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# Metropolis: Emergence in a Serious Game to Enhance the Participation in Smart City Urban Planning

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## Abstract

This article presents a city simulator game named *Metropolis*. It is an emerging serious game that generates emergent properties. *Metropolis* can be used as a smart city for city planning, based on collective decisions. It also analyzes how its emergent properties might be used for managing a smart city and, especially, how it promotes e-participation as an e-decision-making tool within the context of urban planning. In addition, this paper explores the use of *Metropolis* for analyzing a smart city's emergent citizen and urban patterns (urban spatial distribution) based on e-participation.

**Keywords** Emerging serious games · E-participation · Smart cities · Urban planning

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## Introduction

Recent advances in artificial intelligence have become critical in the design of video games. In particular, the concept of *emergent game* marks the beginning of a new era in video games (Sweetser 2007; Sweetser and Wiles 2005): emergent games represent the evolution of games that are adapted to the player while maintaining the central thread of the game. In the emergent games, the emergence is based on the dynamic creation of a world, so that the player's actions influence this world, generating emergent behaviors in the world according to what is happening in the game.

On the other hand, the term participation means taking part in joint activities to reach a common goal. This practice is highly complex due to its goal-oriented process, which involves decision-making and control. E-participation in a smart city supports the participation of citizens in governance through the use of information and communications technologies (ICTs) (Vrabie and Tirziu 2016; Komninos 2018; Deakin 2014). Citizen participation is especially important in a smart city; hence, its planning should consider the needs of its citizens (Chourabi et al. 2012; Graniera and Hiroko 2016; Mellouli et al. 2014; Deakin 2014). In general, e-participation encompasses different purposes: administration, policy-making, service delivery, and decision-making.

With this in view, this paper analyzes the e-participation in the context of decision-making in a smart city (Komninos 2018; Deakin 2014). The processes of collective decisions have significant importance for a smart city. Therefore, it is necessary to define the tools that allow the interaction of the citizens in the decision-making processes about the life in the city. Additionally, it required platforms for the citizens to learn about participation and, specifically, to gain knowledge about the complexity of e-participation in the decision-making processes in a smart city. In particular, this paper studies how to manage the collaboration in decision-making process for urban planning (Komninos et al. 2019). Urban planning involves complex interdependencies and conflicting interests, among other aspects, between citizens, which call for new forms of interaction. Thus, an emerging serious game is used to study this complexity by analyzing the power relations and real collaboration, for developing creative strategies of collaboration. It also determines the forms of managing collaborative efforts in the context of the complex urban planning issue.

Introducing emerging serious games into a smart city allows a transparent integration of technologies into city dynamics. According to (Aguilar 2014), the story, the dynamics, and the arising script depend on the context where the emerging serious game is being given. Thus, the game positions the players in a feedback environment of information and motivation to achieve, guided by an explicit objective other than pure fun, to overcome challenges appropriate to their ability and learn from their own mistakes. Emerging serious games is suitable to be used in different contexts in a smart city. Considering that one of the main characteristics of a smart city is the application of e-participation to facilitate collective decision-making about citizens' services and needs, this work analyzes how *emerging serious games* are used in this context. Therefore, this paper explores the technology needed to construct a vision of urban development in a smart city and in a collective and secure fashion in order to manage the city's assets (schools, hospitals, etc.). Special focus is done in serious games that promote e-participation in the context of urban planning.

In the domain of serious games and e-participation, (Ahmed et al. 2015) proposes a technology acceptance model (TAM) and a trustworthiness model (TM) that facilitate the use of serious games in e-government services and empower citizen engagement and participation. The models are based on serious games to assist governments in increasing citizens' engagement in their online services. Pflanzl et al. (Pflanzl et al. 2016) discuss game design as an approach to motivate, involve, and change citizens' behavior with respect to public service improvement. They propose a serious game for decreasing the gap between public services process opacity and complexity, as well as citizens' lack of interest or competencies to understand them. The benefits and challenges of this approach are discussed using a public service delivery scenario in Brazil. Thiel (Thiel 2016) reviewed recent academic projects concerning gamified participation tools. The gamified participation tools are a novel approach to re-encourage citizens to make use of their democratic rights by using digital participation platforms. Thiel et al. (Thiel et al. 2016) provide a review of gamification strategies in e-participation platforms and an overview of the current state of the art of so-called gamified participation initiatives. Their results suggest that only a small number of the reviewed projects employ gamification. Moreover, gamified participation initiatives currently seem to be mostly restricted to reward-based gamification, a strategy that might only evoke short-term effects and decrease the quality of participation. They also outline avenues to extend gamified participation. (Thiel 2017) provides an overview of the current practice of applying gamification in public participation. The contribution of that research is twofold. Firstly, it offers relevant insights for the design of future e-participation platforms. Secondly, it helps to establish a common terminology for e-participation game research.

In the domain of games for urban planning, (Poplin 2011) focuses on online games and serious games in urban planning. The paper overviews the urban planning games available online and gives some examples of the game stories. Additionally, the author explores the potential of serious games in public participatory planning, in a game entitled B3 Game, applied in the case of a market place in Billstedt. The game enables the players to design their marketplace and discuss their suggestions with other citizens and urban planners. Lundström et al. (Lundström et al. 2016) address urban and regional planning as a wicked game. They explore the obstacles and opportunities of a participatory method in a wicked game called "Citizens' Jury." This game represents deliberative practices designed to garner the opinion of groups to serve as a microcosm of the whole population affected by an issue. Martin et al. (Martin et al. 2014) present research of architects and computer scientists about mobile, context-sensitive serious games for sports and health (so-called exergames). Specifically, they describe an approach that designs exergames by interacting with the topography and social environment and present strategies on how to integrate research on health-oriented urban design and planning to the design of such games. Finally, they analyze how the built environment influences physical activities such as walking, cycling, and stair climbing, and they define how to integrate best practices and guidelines from architecture into the game design process, in order to create attractive and more effective exergames. Recently, Madani et al. (Madani et al. 2017) have proposed a serious environmental management game to improve understanding of environmental sustainability. This game-based learning approach increases soft skills, such as critical thinking, creative problem solving, and teamwork, as well as improving cognitive development, learning retention, and social learning. This kind of game is applied in educational settings to promote awareness about sustainable planning and management among citizens.

This paper explores a subtype of gaming in a smart city, named "construction and management," which are simulations where players build, expand, or manage either fictional communities or projects with limited resources (Ferré 2004; Rollings and Adams 2006). Thereby, the player's objective, in these games, is not to defeat an enemy, but rather to build something in the context of an ongoing process (Aguilar et al. 2011). Examples of these include city construction games such as *SimCity* and *OpenCity* (Adams 1998; Ferré 2004; http://www.opencity.info/ n.d.).

Specifically, this paper presents a game, called *Metropolis*, where the social dynamic emerges from the decisions that people make (Aguilar et al. 2011; Aguilar et al. 2016). This game aims to collectively plan the successful growth of communities. *Metropolis* has as a premise that cities are self-managed, from the decisions taken collectively, in an environment in which all actors (players) have a role of equal importance, and there is no local authority (mayor, governor, etc.). This game can be used for planning a city, managing its limited resources, and identifying the collective interests of its citizens, among other issues. It also can be used for learning to reach collective decisions. Hence, *Metropolis* is both a serious game due to its teaching capability (learning to reach collective decisions) and an emergent system due to the obtained results (management of a city).

Previous research focused on studying emergent behaviors of a city based on rules that govern the interactions between agents (players) that play social roles in this society. This paper uses a mechanism that reaches consensus opinions in *Metropolis* and establishes transparent forms of inclusion for e-participation. Additionally, *Metropolis* encourages the emergence of the collective urban vision of a city based on the interests of its citizens.

*Metropolis*, as an emerging serious game, teaches the players about the complexity of e-participation in a smart city. Specifically, it educates players on how to collaborate. As a result, *Metropolis* facilitates the emergence of smart city behaviors (urban patterns, city features, among others) based on collective decisions. This kind of game exhibits the potential of ICTs in a smart city and encourages its citizens to exploit them.

Thus, this work makes contributions within three domains. First, it establishes the importance of e-participation in a smart city for democratic decision-making processes. Second, it shows the use of an emerging serious game for teaching e-participation, and finally, it confirms the emergence of behaviors in a smart city due to e-participation.

This work is organized as follows. Section 2 presents the theoretical aspects of this paper: emerging serious game simulators of cities and e-participation in a smart city for urban planning. Section 3 introduces *Metropolis*. Section 4 provides examples of the utilization of Metropolis for e-participation in the context of a smart city for urban planning. Finally, conclusions are given in Section 5.

## Theoretical Aspects

In this section, emerging games and serious games are defined. Furthermore, some games/simulators of cities are presented; and finally, the concept of e-participation, in the context of a smart city, is introduced.

## Emerging Serious Games

Emergence (Aguilar 2014; Johnson 2003; Perozo et al. 2013a; Perozo et al. 2013b) “is what happens when a relatively simple system of elements is organized spontaneously and without explicit laws, to give rise to intelligent behavior.” An emerging game responds to the player’s actions and, similarly, is capable of interacting with the players, which adds a new dimension to the game (Sweetser 2007). In the literature, there are several definitions of emerging games. For example, (Sweetser 2007; Sweetser and Wiles 2005) identify an emerging game when a relatively simple set of rules lead to complex game strategies involving different levels.

In general, an emerging game requires a high level of interactivity, to exploit human creativity to find solutions. The emergence in the games is possible by the definition of simple global rules on the behavior and properties of game objects, as well as by the interactions between the game world and players. The emergence of the game allows the game world to become more interactive and reactive, creating a wider range of possibilities for actions and strategies.

Emergent forms are expressed in different ways (Sweetser 2007; Aguilar 2014; Sweetser and Wiles 2005; Johnson 2003; Aguilar et al. 2016):

- An emergence occurs when in a game, based on players’ decisions, appears a pattern of collective behavior, social knowledge, a community result, etc.
- An emergence occurs when the properties of game objects interact to create a completely new game.

This paper focuses on the first type.

On the other hand, serious games are simulations of real-world events or processes, to deal with serious topics or solve a problem (Cruz-Lara et al. 2013; Baskan et al. 2012; Mettler and Pinto 2015). The main purposes of a serious game are to train or educate users, introduce a topic, or broadcast a message (Baskan et al. 2012; Arnab et al. 2015; Wouters et al. 2013). Therefore, it is focused on the audience. In other words, it is any digital game whose main mission is not entertainment, but rather a non-entertainment based purpose. There are different categories of serious games, some of them are (Cruz-Lara et al. 2013; Connolly et al. 2012):

- Educational games: they combine education and entertainment goals, with determined learning outcomes.
- Advergames: is the utilization of games for advertising. This case includes different ways of advertising.
- Simulation games: they are used for the acquisition or exercise of different skills, like behavior teaching, among others.
- Political games: they are designed to educate the public about their rights and obligations as citizens, promote civic behavior, denounce injustices, or promote social awareness. Political groups have used them to communicate some aspects of their campaigns or their governments.
- Games of religion: games to disseminate religious-themed. The most commons are about Christian-themed.

- Games for health: for psychological therapy, cognitive training, and physical rehabilitation, among others.

In general, serious games have been used in different domains: education, military training, healthcare, and many other sectors of society.

Finally, (Aguilar 2014; Aguilar et al. 2019; Aguilar et al. 2018) define the types of emergencies that might occur in an emergent serious game:

1. *Strategies*: new logistics (a series of actions aimed at a specific purpose) and tactics (a procedure that is followed to execute something) are generated, following the rules, laws, and rules of the game, which have not been intended by the game designer.
2. *Sequence/plot*: new plots (the chronological order of various events presented to a player) or thematic (context of their development) is created in the game.
3. *Property*: changes the characteristics and capacities in the objects of the game.
4. *Final*: determines when the game should end.
5. *Business model*: it is the emergence of service models around games.
6. *Utility*: it allows the emergence of how the game will be used by the players in their lives.

In the context of *Metropolis*, the type of emergence used is about properties, such that its properties are modified according to the players' e-participation.

### Simulation of Cities

This is a type of game where the players build and manage a city, with limited resources. Some city simulators are:

- *SimCity*: is a city-building game where the goals are the creation, management, and evolution of cities (Adams 1998; Ferré 2004). The player starts the game with a blank map of the city and expands the city with its budget. The city must provide to its citizens the basic services, such as water, electricity, and urban waste management. In addition, the citizens must have access to health, education, security, and entertainment venues, all represented by different buildings. The main sources of income of the city are taxes, services revenue to the neighboring cities, or special buildings located within the city (casinos, military bases, etc.).
- *LinCity*: the aim is to achieve a sustainable city or build a rocket to escape when the pollution is unbearable (Lincity n.d.). Some constructions and game mechanics help the sustainability of the city (solar power plants, recycling centers, etc.), and others are inherently unsustainable (e.g., landfill, and uncontrolled imports). During the game, the progress in technology generates new constructions to the disposition of the players. Meanwhile, the natural resources are consumed (they are limited), and there is an accumulation of pollution.
- *Opencity*: It is a game similar to *SimCity*, where the player builds a city by marking the land as residential, commercial, or industrial zones, which depend on each other to grow. The player must supply the city with power and connect the zones with roads.

*Metropolis* does not follow the same philosophy of games like *SimCity*, *LinCity*, or *OpenCity*. This is a self-management model, inspirited in the prisoner's dilemma problem. This problem is a clear example of a nonzero sum problem. In this game, it is assumed that each player, independently, tries to maximize their own advantage regardless of the other players (Aguilar et al. 2011). In the techniques of analysis of standard game theory, for example, to determine the Nash equilibrium, each player can betray the other, but interestingly, both players would get a better result if they cooperate (Aguilar 2014).

This is the key point of the game. In *Metropolis*, like the prisoner's dilemma, the cooperation is obtained as an equilibrium result: the game is played repeatedly, which gives to each player the opportunity to punish other players for not cooperating in the previous games. Thus, the incentive to cheat may be overcome by the threat of punishment, leading to a better result, cooperation.

Particularly, in *Metropolis*, the possible outcome of the decision-making process of the players is the increase of happiness if all players cooperate by making decisions based on the general interest of all. This allows raising the satisfaction index of the city. On the contrary, the players will be punished if they decide not to cooperate and maintain their specific interests, leading to the decrease of the satisfaction index. Thus, the decision-making process of the players promotes a collaborative scheme that maximizes their happiness (it improves the satisfaction index of the city).

## E-Participation and Urban Planning in a Smart City

A smart city should be understood far beyond the use of ICTs (Vrabie and Tirziu 2016; de Mello et al. 2016; Chourabi et al. 2012; Vanolo 2014) (Komninos 2018). For example, giving citizens the possibility of online participation in the city's managing activities is an important element of what makes a city smart, not only from a technological point of view but, mainly, as this type of city listens and attempts to satisfy the needs and requirements of its citizens (Graniera and Hiroko 2016; Gurstein 2014).

E-participation is considered to be an essential element for the functioning of a smart city. It helps individuals get involved in the policy-making process, by using electronic means. Classically, the three types of e-participation are (Vrabie and Tirziu 2016; de Mello et al. 2016) (Mellouli et al. 2014; Deakin 2014):

- E-decision-making, empowering citizens on the co-design of policy options and service components
- E-information, enabling the participation of the citizens by providing them with access to information
- E-consultation, engaging citizens in the discussions and contributions on the public policies and services
- In general, the e-participation supports the development of smart cities, providing (Vrabie and Tirziu 2016; de Mello et al. 2016):
- More focused on citizen needs: cities might improve their online public services, in order to meet its citizens' needs and requirements.
- Improved government responsiveness: for a success of the democracies, governments must give good responses to their citizens.

- Greater government transparency: through open government initiatives, where public authorities offer citizens access to government information.
- Increased citizen involvement: social media (Twitter, Facebook, YouTube, among others) are platforms of e-participation and are used both by individuals to share their opinions, as by the government to provide information.

There are several mechanisms of e-participation, for example:

- Electronic voting: also known as e-voting, refers to voting using electronic means in order to automate the task of counting votes. Depending on the implementation, e-voting might use electronic voting machines (EVM) or computers connected to the Internet. The degree of automation is very variable and may cover all the system: vote input, vote recording, data encryption, transmission to servers, and consolidation of results.
- Reputation systems: they are programs that allow users to rate each other, in online communities, in order to build trust through reputation (Sweetser 2007). Some common uses of these systems are on e-commerce websites, such as eBay and Amazon.com. The role of reputation systems is to gather a collective opinion in order to build trust between users within an online community. The reputation systems are very popular in online communities for shopping, advice, and exchange of other important information.
- E-petition (or Internet petition) is a form of a petition that is signed online, usually through a form on a website. Visitors to the online petition sign the petition by adding their details, such as name and e-mail address. Typically, after there are enough signatories, the resulting letter may be delivered to the subject of the petition, usually via e-mail.
- Online communities: is a virtual community whose members interact with each other primarily via the Internet. For many, online communities are a “family of invisible friends.” An online community is an information system where members post, comment on discussions, give advice, or collaborate. Commonly, people communicate through social networking sites, chat rooms, forums, e-mail lists, and discussion boards.
- Online social networking: a social networking service is a web application that people use to build social networks or social relationships with other people who share similar personal or career interests, activities, backgrounds, etc.

This work analyzes e-decision-making, using emerging serious games, in order to introduce, promote, and learn e-participation. This paper is not focused on the utilization of social networks.

Further, urban planning is an interdisciplinary field that includes architecture, civil engineering, and public administration (Komninos et al. 2019). It is a technical and political process related to the development and design of land use in an urban environment. Urban planning considers the physical layout of human settlements, the protection and use of the environment, as well as effects on social and economic activities (Komninos et al. 2019). It is also responsible for the planning and development of water use and resources, rural and agricultural land, parks, etc. This discipline includes different subfields, such as land use planning, economic development, environmental planning, and transportation planning.

Thus, urban planning encompasses the development and design of land use and the environment by guiding an orderly development in urban, suburban, and rural areas. In this context, it is closely related to the field of urban design by providing designs for streets, parks, buildings, and other urban areas. Urban planning is also referred to as urban development, including services like infrastructure, transportation, water, and communications, among others.

There are several city gamings in the context of urban planning. Among the recent publications, (Tan 2018) presents some applications of city gaming in various planning and city-making contexts. The author realizes that city games are helpful to understand urban development and to turn the stakeholders into players who actively influence the urban environment. In (Potts et al. 2017), the authors report the findings of a survey of 994 Australian players about whether augmented reality games affect user needs in public spaces and the implications for urban practitioners. The paper is based on the Pokémon Go, because it has succeeded to entice people of all demographics into the streets of cities around the world. In (Stephens 2016), they discuss about urban planning games, considering that early games were based on a linear (mechanical) approach to urbanism. The authors consider that today's computer simulations allow various degrees of autonomous system interactions, which give the ability to mirror more integrated urban systems and explore a wide range of scenario planning alternatives. They consider that future simulations will include more autonomous interactions and, eventually, artificial intelligence-designed environments. This is our case with *Metropolis*.

In a smart city, the urban planning is a collaborative process, where its citizens participate in the process of its construction using e-participation tools. *Metropolis* tackles this aspect using adaptive mechanisms based on its emergent properties.

## Game Description

This section introduces *Metropolis*, particularly its philosophy, rules, and components: types of buildings, the personalities of the players, the determination of the development, and happiness index, among other issues.

### Game Philosophy

The crucial aspect of the game is that each player is encouraged to benefit individually (Aguilar et al. 2011; Aguilar et al. 2016). But, inspired by the prisoner's dilemma, cooperation is crucial in this game; it allows the balance between the wishes of all, leading to collective happiness (the cities are punished when the people do not cooperate as the quality of the city will be worse). In *Metropolis*, the happiness of each player is linked to the required buildings according to their personality. For example, if the player has health problems, it would require health buildings. Hence, the percentage of health buildings in the city determines the happiness of this player. Finally, the happiness of the city is the average of the happiness of all players. Thus, the incentive to cooperate emerges as the city must have the characteristics where all players feel better (consensus of the community life). In general, the game has the next elements:

- Players: each one represents a citizen community (residents of a neighborhood, individuals with common interests, social networks, among others).
- Council: decision-making space of the communities in the game.
- Other agents: they represent social groups, artificially created by *Metropolis*, with a random profile of characteristics.
- Buildings: the constructions that can be in a city, which the players in the council decide to build according to their interests (profiles).

The basic element of the game is the decision-making: the council. In the council, each agent belonging to a group has the opportunity to vote for or against certain types of building constructions, using the city budget (shared by all). There are two types of agents, one representing the players and other randomly generated and controlled by the game. Personalities are assigned to the agents, and they determine the types of construction that are more interesting for them, both to build as to vote in the council. The city evolves when the agents decide to build or destroy. Thus, each player's action directly affects the city.

In essence, each player represents a percentage of the city population (a community). When someone wants to build in the city, the project is submitted to the popular vote in the council. The game has a scoring system calculated each year. The score is based on the development rates in the city as well as on the happiness of its population (the happiness of all the agents affects the happiness index). The development rates of the city are measured according to the balance between the different areas of improvement (environmental, educational, industrial, etc.). They are individually assessed and added to determine the development rate of the city. Moreover, people's happiness comes directly from the agent's happiness.

### Game Rule

The game can be played with one or more players in one or more teams (each agent represents a team). The players set a time limit, which is the number of years to finish the game. Each agent may vote for or against the construction of a particular building, in a specific area.

Every city has 10 agents, where at least 5 are artificial to simulate the portion of the citizens who cannot be controlled by the players. These agents are randomly generated and make decisions in the same way that the non-artificial agents. These non-artificial agents have personalities randomly created or user-defined (see below this explanation). The players can request to build the facilities they want in their preferred areas by specifying the coordinates. The features of the city to calculate its development rate are health, education, environment, trade, industry, and technology.

### Characterization of the Building

Each type of construction in the map box (coordinate) is represented with a numeric value. Furthermore, each type of construction will have a certain effect on the game and the surrounding area. Table 1 shows the details of the buildings available in the city (determine its effect): the coverage radius of each building in the city; the cost of the construction, to which group they belong; and the bonus or penalty that it gives to the development rate.

*Metropolis* has two types of buildings: the primary buildings add/remove points to the development rate, and the secondary buildings add/remove a percentage of points from the development rate. As is noted above, every building has a radius of action, which for simplicity is a diamond, with a diagonal length of twice the number given in Table 1. While the range of two identical buildings (primary/secondary) is not intercepted, the buildings will bring their total score. When there is an interception, then the positive bonus declines 50%, while the negative remains unchanged.

## Personalities of the Agents

At the beginning of the game, players must choose four types of personalities. Artificial-agent personality types are randomly chosen or selected by the player. The personality determines the behavior of the agent during the game.

The performance of the players differs between humans and artificial agents. In the case of humans, it is used to calculate the happiness of the player. For artificial agents, it determines their happiness and their behaviors during the game (e.g., an artificial agent which is an environmentalist always votes against proposals that include harm to the environment).

The personalities of an agent determine its basic needs (happiness). For a given agent, the non-activated personalities remain by default at a normal level

**Table 1** Radios, bonuses, and penalties, for each construction type

| Number | Type | Group | Radius | Bonus | Penalty | Cost |
|---|---|---|---|---|---|---|
| 0 | Empty | – | – | – | – | – |
| 1 | Tree | – | – | +1 environm. | – | 20 |
| 2 | Home | – | – | – | – | 500 |
| 3 | Street | – | – | – | – | 40 |
| 4 | Health institution | Primary | 7 | + 250 health | - | 7000 |
| 5 | Educational institution | Primary | 4 | + 150 educat. | – | 4000 |
| 6 | Environm. institution | Primary | 7 | + 100 environ. | – | 4000 |
| 7 | Commercial institution | Primary | 2 | + 50 commerc. | – | 5000 |
| 8 | Industry | Primary | 7 | + 200 industry | − 75 environ. | 7000 |
| 9 | Technological institut. | Primary | 3 | + 170 technol. | – | 3000 |
| 10 | Health institution | Secondary | 2 | + 15% health | - | 1000 |
| 11 | Educational institution | Secondary | 2 | + 10% educat. | – | 800 |
| 12 | Environm. institution | Secondary | 2 | + 12% environ | – | 800 |
| 13 | Commercial institution | Secondary | 1 | + 7% commer. | – | 600 |
| 14 | Industry | Secondary | 3 | + 18% industry | − 8% environ. | 1000 |
| 15 | Technological institut. | Secondary | 2 | + 10% technol | – | 800 |

**Table 2** Personality types and indexes of happiness

| Personality | Health | Education | Environm. | Commerce | Industry | Technol. |
|---|---|---|---|---|---|---|
| Hypochondriac | 1250 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Healthy | 750 | 1000 | 1000 | 1000 | 1000 | 1000 |
| With difficult. | 1000 | 1250 | 1000 | 1000 | 1000 | 1000 |
| Self-taught | 1000 | 750 | 1000 | 1000 | 1000 | 1000 |
| Indifferent | 1000 | 1000 | 1250 | 1000 | 1000 | 1000 |
| Environmentalist | 1000 | 1000 | 750 | 1000 | 1000 | 1000 |
| Saver | 1000 | 1000 | 1000 | 1250 | 1000 | 1000 |
| Buyer | 1000 | 1000 | 1000 | 750 | 1000 | 1000 |
| For industry | 1000 | 1000 | 1000 | 1000 | 1250 | 1000 |
| Against industry | 1000 | 1000 | 1000 | 1000 | 750 | 1000 |
| Antiquated | 1000 | 1000 | 1000 | 1000 | 1000 | 1250 |
| Geek | 1000 | 1000 | 1000 | 1000 | 1000 | 750 |

(1000 points), while for the activated personalities, the range is 1250–750 points. Table 2 shows the personality types (saver and healthy, among others) and the relationship with the type of buildings to calculate the happiness of a player. For example, the happiness index for a healthy player is 750 regarding health buildings (that means, it does not require a large number of health buildings in the city).

## Council

The council makes decisions based on each player's preference, according to the personalities of the agents who vote for or against a building. The votes of 10 players set the decision. Thus, the decision will be determined by majority vote.

## Assessment of the Proximity of Buildings

Table 3 specifies the penalties or bonuses related to the proximity of certain types of buildings. Proximity is related to the distance between construction types. For example, the game awards a bonus for types of buildings that players prefer to group together; otherwise, it issues a penalty. Hence, *Metropolis* promotes or penalizes the clustering of certain types of construction projects in the city. It allows defining zones (e.g., industrial zones, educational campuses) since buildings attract other buildings with similar functions. For example, the proximity of a hospital (primary healthcare) to an industrial building would result in 6 points of penalty applied to *both* buildings based on their proximity. In contrast, if a research center (technological institution) is built near a school or university (educational institution), both construction projects would receive a bonus of 3 points. The area that each type of building covers determines its proximity (see Table 1).

## Total Score of a Development Index

In a city, each development index is linked to a type of personality and building. For example, for a higher development index in education, the city must have a large number of primary and secondary educational buildings. It is determined by the impact of each building (and the number of them) in the city's development, derived by the bonus or penalization of each type of building in each type of development (see Table 1). In general, the total score for each development index j is calculated as:

$$PT_j = \sum_l \sum_i \left( \mathrm{PC}_{ij}^{l} + \sum_s \mathrm{CER}_{\mathrm{si}} \right) + \sum_m \sum_k \left( \mathrm{PC}_{\mathrm{kj}}^{m} + \sum_s \mathrm{CER}_{\mathrm{sk}} \right) \quad (1)$$

where $l$ are all the primary buildings and $m$ the secondary buildings in the city, respectively; $CER_{ik}$ are the bonuses or penalties depending on the proximity of the buildings $i$ and $s$ (or k and s, respectively) according to Table 3 (it determines the closeness between two buildings if not more than 3 boxes there are among them). $PC_{ij}$ is the total score of a building $i$ for a development index $j$ in which it influences (see Table 1). So, Table 1 defines the value of PC (fifth and sixth columns) and Table 3 the value of CER. The development index (PT) considers the relationship between a given development type and the buildings in the city as well as the closeness of the buildings. Thereby, the total score of an index is calculated.

## Calculation of the City Happiness

Next, the happiness of the city is calculated. Therefore, *Metropolis* determines the relationship among each development index of the city (calculated previously) with the

**Table 3** Bonus and penalty according to the proximity of the types of construction

| | P Heal | P Ed | P En. | P Com. | P Ind. | P Tec. | S Heal | S Ed | S En. | S Com. | S Ind. | S. Tec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P Heal | −4 | | | −2 | −6 | | +3 | | | | −4 | |
| P Ed | | | | | −4 | +3 | +3 | +3 | | | −3 | +3 |
| P En. | | | | | −3 | +2 | | | +3 | | −2 | |
| P Co. | −2 | | | | −3 | | | | | +3 | −2 | |
| P Ind. | −6 | −4 | −3 | −3 | | −3 | −5 | −3 | −3 | −3 | +3 | −3 |
| P Tec. | −2 | +3 | +2 | | −3 | | | +3 | +2 | | −2 | +3 |
| S Heal | +3 | +3 | | | −5 | | | +3 | | | −3 | |
| S Ed | | +3 | | | −3 | +3 | +3 | | +2 | | −3 | +3 |
| S En | | | +3 | | −3 | +2 | | +2 | | | −2 | +2 |
| S Co. | | | | +3 | −3 | | | | | | −2 | |
| S Ind. | −4 | −3 | −2 | −2 | +3 | −2 | −3 | −3 | −2 | −2 | | |
| S. Tec. | | +3 | | | −2 | +3 | | +3 | +2 | | | |

(*P Heal* primary health, *S Ed* secondary education, and so for the rest) personality of each player, and the overall constitutes the happiness index of each player. The calculation of the score of the happiness index for each player's $p$ is:

$$VI_p = \sum_j \frac{1000 * \mathrm{PT}_j}{\mathrm{TRJ}_{\mathrm{pj}}} \quad (2)$$

where $TRJ_{pj}$ is the total required by the player $p$ for the index $j$, according to its personality (see Table 2). The general happiness index of the city is the average of the happiness index of each agent.

## Experiments

This section defines several experiments with Metropolis, in the context of e-participation in a smart city. Each scenario tests a different characteristic provided by the utilization of *Metropolis* as an e-participation tool for supporting the development of a smart city. For the experiments, it is assumed that each player represents a community of the city, with its respective personality.

It is defined as a hypothesis that the emergence in a smart city is highly important since it allows the adaptation of the smart city to the necessities of its citizens. *Metropolis* is tested in two contexts: First, if the citizens (players) can learn about the importance of e-participation in democratic decision-making processes, and second, if e-participation generates in a smart city emergent behaviors or characteristics, particularly, urban patterns based on collaborative urban planning. Therefore, it is proved if e-participation contributes to the emergence of urban planning in a smart city and if *Metropolis* is suitable for teaching e-participation in the context of decision-making.

### Case 1: The Emergence of Urban Patterns

In this first example, we set up the playing time in 3 years and the number of real players in 2 (the rest of the players are artificial agents managed by the game, see "Simulations of Cities" for more details). In general, the personalities of the players are randomly generated. In the upper right of Fig. 1, below the turns (shift) button (*Proximo Turno*), there is information about the current turn (*Turno 1 de 36*) and the current player playing (*jugador 1 de 2*).

Each game turn represents 1 month for each one of the players. In this experiment, since it selected 3 years of play, the game will have 36 turns before to finish. Every 12 months, a window will show the development rates of the city, as is shown in Fig. 2. For that first year (see Fig. 2), in this example, the higher development rates were for education (13%), technology (22%), and industry (12%).

At the end of each year, an amount of money to the city budget (equivalent to taxes, donations, etc., received by the city) is added. Similarly, the development index changes each year (see Fig. 3, the development index of the second year). At the same time, it starts the emergence of urban patterns (e.g., zones with only educational institutions). Figure 4 shows the emergence of the industrial zone on the left side, from turn 29. Figure 3 depicts an increase in all the indexes, especially in education. The

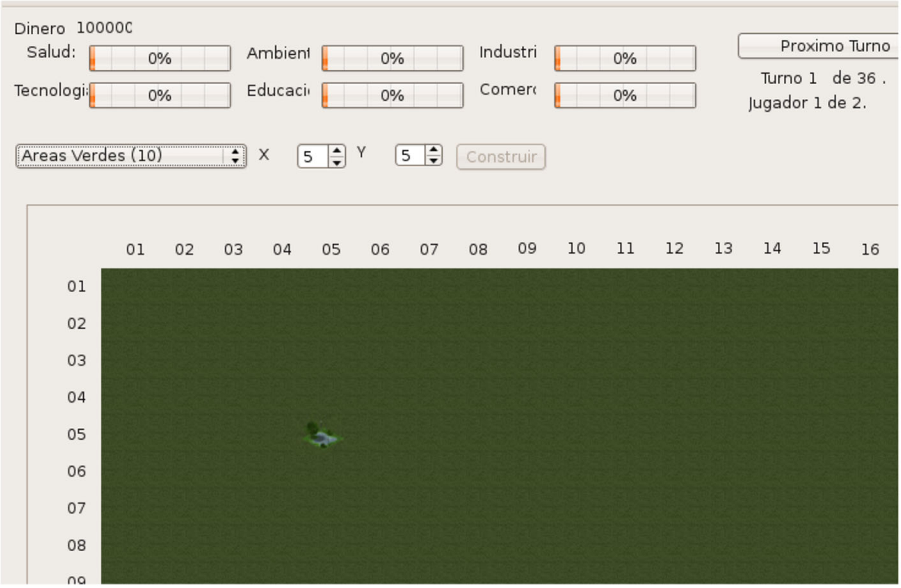


**Fig. 1** The initial screen of Metropolis (*Dinero* = money, *jugador*= player, *turno* = turn)

different figures in the green zone represent the different types of buildings in the city. Each represents an educational or health institution, among other possible institutions enabled in *Metropolis* (see the different types of buildings in Table 1).

Once the game is completed, we studied the density of each type of construction/building in the city, which is understood as the number of buildings concentrated in a territorial space. Figure 5 indicates the density of educational institutions in the city when the game finishes.


**Fig. 2** Development index of the city for the first year (the results are *Salud* = health 9%, commerce 4%, *Ambiente* = environment 9%, etc.)


**Fig. 3** Development index after 2 years

The densities show an emerging urban behavior as a result of the decisions made by the agents. There are emergencies of urban zones, according to the profile of the players' personalities (communities in the city). This behavior consists of patterns generated in the city, where similar buildings are grouped in the same zone (see Table 3).

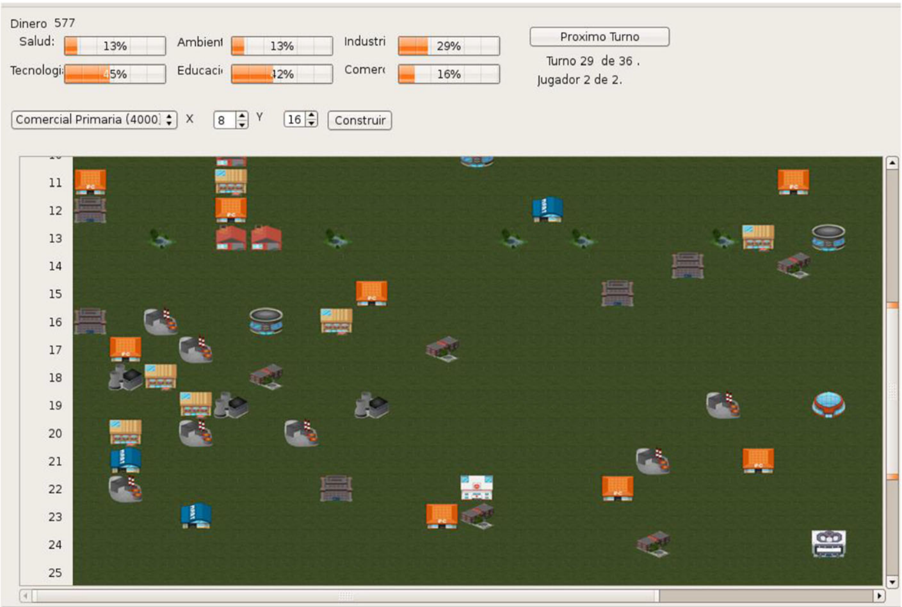


**Fig. 4** Case 1, turn 29

*Metropolis,* as a tool for e-decision-making in a smart city, shows the emerging patterns as the product of the city adaptation to its citizens. The patterns are determined by the collective decisions of their citizens, and if it is assumed that their decisions depend on their personalities (they describe their needs and requirements), then it is an adaptation process of the city.

This aspect is highly relevant since the recognition of urban patterns in a smart city can support the definition of public policies, the local urban planning, etc. Hence, the city can make intelligent decisions about the next inversions, social rules, among others, to be included in the city planning. Particularly, *Metropolis* as an e-participation tool, allows the development of a smart city more focused on citizen needs (see "E-Participation and Urban Planning in a Smart City" and (Vrabie and Tirziu 2016), where the pillars of e-participation in a smart city are explained).

In general, in this first case, it is shown that e-participation allows the emergence of urban patterns in a context where *Metropolis* enables the citizens (players) to learn its importance. It is proved the behavior of *Metropolis* as an emerging serious game to educate about e-participation.

### Case 2: The Study of City Patterns for the Specific Needs of an Agent

For the second case, the agents 6 and 8 are configured, and the rest is generated randomly. The playing time is 2 years, and the number of players is 4 (the others are artificial agents, see "Game Rule"). The configurations of the agents 6 and 8 are:

- Agent 6: difficulties in education, industrial, and hypochondriac
- Agent 8: hypochondriac, environmentalist, thrifty, and self-taught

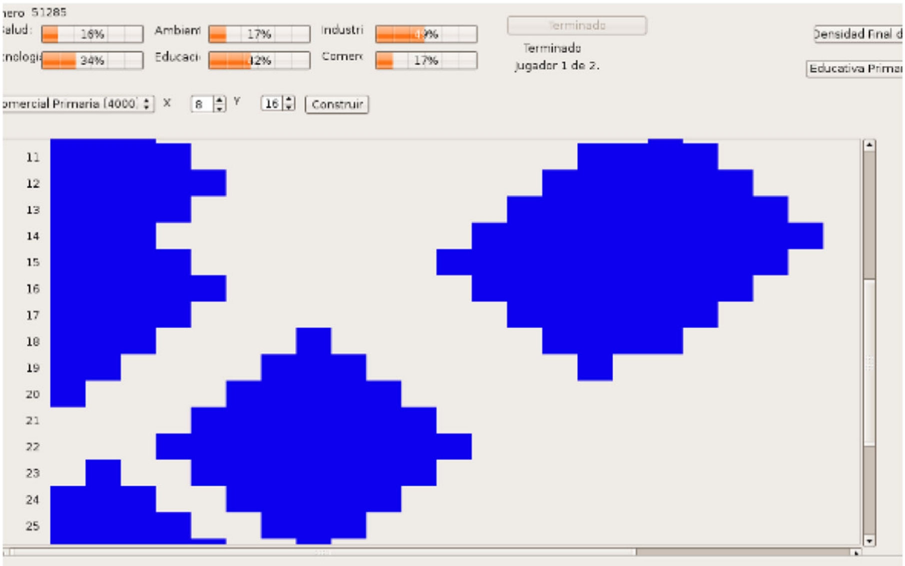


**Fig. 5** Density of the educational institutions in the city

In this case, the personalities are almost all different to test how the game allows reaching an index of happiness that satisfies agents with different characteristics.

Figure 6 shows the state of the buildings in the city when the game has finished. The results of the development indexes of the city for the first year are as follows: health 27%, commerce 0%, industry 33%, environment 8%, education 9%, and technology 6%. In the second year, the development indexes are as follows: health 34%, commerce 4%, industry 41%, environment 8%, education 23%, and technology 11%. Similar to Fig. 4, the different figures in the green zone represent the different types of buildings in the city.

The final results of the city are consistent with the personalities of the agents, because their main necessities were in health, education, and industries (see Fig. 7). It is observed as a pattern emerges in the city that satisfies those needs. In the case of the industrial index, even when there is an environmentalist (agent 8), we obtain an industrial rate (41%) higher than the environmental rate (8%), because the rest of the players are industrial (the agent 6 and the artificial agents).

It is another type of emergence: the personality of the city is the union of the different personalities of each agent. This personality is used to achieve a common goal in a smart city: improving the development rate of the city. Figure 7 shows how the personalities of the agents are translated into a pattern of the city (its personality). That constitutes the behavior pattern appropriate for its citizens. We could calculate an overall happiness score to the results that might hide the happiness profile of each player, which is important to consider in the emergent process of the city since it describes the aspects more relevant of each player (e.g., the ecological aspects for the environmentalist).

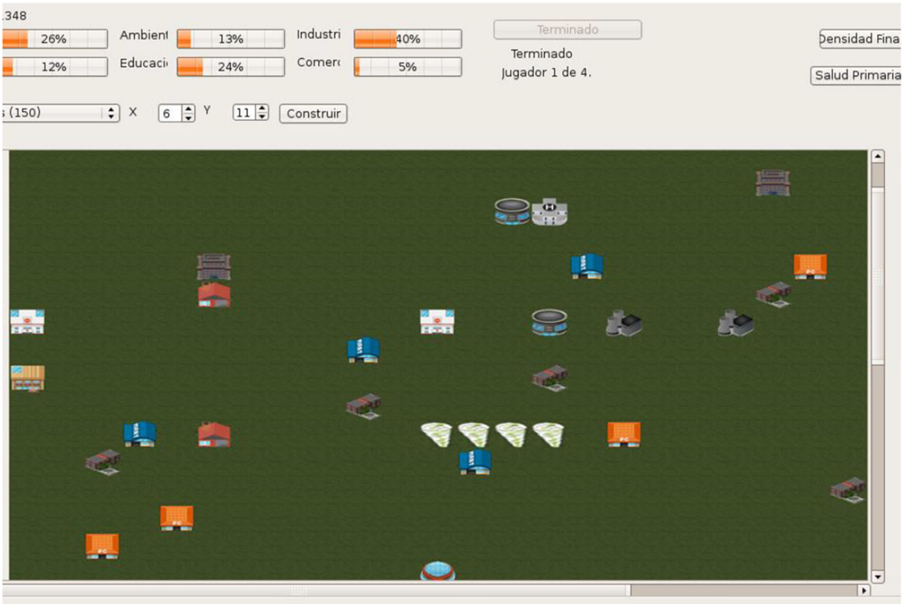


**Fig. 6** Map of the city when the game has finished for the second case

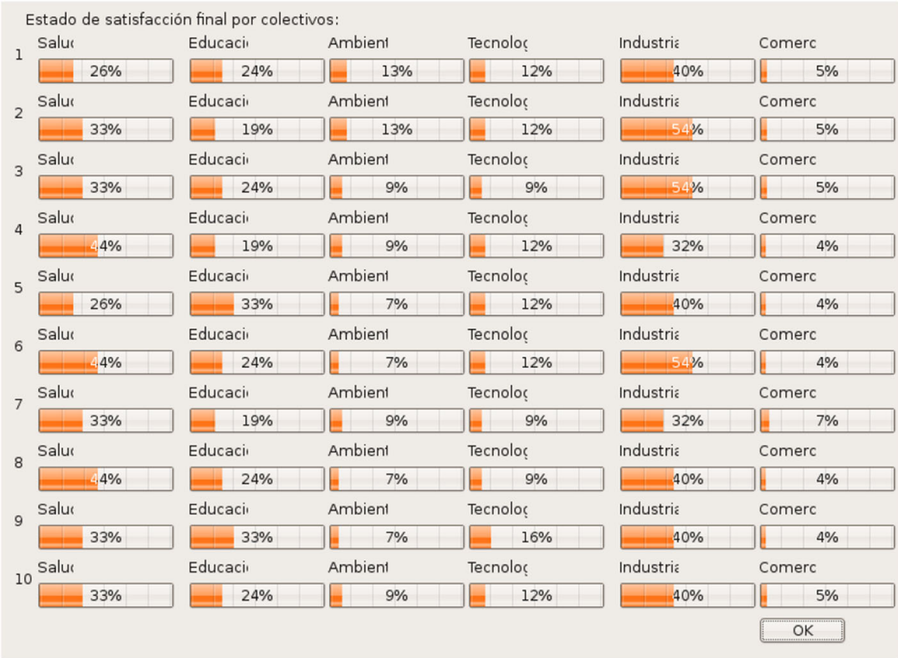


**Fig. 7** Case 2: Happiness for the agents (*Estado de satisfacción final por colectivos* = state final satisfaction by collective)

The personality of a city guides the interest to be included in the city planning. This personality specifies the requirements and necessities of the citizen. A smart city must plan the way to reach them.

*Metropolis,* as an e-participation tool, enables the development of a smart city more focused on citizen needs. Additionally, it increases the citizen involvement and their capacities, due to the learning process about collective decisions immersed in the "emerging serious game." It is transparently developed (see (Vrabie and Tirziu 2016) for more details about the pillars of e-participation in a smart city).

In this second case, Metropolis analyzes two relevant aspects: First, the importance of e-participation of the citizens in a smart city for democratic decision-making processes; and second, how the smart city can adapt to the real necessities of its citizens. The results of the game revel to the players that their participation in the life of the city is essential if they want the city to adapt to their needs. Thus, e-participation in a smart city allows the adaptation of the city to its citizens. It is made in a context where *Metropolis*, as a serious game, enables the learning about the importance of e-participation.

## Metropolis in the Context of E-Participation

We have made several experiments about the decision-making process for different characteristics of the players. In that sense, we suppose two player types:

1. Players representing social communities
2. Players representing individual interests

And the profile relationships among the players can be:

A. Antagonistic interests
B. Similar interests
C. Different interests, but they do not collide
D. Different interests, but they need to collaborate

The combinations of the different profiles (characteristics) of the personalities are chosen, in order to analyze the effects during an urban planning. In this way, we can study the implications of the contradictions in the profiles or the combination of certain characteristics, among other things.

Based on them, we show the happiness indexes that emerge in the city (see Table 4). These are the satisfaction index of the city, once the game is over. Each result represents the average of ten games for each scenario.

According to Table 4, the players that represent the community interests always give the best results (cases 1). Additionally, when the individuals follow their interest and they do not collaborate, then the satisfaction index of the city is very bad (cases 2-A and 2-C). In general, a collaborative decision-making process for urban planning allows a higher satisfaction index in the city. At this point can be determined that the collaboration is the best option to obtain an adequate urban planning for all citizens (see in Table 4 1-D and 2-D), no matter if there are antagonistic interest or not.

### Relationship Between Metropolis and Smart Cities

The previous scenarios allow us to verify our hypothesis about the important role that the emergence plays in a smart city; mainly, the emergence allows the smart city to adapt to its citizens' needs.

On the other hand, the main feature of the smart cities is the use of ICT in all aspects of their life (Chourabi et al. 2012; Vanolo 2014). But one point of tension in the smart cities concerns the citizens' "engagement" or "participation" and the relative weakness of both actual practices and research results related to these issues (Graniera and Hiroko 2016; Gurstein 2014). In this regard, e-participation is a core element in the process of

**Table 4** Satisfaction index of the city for different types of players

| Scenario | Satisfaction index of the city |
|---|---|
| 1-A | 25.3 |
| 2-A | 3.2 |
| 1-B | 69.4 |
| 2-B | 10.3 |
| 1-C | 24.7 |
| 2-C | 8.6 |
| 1-D | 30.2 |
| 2-D | 16.7 |

developing communities for a socially inclusive governance (Vrabie and Tirziu 2016; de Mello et al. 2016; Mellouli et al. 2014). The e-participation is inclusive if it is focused on the citizens' needs and requirements. Although technology is a main e-participation element, it is necessary to consider the capability and willingness of citizens and the collaboration of the public institutions, in the decision-making processes.

In this way, the e-participation is a tool for the engagement and the collaboration between the citizens in the governance (Gurstein 2014). The e-participation can be (Vrabie and Tirziu 2016; de Mello et al. 2016; Graniera and Hiroko 2016):

- In the context of the administration, in order to participate in the governance of a region
- In the context of the definition of public policies and in its execution and observation
- In the context of service delivery, in order that the citizens can participate in the provision of services but, also, in their use
- Finally, in the context of the decision-making processes, where democratic schemes are required

In this last case is where Metropolis can be used, in order to teach about the different aspects to consider in the decision-making process: the components, the control mechanisms, the citizen roles, etc.; all necessaries for a real democratic decision-making process are guided by the collective goals of a society.

The Metropolis game allows the training in the participation in democratic decision-making processes. In this way, it is a serious game where the players can learn to make collective decisions, where the common goals are more important than individual goals. With Metropolis can be learned to define these common goals, to make rational collective decisions (based on the goals), etc.

Metropolis can be used to define these common goals, where the specific aspects of the citizens with the collective goals of the society must be balanced. Specifically, Metropolis allows:

- Learning about the importance of the e-participation in the context of a smart city, in order to consider the real necessities of the citizens (serious game)
- Being used as a mechanism of democratic decision-making in the city (e-participation in a smart city)
- Showing the emergence of behaviors in a smart city, due to its adaptation to the necessities of its citizens, which generates urban patterns in the city and set of general features in the city (personality), among other things (emergent game)

The previous experiments show these capabilities of Metropolis, which can adapt a smart city to its citizens.

## Conclusions

The city is a living entity that is constantly changing and evolving (Sweetser and Wiles 2005). How its residents interact generates effects that can be analyzed at a deep level.

We face a phenomenon in which simple behaviors generate complex organization and patterns on a larger scale (Sweetser and Wiles 2005). The underlying factor at play is the exchange of information between urban components.

The city is a dynamic system whose evolution does not depend on one, two, or several agents, but rather depends on what emerges within it as the product of the collective decisions of its agents producing upward forces that directly affect its overall structure. These forces are unpredictable (Aguilar 2014; Sweetser and Wiles 2005). Particularly, urban planning is a collaborative process that has been studied in previous city gaming (Tan 2018; Potts et al. 2017; Stephens 2016). The originality of *Metropolis*, as an emergent game, is its adaptation to the players' behavior, which allows its use in any urban planning context guided by e-participation.

*Metropolis* studies the dynamics of the city. City behaviors emerge from the decisions made by its agents regarding the construction types of their interest. The behaviors that emerge correspond to urban patterns configured within the city structure; e.g., certain buildings attract similar constructions within their proximity, resulting in the emergence of urban zones composed of like buildings. Another behavior is the pattern of the city, reflected in its development rate. Towards the end of the game, the city's pattern stabilizes to incorporate the needs arising from the fusion of the residents' personalities within the society, combining in some way these personalities.

This paper presents the use of *Metropolis* as an emerging serious game in a smart city. Particularly, its emergent behavior produces two relevant results (Aguilar 2014; Perozo et al. 2013a; Perozo et al. 2013b; Perozo et al. 2012): urban and citizen patterns of the city. They are built as results of the game, and a smart city can extract and use this information for its urban planning. Especially, *Metropolis* allows building these patterns during the self-management of a smart city.

The paper shows the advantage of a collaborative decision-making process for urban planning to gain a higher satisfaction index in the city. Urban planning involves complex relationships among citizens. Here, *Metropolis* allows the analysis of this complexity to study the power relations and the real collaborations, for developing creative collaborative strategies.

In conclusion, *Metropolis* is an "emerging serious game," which can be used in a smart city with several goals. It is an e-participation mechanism to reach consensus opinions to build a collective urban vision of the city considering the interest of the citizens. Among the educational aspects, *Metropolis* allows learning about collaboration and co-dependence in the planning process, as relevant points for building a new type of citizen. Moreover, its utilization as an e-decision-making tool allows the emergence of urban patterns, a product of the adaptation of the city to its citizens, enabling the development of a smart city more focused on citizen needs. *Metropolis* might be used to envision future urban scenarios, according to the alternative decisions that can take their citizens. Its adaptive capability based on its emergent property permits its use by urban planners.

Hence, the contributions of this work are several. It defines the importance of e-participation in the context of decision-making processes in a smart city. It has also shown the utilization of *Metropolis* as a serious game to teach citizens about e-participation in a smart city. Finally, it describes the emergence of characteristics in a smart city (e.g., city patterns, urban spatial distribution) due to e-participation.

This last aspect is outstanding as the emergence is a core characteristic in a smart city for developing a behavior adapted to the citizens' necessities (Aguilar 2014). Additionally, *Metropolis* allows teaching about the democratic collective decision-making processes and understanding the different aspects considered in these processes, e.g., budget management and interaction mechanisms, among other aspects.

Future works must explore extensions to this study, such as the use of *Metropolis* with the social networks to include a massive participation of citizens. Also, future studies must analyze the new perspectives generated by the urban and citizen patterns through serious games, for urban planners and researchers.

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