Zhan, & Wu, 2021), which was fundamental for the development and evolution of augmented computing technologies.

Augmented computing uses different technologies, being highlighted: artificial intelligence (AI); machine learning (ML); virtual reality (VR); and augmented reality (AR).

With these technologies is possible improved the efficiency and productivity of the urban areas (Alzahrani & Alfouzan, 2022) (Fig. 1). The combined use of these technologies allows creating powerful augmented computation systems, allowing human-computer relationships to be smarter and more immersive.

Currently, AC has widespread use, in education to health among others, improving human work capabilities in terms of effectiveness and efficiency.

One of the main areas of development in augmented computing is virtual reality and augmented reality. VR and AR are two technologies that have different characteristics and objectives, while VR takes us to a new environment created by computer; AR includes projections of content and complementary information in the real world (Kohli, Tripathi, Chamola, Rout, & Kanhere, 2022).

Both technologies need an intermediary to be accessed, which can be an application or an accessory, offering completely different experiences for users.

VR allows users to experience immersive digital environments, while AR overlays digital information and graphics onto the real world.

AR is about the real world. It's when you look at an existing environment and see overlapping elements, with information and graphics specific to a location, for example.

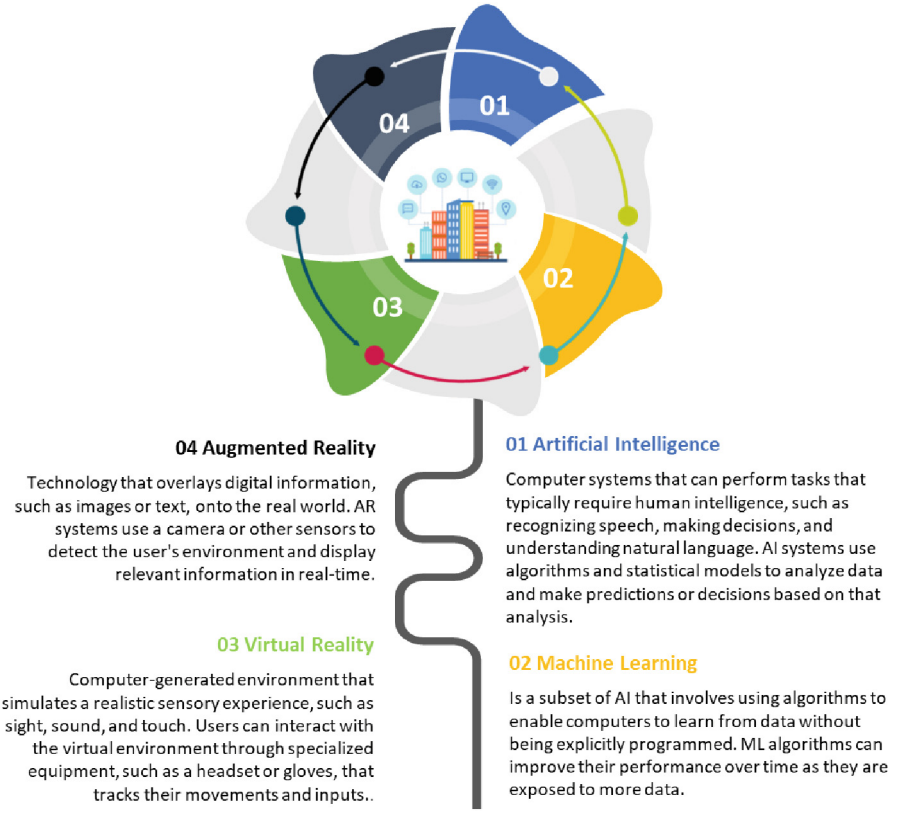

Fig. 1. Augmented computing augmented computing used technologies.

AR can be defined as a system that: combines virtual elements with a real environment; it is interactive and has real-time processing; it is conceived and displayed in three dimensions.

Augmented computing enabled a more efficient and productive use of resources, providing an important role in the sustainability of smart cities. AI and ML can be used in the optimization of the use of resources, predicting and preventing equipment failures, optimizing energy use in buildings, and others.

AC can have a significant impact on the sustainability of cities, analyze the possible negative impacts, to be possible maximize the benefits of AC on the sustainability of cities.

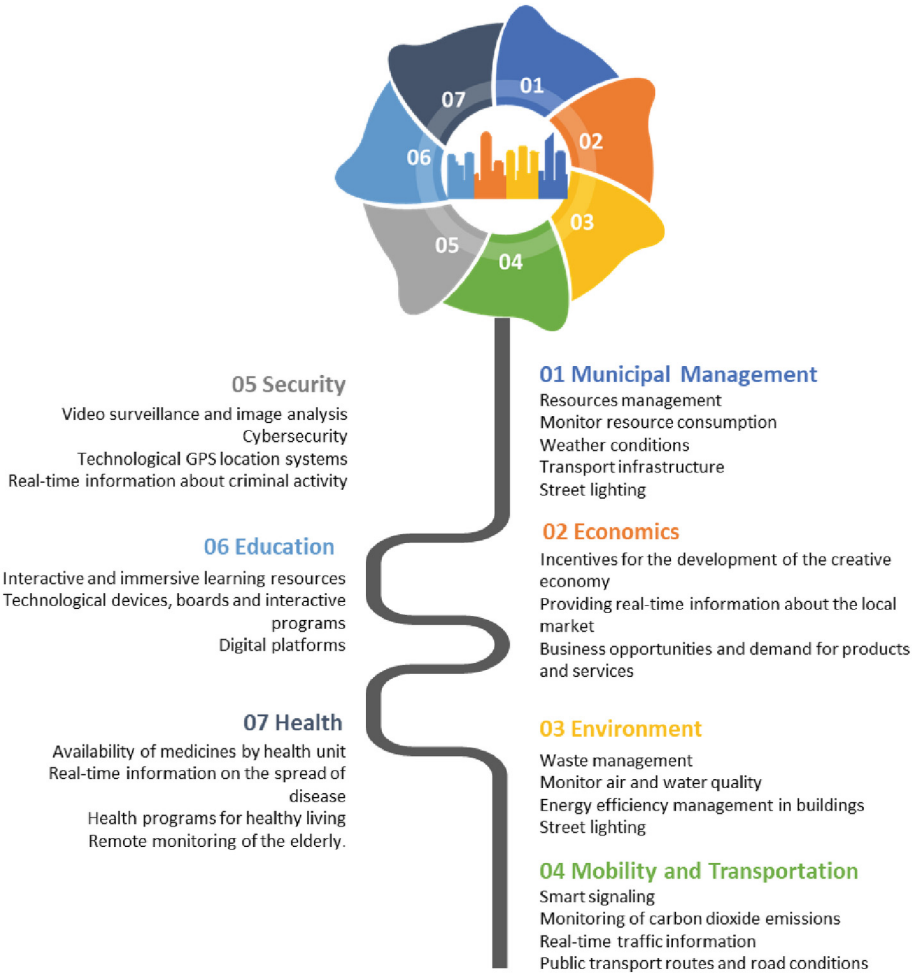

Fig. 2. Augmented computing application areas in smart cities.

There are several areas of application for augmented computing in smart cities, such municipal management, economics, environment, mobility and transportation, security, education, and health (Fig. 2).

3 Smart Cities and Sustainability

The bases of the concept of smart cities are the economic development, the citizen's life quality, and the sustainability. The overall objective of smart and sustainable cities is to improve sustainability with the help of technologies (Albino, V., Berardi, U., & Dangelico, R. M. (2015). Smart cities: Definitions, dimensions, performance, and initiatives, 2015).

The concept of Smart Cities is closely related to the digital transformation paradigm that can be explained as changes in the way of connecting, collecting and analyzing data caused by the adoption of new information and communication technologies (Caragliu, Del Bo, & Nijkamp, 2011). The simplest definition of a smart city is a city that through the use of technology improves the life quality of the citizens (Abadía, Walther, Osman, & Smarsly, 2022).

A smart city aims to create a more efficient, sustainable and livable environment, through the use of technologies that allow monitoring and optimizing the various systems. Sensors, Internet of Things (IoT) devices, and digital solutions leverage optimization and monitoring processes, facilitating data collection and subsequent analysis, thus making it possible to automate and optimize different processes and systems (Whaiduzzaman, y otros, 2022). By using technology to optimize and monitor various systems, cities can reduce resource consumption and waste production, leading to a more sustainable and livable environment.

The sustainable city is the most durable type of human settlement, providing an acceptable standard of living for all without serious damage to the ecosystem or the biogeochemical cycles on which it depends, as opposed to the current urbanization model, which considers natural resources inexhaustible and free (Newman & Jennings, 2012).

Sustainability is very important in some areas, particularly: sustainable development; the environment; the energy; the foods; the transport; consumption and production (Fig. 3) (United Nations, 2015).

Sustainable development expresses the relationship between economic growth, environmental conservation and social concern (Moreno, Allam, Chabaud, Gall, & Pratlong, 2021; Jiang, Gao, Jin, & Liu, 2021). Based on society's awareness of the irrational use of natural resources and the environmental impacts generated by human action, the concept of sustainable growth emerges as an alternative, which promotes the interdependence between economy, environment and society (Sachs, 2015).

Sustainable development is anchored in the economic development of humanity based on the conservation of natural resources. Thus, development in a sustainable manner means that natural resources are used rationally, that is, without their depletion, with a view to conserving these resources for future generations. Therefore, society's economic progress is sought based on the importance of environmental resources for productive activities and also on their conservation, in a clear concern for the future of humanity (United Nations, 2015).

Despite the problem of urbanization and the design of smart cities, a global concern has already turned to the issue of sustainability, as it enables us to provide a future for the next generations in our cities. The vision of sustainability helps us to seek innovative solutions, for example, for the excessive volume of solid supplements produced daily in cities and to combat the fuel produced by proteins and the volume of vehicles on the streets, but without reducing employability levels (Marjanović-Halburd, Halburd, & Manfredi, 2017).

However, the United Nations itself has expanded this concept of sustainability in recent years, maintaining the guarantee of opportunity for all, that is, social inclusion is part of this more current concept, since urbanization has brought a world where poverty and inequalities are endemic, which results in greater ecological problems (Caragliu, Del Bo, & Nijkamp, 2011).

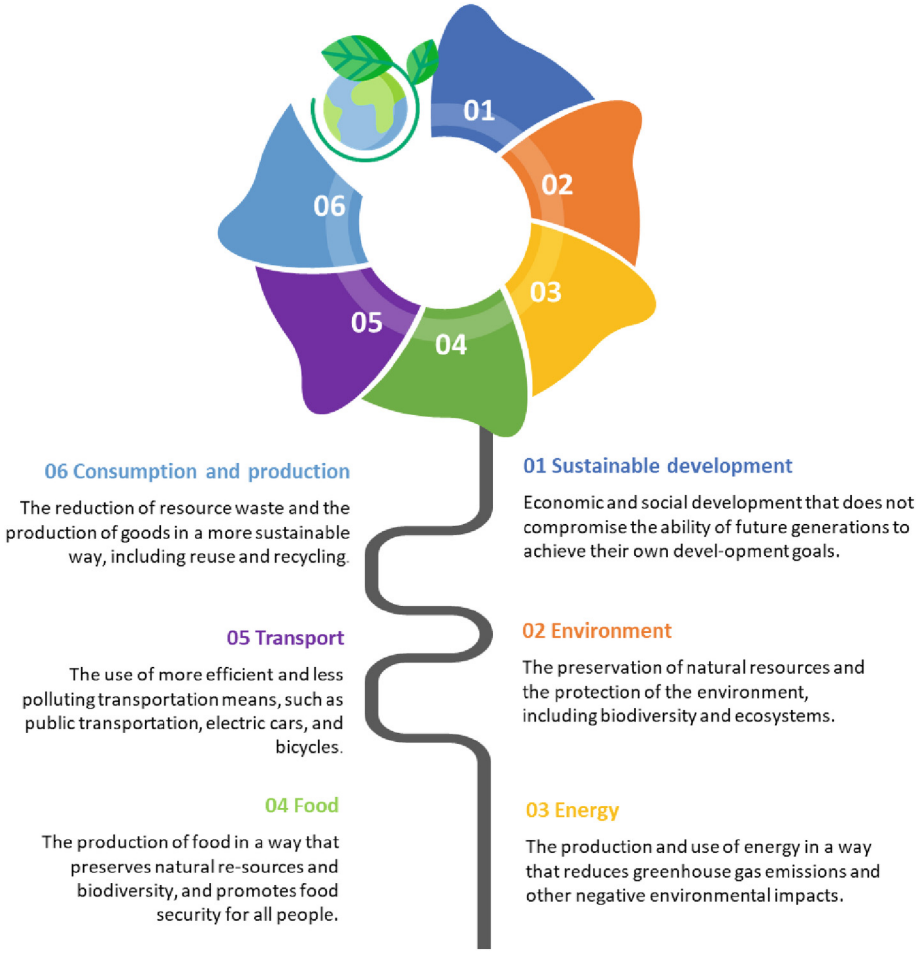

Fig. 3. Sustainability important areas.

Therefore, the design of smart cities needs to encompass sustainability actions aimed at recovering and maintaining our consumed natural resources, promoting the use of renewable energy conversion, treatment and cleaning of rivers that supply cities, treatment of the volume exponential growth of solid waste, the use of innovative construction solutions, among others. Smart city will be in how sustainable development will concern future nations and promote resilience, avoiding shortages of natural resources, new epidemics or other natural disasters (Ramirez Lopez & Grijalba Castro, 2020).

4 Challenges and Impact of AC on Smart Cities Sustainability

With the increase of urban population, the cities grow and face more challenges in terms of sustainability (Biadacz & Biadacz, 2021).

With the transformations imposed by the effects of globalization around the world, society and cities have been undergoing profound transformations in their most diverse aspects (Kara, 2019). In this context, it is urgent to look for innovative solutions that help solve these problems, and to carefully analyze the challenges and impact of technologies, namely AC, which must be used responsibly and sustainably in smart cities.

In the main challenges of AC in the smart cities sustainability it is worth mentioning its integration with other smart cities technologies (IoT, AI, ML, Bid Data, among others), and it depends of the development of the sustainable technologies, that must ensuring the privacy and security of the users data.

In the process of developing sustainable technologies for smart cities, the environmental sustainability cannot be neglected. It should be taken into account that privacy and security of user data must be guaranteed.

For a better use of AC in smart cities, training is essential. This is the only way to take advantages of the benefits offered by AC, and at the same time minimize the possible negative impacts (Javed, y otros, 2022). For that regulation is vital to ensure the responsible and sustainable use of AC in smart cities.

AC technologies can be used in smart cities to improve the efficiency and sustainability of urban areas. We can highlight: training in virtual reality: maintenance of augmented reality; intelligent transport; predictive maintenance; smart buildings; intelligent energy management; and waste management (Fig. 4).

Augmented computing can have a significant impact on the sustainability of cities on several levels: improving energy efficiency, environmental monitoring; developing innovative solutions; and improving life quality (Ismagilova & Raman, 2019).

AC can also have a negative impact on the sustainability of smart cities, such as the digital exclusion, lack of security and privacy in data collection, and lack of regulation, among others.

With the introduction of new technologies in smart cities, which present different scenarios and new challenges, the concern with regulation in terms of privacy and security of personal data prevails The regulation must accompany the new technologies adoption.

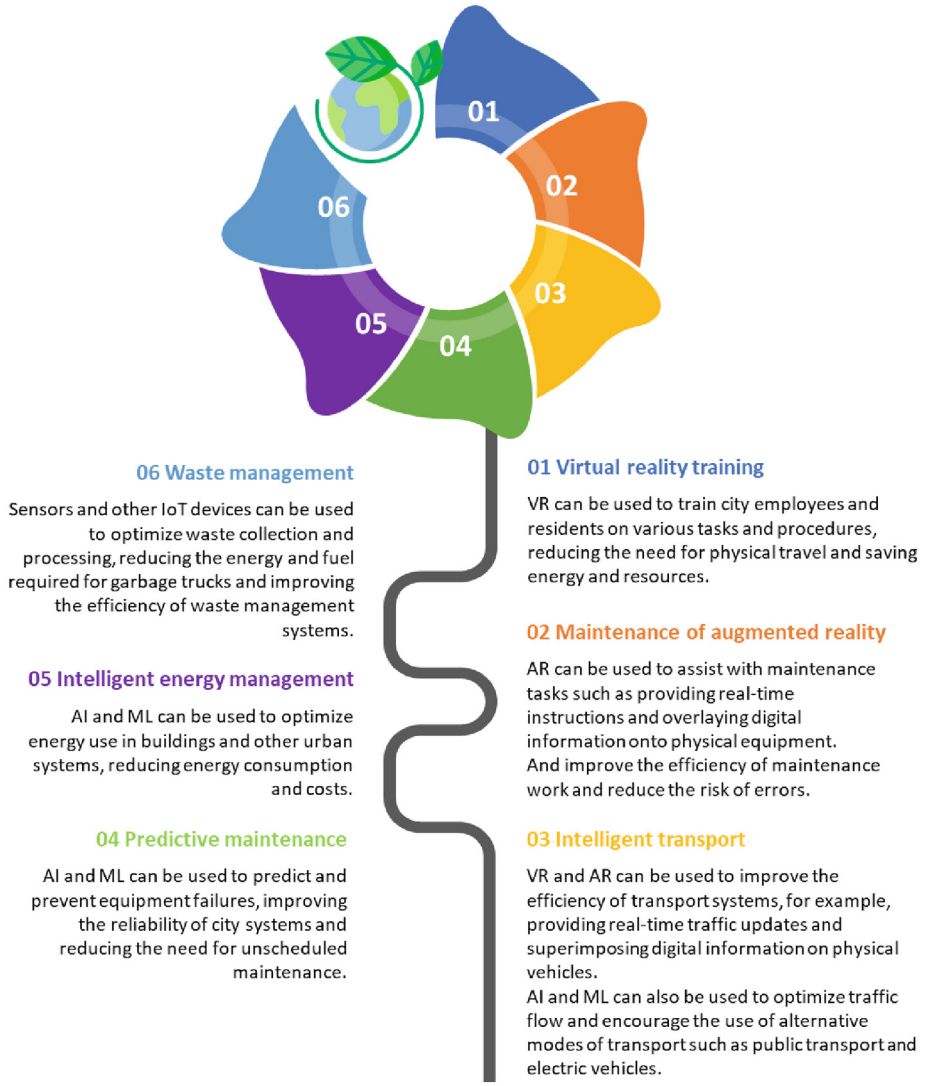

Fig. 4. Areas of smart cities that can be improved by technologies in terms of efficiency and sustainability of urban areas.

5 Conclusions

Smart cities and augmented computing have the potential to significantly improve the sustainability of urban areas. By using technology to optimize and supervise various systems, cities can reduce their resource consumption and waste production, improve the energy efficiency and environmental monitoring, developing innovative solutions, leading to a more sustainable and livable environment. Augmented computing can also contribute to the sustainability of smart cities by enabling more efficient and productive

use of resources. As these technologies continue to advance, it is important to consider their potential impact on sustainability and to develop strategies to maximize their benefits for the environment.

However, the use of AC in smart cities also presents challenges and ethical issues such as privacy, security and equal access to technology. Furthermore, the production and disposal of electronic devices for accessing AC can have negative impacts on smart cities sustainability such as the digital exclusion, lack of security and privacy in data collection.

Therefore, it is important that the impacts and challenges of augmented computing on the sustainability of smart cities are carefully considered, to ensure the responsible and sustainable use of this technology for the benefit of society.

Acknowledgement. The authors are grateful to the Foundation for Science and Technology (FCT, Portugal) for financial support through national funds FCT/MCTES (PIDDAC) to CIMO (UIDB/00690/2020 and UIDP/00690/2020) and SusTEC (LA/P/0007/2020).

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