Introducing the Smart City to Children with a Tangible Interaction Table

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Expliquer la ville intelligente aux enfants avec une table d'interaction tangible

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ABSTRACT

Smart Cities come as a solution to the urban challenges faced by the territory. They have grown in popularity in recent years and are now an integral part of the development strategy of many cities. However, this concept remains fuzzy to the larger public whose participation in the smart city is however crucial to its success. To address this issue, an activity has been created to educate children to this concept. The central part of this activity is the construction of a paper-based city model which serves as discussion support for the remaining of the activity. However, the evaluation of the activity revealed that this paper-based support lacks interactivity and does not offer a dynamic and clearly visible response to children's decisions, and therefore provides only limited input to the discussions. We propose to replace the paper city model with a tangible tabletop interface to overcome this problem. This article presents the design of the interface.

CCS CONCEPTS

• **Human-centered computing → Information visualization**; **Displays and imagers**; • **Applied computing → Collaborative learning**.

KEYWORDS

Smart city, Education, Tangible interaction

RÉSUMÉ

Les villes intelligentes se présentent comme une solution aux défis urbains auxquels font face le territoire. Elles ont grandit en popularité ces dernières années et font aujourd'hui partie intégrante de la stratégie de développement de nombreuses villes. Cependant, ce concept reste flou pour le grand public, dont la participation à la ville intelligente est pourtant cruciale pour son succès. C'est pour répondre à ce problème qu'une activité d'éducation à ce concept destinée aux enfants a été créée. Une partie centrale de cette activité est la construction d'une maquette de ville en papier servant de support de discussion pour la suite de l'activité. Cependant, l'évaluation de l'activité a fait ressortir que ce support papier manquait d'interactivité et n'offrait pas de réponse dynamique et clairement visible aux décisions des enfants, et donc n'alimentait que de façon limitée les discussions. Nous proposons de remplacer la maquette de ville papier par une table d'interaction tangible afin de pallier ce problème. Cet article présente la conception de cette table.

MOTS-CLÉS

Ville intelligente, éducation, interaction tangible

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1 INTRODUCTION

Giffinger [9] writes that the smart city refers to "the search and identification of intelligent solutions which allow modern cities to enhance the quality of the services provided to citizens." Many other authors give a more central importance to ICT when defining the smart city, which resulted in smart cities being systematically linked with, and even defined solely by, the presence of technology in the city. However, the initially technological orientation of smart cities fell short due to its failure to take into account the specificities of their territory and their citizens' needs when pushing solutions [7]. Scholars, increasingly joined by practitioners, argue that smart city solutions should emerge from citizens' needs, and that the participation of citizens in the design of these solutions is essential to their success [15]. As a result, citizens are more and more expected to take an active role in the smart city and many methods have emerged to enable this participation such as workshops, living labs, and online platforms [21]. However, the ins and outs of this concept remain unclear to the larger public due to the plethora of definitions qualifying it and to the fuzziness of political discourses around smart cities [1, 4]. This is problematic, as citizens cannot feel concerned by a concept they do not understand. This issue is also a political transparency one because smart cities are increasingly included in territory development strategies, and therefore drive political decisions and consume public money.

When discussing citizen participation, it is often assumed that citizens are adults. However, children are an important subgroup of the citizenry and should be sensitized to the concepts of smart city and participation as well. Indeed, such preparation would be beneficial to their future participation as adults [5, 6] and is essential to prevent participation divide [11]. In addition to preparing children to adult participation, it is also important to enable them to participate before. Children participation is beneficial to the democratic vitality of cities [12, 13] and is also part of their fundamental rights according to the UNICEF [19]. Still, in practice, children are left behind in participation initiatives.

While there is a need to introduce the concept of smart city and its participative implications to citizens and especially children, this perspective is to the best of our knowledge missing in the literature. To address this issue, we have developed an education activity to introduce the smart city concept and citizen participation to 12-14-year-old children [22]. It takes the form of a workshop given over two separate sessions, each lasting 100 minutes. The workshop is composed of three steps. The first two steps take place over the first 100-minute session, while the second session is fully dedicated to the third step. **Step 1** is a theoretical introduction to the smart city concept. It is supported by a poster presenting the definition of the smart city on which the workshop is based. It defines a smart city as "a city that uses innovative solutions (involving or not technology) to meet the needs of the citizens living there." The poster also presents the six smart city dimensions defined by Giffinger, which list the domains in which the smart city paradigm intervenes. The dimensions are mobility, economy, living (i.e. well-being), governance, people (i.e. human capital), and environment. This set of dimensions is well-known by practitioners and is often used in communication related to smart cities. Then, some examples of smart city projects are discussed with children who have to assign the right dimensions to each project. This introduction helps framing the scope of the smart city. **Step 2** is the construction of a city model which serves as common ground for discussions in the rest of the activity. Children are divided into four groups and are provided with a box containing 15 buildings. They are then presented with an empty paper city map on which they will put buildings of their choosing to build the mock city. Each group has to reach an agreement on three buildings to place on the map, for a total of 12 buildings. In **Step 3**, children reflect on the completed city model and attempt to identify issues that citizens who would live in that city could face. Then, they agree on one issue to address and elaborate a tentative solution to this issue. They are provided with block programming interfaces suitable for novices (i.e. micro:bit and Makeblock) to help them prototype their solution.

The evaluation of this activity showed success in improving children's understanding of the concept as well as interest for participation and mature discussions around it [22]. However, one major issue that arose is the lack of depth of the debates around the city model, which is limited by its low interactivity. Indeed, when placing a building on the model, no information on the impact of the building is rendered, which makes it difficult for children to ground their discussions. Instead, the debates were driven by children's personal preferences or by high-level questions such as the overall concentration of buildings. We aim at addressing this issue by proposing a collaborative tangible interface to support the city model construction as an alternative to the current paper-based approach. This article presents the preliminary results of the research efforts undertaken in this direction.

Figure 1: Example of a city model built by children during one session of the activity (reproduced from [22])

2 CONTRIBUTION

The search for improvement leads started by an analysis of several city construction games that incorporate smart city related issues such as environment. The researchers who developed the original activity [22] explain that they have developed it by analyzing the literature. Therefore, in order to search for leads in a complementary way, we stepped back from the literature and we made a selection of games (including both board and video games) using non-academic search engines. From our analysis of five games and of the original activity, one trend emerged. Board games are successful in sparking debate and fostering interaction between participants. However, they involve paper and plastic items which fail at giving a dynamic and visual response to participants' actions. On the contrary, the strength of video games is that the impact of participants' actions can be displayed visually and in real-time, but collaboration and discussions are impeded by the use of individual machines.

The best of both worlds could thus lie in collaborative technologies. One of such technology is tangible interaction, which has been reported in the literature as especially suited for collaborative work and discussions [16, 20], and implemented in the classroom environment [14]. Previous studies have demonstrated the high potential of such systems in supporting learning activities for children [2, 18], including in a classroom setting [18]. Dillenbourg and Evans [8] discuss the advantages of tabletops in supporting educational activities. Among others, they report that tabletops are designed to support multiple users, for co-location, and for hands-on activities, which are essential aspects of the smart city introduction activity that our proposal should preserve. Furthermore, tangible interaction has been successfully applied to urban planning activities [23], which are related to the city model building part of the smart city introductory activity.

We envisioned the improved city model as an interactive table onto which an empty city map would be projected. The buildings placed on the table would then be recognized by a unique identified and data on the impact of the building on e.g. road congestion or pollution could be projected onto the city map to fuel the discussions.

We chose to develop the table using the reacTIVision framework [17]. The tables using this framework are all based on a similar architecture. A camera placed below or above the table captures the movements of specific fiducial markers. A computer containing the client application captures these movements and interprets them. Via a projector, a visual representation is finally produced and displayed on the table screen. reacTIVision is an open source framework that defines a common API for interactive surfaces. The abstraction it offers allows the rapid development of functional interfaces for this type of medium.

The table has to be usable by 12-14-year-old children and the activity has to fit within two class hours due to field constraints. Therefore, interaction needs be kept as simple as possible and children should be able to use the table without time-consuming training beforehand. For these reasons we designed only two types of fiducial markers, namely the buildings and the domain views. The buildings were not changed from the original activity. They were selected by the authors to ensure sufficient diversity, and the authors reported no issue regarding this selection occurring during the sessions of the activity. The domain views are related to one specific domain such as mobility or environment and, when placed on the table, act as filters showing the impact of all present buildings on the domain they represent. Domain views have a circular shape allowing them to be quickly differentiated from the buildings.

The challenge was to ensure a complete coverage of the smart city dimensions [10] while not inducing too much complexity in the activity. Therefore, eight domains were selected. **Mobility** describes the impact of buildings on road congestion, in terms of how many citizens they attract. **Health** describes the sanitary impact in terms of facilities provided. **Well-being** concerns the satisfaction of different age groups. **Noise** regards the noise disturbance caused by the buildings. **Economy** indicates the extent to which the buildings are funded by public and private money. **Safety** concerns the impact on security. **Environment** reflects the pollution caused by the buildings. Finally, **Energy** quantifies the energy consumed and produced by the buildings. When placed on the table, domain view markers display the impact of every individual building through visual effects around the building marker. The information of all buildings are also aggregated to give a global view on the city that is projected around the domain marker. To avoid the visual clutter that would result from overlapping representations, we decided to allow only one domain to be considered at a time. Figure 2 shows the domain view markers, prototyped with Camembert boxes to honor French terroir.

Figure 2: Prototype of the domain view markers (English translation from left to right: mobility, health, well-being, noise, economy, safety, environment, energy)

Figures 3–10 illustrate how the impacts are visually projected onto the city map. The impact representations were designed in order to convey the information in the simplest way possible, considering that the target end-users are children. When feasible, consistency was kept between the representations of the individual buildings impact and the citywide impact. Concerning mobility (Figure 3), congestion is depicted by a purple circle around each building. A wider circle represents a more severe congestion, symbolizing the fact that more severe congestion generally impacts mobility in a larger geographical area. Overlapping circles also help identifying highly impacted areas. The citywide congestion is represented by a three-color gauge ranging from green (i.e. overall fluid traffic) to red (i.e. overall highly congested traffic). Regarding energy (Figure 4), consumption and production are represented respectively by a green and a red battery. The battery metaphor is amongst the best-known for representing energy data, and is frequently encountered by children, notably on devices to denote the power level. The filling of the batteries indicate a higher production or a higher consumption. The citywide energy situation is represented in the same way. As for economy (Figure 5), a donut chart around each building gives the funding proportion for public (yellow) and private (brown) spending. The citywide situation is represented in the same way. The impact on pollution (Figure 6) of each building is represented by a rust-colored cloud surrounding it, with larger clouds indicating a more polluting building. The overall impact is represented by a three-level gauge. Regarding health (Figure 7), the contribution of each building to the provision of health facilities is represented by a circular green gauge. A further filled gauge represents a higher impact. The citywide situation is again represented by a three-level gauge which however starts with the red color. A less filled gauge represents a lower amount of health facilities, and therefore a negative situation, which is why the health gauge goes from red to green. The same representations were chosen for security (Figure 8), with a change of color for the impacts of the buildings to avoid confusion with the health domain view. A less filled gauge represents a lesser contribution to citizens' safety. Concerning noise (Figure 9), the impact was represented by a red circular waves emanating from each building, following the sound propagation metaphor. Waves with a larger radius indicate that more noise is generated. Overlapping waves indicate areas

Figure 3: Representation of the impact of individual buildings (left) and on the city as a whole (right), for the mobility domain

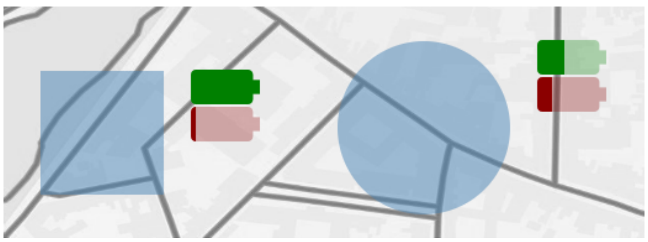

Figure 4: Representation of the impact of individual buildings (left) and on the city as a whole (right), for the energy domain

subjected to high noise disturbance. The overall impact was not represented visually. Contrary to the other domains, the impact of noise remains strictly local to the disturbed areas. Instead, the domain view represents the noise level of the specific location on which it is placed. In order to provide a more realistic insight into the nuisance, the noise was represented by playing a city noise audio file at the corresponding volume. The drawback of this approach is that the table has to be equipped with speakers. Lastly, the impact on well-being (Figure 10) was represented by three colored smileys, each depicting the satisfaction level of an age group. The considered groups are children (i.e. under 18 years old), adults (i.e. 18 to 65 years old), and elders (more than 65 years old). Three levels of satisfaction are represented by a neutral red smiley, a neutral yellow smiley, and a happy green smiley. The filling level of the outer border of the image gives a finer-grained information. We chose to sideline unhappy smileys to avoid confusion between satisfaction and happiness. A citizen can find no interest, and therefore no satisfaction, in a building, without having her happiness level affected because of it. The information of all buildings are aggregated to represent overall satisfaction levels using the same representation.

In the original activity, children are divided into four groups, each deciding on three buildings to place on the city map. We therefore generated completed city model examples and examined how the impacts are projected onto the city model to ensure that there is no information overload. Figure 11 shows an example of a city model holding 12 buildings and the environment domain view. The individual and collective impacts of the buildings as projected onto the city model are presented in Figure 12. The projected impacts remain easy to read with 12 buildings. However, projecting the

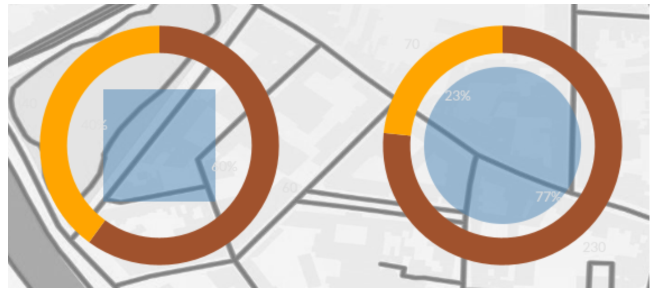

Figure 5: Representation of the impact of individual buildings (left) and on the city as a whole (right), for the economy domain

Figure 6: Representation of the impact of individual buildings (left) and on the city as a whole (right), for the pollution domain

Figure 7: Representation of the impact of individual buildings (left) and on the city as a whole (right), for the health domain

impact for more than one domain would certainly cause a too high visual clutter.

3 FUTURE WORK

The software is fully implemented and runs on a TUIO simulator. Regarding deployment on the physical table, one constraint of the project was to reuse an existing reacTIVision table in order to provide multiple activities on the same piece of hardware. However, the table is located on campus site and access to the premises has been restricted since March 2020 due to COVID-19. Therefore, the next step is to deploy the software on the physical table and to

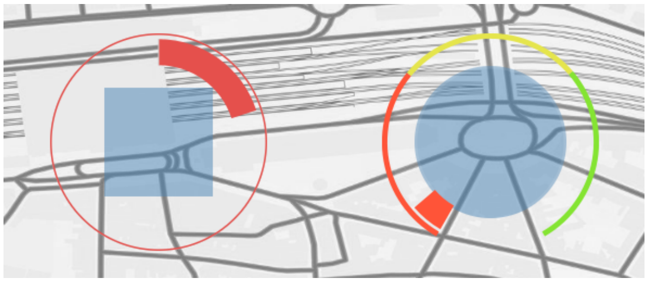

Figure 8: Representation of the impact of individual buildings (left) and on the city as a whole (right), for the security domain

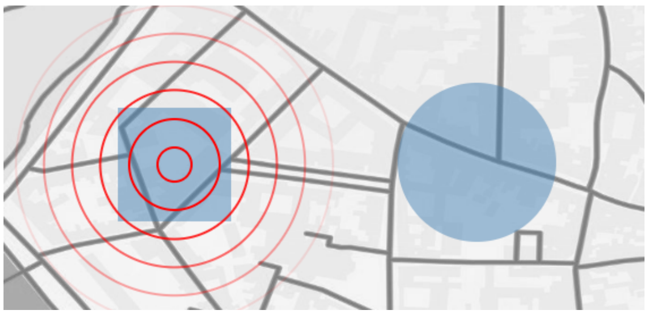

Figure 9: Representation of the impact of individual buildings (left) and on the city as a whole (right), for the noise domain

Figure 10: Representation of the impact of individual buildings (left) and on the city as a whole (right), for the well-being domain

make the necessary adjustments regarding e.g. performance and fiducial marker size for detection.

Without running the software on the table and without having access to end-users due to the pandemic, it was also impossible to conduct a user-based evaluation of the proposal. After having performed the aforementioned deployment adjustments, we plan to conduct a two-part end-user evaluation. First, a controlled study to assess the ease of use of the table and the clarity of the impact visualizations. Indeed, the design of the visual representation was

Figure 11: Example of city model that could be built during the activity. The environment domain view is placed on the city map.

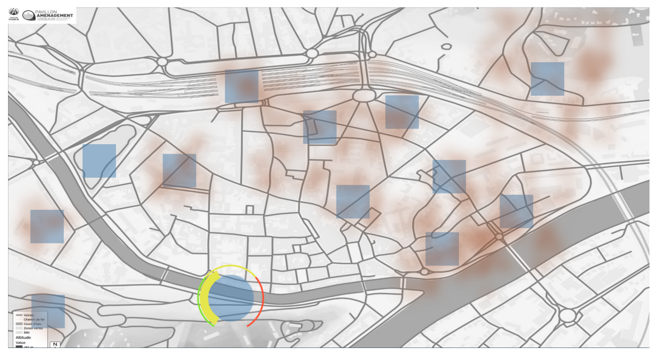

Figure 12: Projected impact of the buildings on the environment

chosen without involving teachers nor children, and is therefore an essential aspect to evaluate before the field study. Second, a field study to assess the integration of the table into the whole smart city introduction activity, with a comparison against the results reported for the original activity.

The data related to the impact of the buildings was fabricated by determining approximate orders of magnitude (e.g. a mall generates more pollution than a grocery shop). However, cities are publishing open data [3] related to domains covered in the activity. In the future, such data could be leveraged to render the impacts more accurately. At the same time, the activity would raise awareness of open data, which is increasingly used in citizen participation initiatives. A first experience with open data would thus further benefit their preparation for adult participation.

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