Playing against dengue

Design and development of a serious game to help tackling dengue

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Abstract—Dengue is a global public health challenge. The dengue virus is transmitted mainly by the Aedes aegypti mosquito, which is also a vector of other diseases such as zika, chikungunya and urban yellow fever. Its transmission dynamics is complex, involving several actors, factors and processes. Acting against vectors is still an important strategy, mainly due to limitations in efficacy and accessibility of vaccines. We believe that including and awareness of population is an important factor to address the problem. This project aims to design and develop a serious game to support actions and strategies based on prevention and epidemiological surveillance. In order to raise awareness about vector ecology and disease transmission dynamics, the game design presents information and seeks to encourage behavior changes in a playful environment. Moreover, gamification strategies are being used to stimulate concrete actions in real world. A mix of 2D-based game, augmented reality, virtual reality and the real world itself, will provide the proper environment to offer fun with the purpose of helping to deal with this complex problem. This paper presents the game design and current development stage. The artifacts are being developed in an iterative and incremental way, involving activities of conception, design, construction/prototyping and evaluation. Results include the game design, prototypes and the release of a demo version.

Index Terms—Serious game, dengue, Aedes aegypti, public health.

I. INTRODUCTION

Game-based approaches are interesting strategies to deal with some real world challenges. For instance, “gamification”, which consists in the use of game design features in a non-game context [1], has been applied to provide rich experiences and to stimulate motivation and engagement of a target public [2]–[4]. Another example is games designed to promote learning and behavioral change, which were applied in a variety of areas and contexts [5]–[9]. The serious games, as they are commonly called, does not have the primary purpose of fun and entertainment [8]. Even so, they should offer enjoyable experiences to the user.

Themes frequently addressed are education and health [6], [10], in particular dengue [11]–[15], a global concern in public health. Dengue is a mosquito-borne viral infection which incidence increased rapidly in the last two decades [16]–[18], putting at risk about half of the world’s population [17]. The main vector is the Aedes aegypti mosquito, which also transmits zika [19], chikungunya [20] and yellow fever [21].

The transmission of dengue virus has a complex dynamics, which is affected by several factors (e.g. microclimate conditions, urban development level, urban landscape, population density) and driven by distinct processes (e.g. vector ecology, virus transmission, mobility of hosts and vectors). We have different actors (viruses, vectors, humans) interacting in a complex and heterogeneous space. Currently there is only one licensed vaccine [22], [23], which has moderate levels of protection [24], [25]. Therefore, the main way to tackle dengue and other diseases transmitted by the A. aegypti is through vector surveillance and control.

The individual (and collective) behavior of humans can influence vector ecology and positively (or negatively) affect the transmission cycle [26]–[29]. For instance, the water crisis in some places leads the population to stockpile water, often inappropriately. This behavior may increase the amount of vector breeding sites, and in turn, the number of dengue cases [27], [30], [31]. Thereby, to be effective, a vector control program should include the population and promote awareness about how their behavior can affect dengue transmission dynamics. Many initiatives have been undertaken with this aim [32]–[37], but not always education and awareness generate behavioral changes [38]. Game-based strategies could help to enhance and extend these outcomes.

To face this problem, we propose a serious game to support education and awareness about dengue, which can be used as an alternative strategy to assist vector surveillance and control. It is an ambitious and long-term project, as it aims to influence the behavior of people to stimulate favorable attitudes towards vector control. The initial steps, presented in this paper, are related to the design and development of the game.
This section presents some basic concepts and related work on dengue, vector control strategies, serious games and gamification.

A. Dengue

Dengue is a viral infection transmitted between mosquitoes and humans. There are four distinct serotypes of the virus: DEN-1, DEN-2, DEN-3 and DEN-4. An individual infected by a particular serotype will acquire lifelong immunity against this one, but not against the others (there is cross-immunity, but it is partial and temporary). The risk of developing dengue hemorrhagic fever (or severe dengue), a potentially deadly complication, is increased by successive infections. A more detailed description of the disease can be found in [39]–[41].

The primary (Aedes aegypti) and secondary (Aedes albopictus) vectors are spreading geographically throughout the world [41]–[43]. The epidemic risk, previously limited to tropical and subtropical regions, is expanding to North American and European regions [18], [39], due to the presence of Aedes and the introduction of the virus. Almost 390 million new infections occur each year [18], and about half of the world’s population is at risk [17]. Nevertheless, the full impact of the disease is unknown (there are problems such as underreporting and case misclassification), and new approaches for surveillance are required [41]. The challenge further increased with the emergence of new arboviruses, such as chikungunya [20] and zika, [19] and the resurgence of others, such as urban yellow fever [21].

Dengue virus transmission dynamics is affected by aspects such as microclimatic conditions (e.g. temperature and precipitation) that affect vector life cycle [44], [45]; air and land transportation systems, unplanned urbanization and high population density which speed up vector and virus propagation [46], [47]. Deficiencies in prevention strategies and epidemiological and entomological surveillance systems also contribute negatively to the problem.

Currently, there is only one licensed vaccine (Dengvaxia CYD-TDV). However, it is not yet widely accessible to the population, and it has some efficacy limitations which has generated some criticism [48]–[51]. There are other candidates in different stages of development and evaluation [23]. However, none dengue vaccine will be an immediate global panacea for all dengue cases [20].

B. Games and Gamification

In this paper, we adopt Juul’s game definition: "a game is a rule-based system with a variable and quantifiable outcome, where different outcomes are assigned different values, the player exerts effort in order to influence the outcome, the player feels emotionally attached to the outcome, and the consequences of the activity are negotiable" [64]. Games have been used to support teaching/learning activities in various contexts [7], [9], [65]–[69]. For even a serious game, which is designed without having fun and entertainment as its primary goals [8], it is essential to provide rich experiences for users. For instance, the study conducted by Giannakos (2013) [70] pointed a significant relation between learning performance and enjoyment with the game, suggesting that "enjoyment could play a vital role in determining the knowledge acquired by the learner". Many other studies were developed aiming to investigate the relationship between the use of games (with their features and promoted experiences/sentiments) and the generated outcomes (e.g. learning performance, motivation) [5]–[7], [71]–[73].

In turn, "gamification" consists of using characteristic elements of games in a non-game context [7]. There are several examples of its application, in different areas and for a
variety of purposes [1], [3], [4], [74]–[76]. For example, a systematic review regarding the gamification usage for health and wellbeing suggests that gamification can help to achieve positive impacts [76]. Several examples related to healthcare can be found [76]–[78], mainly designed for individuals and physical activities.

The use of games and gamification can promote motivation and engagement of a target audience for specific purposes (e.g. "fight" against a disease such as dengue). For instance, Luz et al. (2016) [10] developed a serious game focused on two neglected and related infectious tropical diseases (Visceral Leishmaniasis and American Cutaneous Leishmaniasis) aiming to inform and encourage behavior changes in population. The game development involved a team formed by people from different knowledge areas, and a multidisciplinary group of experts helped with the initial assessments. Authors highlight the importance of getting this feedback before releasing the game for the local population and conducting future studies on its benefits.

An important step that precedes the experimental study is related to the development of the game itself. Therefore, it is necessary to carry out a set of activities that involve conceiving and design to construction, testing, and evaluation.

### III. Development

The game development was divided into two main components: research and development. The research activities involved carrying out study activities aiming at acquiring the required specific knowledge related to the application domain (e.g. dengue transmission dynamics, vector life cycle, control strategies, actors and factors which affect intrinsic). Besides, we are performing a survey and analysis of serious games aimed at the areas of public health, vector-borne diseases, and more specifically, related to dengue. Although it is possible to find many games and apps in online stores, most of them are not based on academic-scientific research, making it difficult to carry out a more in-depth analysis. To the extent of our knowledge, there are few examples of games related to dengue documented by academic-scientific reports, such as [11]–[14], [79]–[84].

The development component involved conceiving, designing, building and evaluating prototypes/versions of the game. No formal software development process (e.g. RUP) has been adopted. Instead, the development is being based on the principles of agile methodologies and simplified and star life-cycle models [85]. Short cycles (biweekly) involving conceive, (re) design, construction/prototyping, and evaluation activities were performed. The current team is multidisciplinary, formed by researchers, undergraduate and postgraduate students, in areas of computer science, biology and epidemiology in public health.

The game still needs some improvements in order to be ready to be used in an experimental study. Some already achieved results will be presented in the following sections, such as the game design, prototypes and the two demos released - a 2D-based game with augmented reality module (Figure 1) and a virtual reality module which can be played with a Google Cardboard.

![Demo version published in Google Play.](image)

### IV. Results

In this section, some of the achieved results are presented, next game improvements are identified and future directions of the research are discussed.

#### A. X-Dengue: Game Design

The game story is centered on the character Pedrinho. When his friend, Rafael, was bitten by the *Aedes aegypti* mosquito, he was infected by dengue virus and became ill. Without the company of his best friend to play, Pedrinho decides to understand this disease better and fight against dengue in the whole world. However, first, he had to start at his house - changing his habits and influencing the behavior of his parents.

The game X-Dengue is organized in four modules (Figure 2). The player will control a character with the aim of fighting dengue. The extent and impact of the player’s actions will increase with the completion of each module. In the first module, the player will act in the interior of his house, directly against the dengue vector, especially in the adult phase, using resources such as hands, electric rackets, and insecticides. Indirectly, the player will realize that it is ineffective acting against vector only in its adult phase. Thereby, in the second module, the player will expand its actions to also prevent the emergence of new adults, with the elimination of existing breeding sites in his home. Then, it will be possible for the player to understand that his actions, isolated and limited to his house, are not able to eliminate dengue risk, even in his home. In the third module, the player actions will be extended to cover his neighborhood. Finally, in the fourth module, the player will be responsible for the whole city, being able to carry out interventions and actions of public policies that will have a broader impact.

It is important to mention that each "weapon" (or action) has its pros and cons. For instance, the player will receive penalties if he makes indiscriminate use of insecticides due to the environmental impacts generated by them. Examples of
"weapons" that can be used in the game include: (i) player’s hands, which allow killing adult mosquitoes as they fly through the rooms; (ii) electric racket, which can be dragged across the screen and reach mosquitoes more effectively and efficiently, at least while it is charged; (iii) sand, which prevent emergence of breeding sites in pots of plants; (iv) insecticide spray, which slows mosquitoes, but can also harm the baby and the dog, or even cause food poisoning.

One of the innovative aspects proposed by the game is the interaction between the virtual world (the game itself) and the real world. In each of the modules, real-world information will be applied to define the behavior of the game. For example, the climatic conditions of the region where the player is physically located may lead to an increase/decrease in the number of mosquitoes in the game. Moreover, players will be invited to perform actions in the real world such as take pictures of places which can have mosquito breeding sites and attend educational campaigns. Thereby, the game may be used to support public health as an additional surveillance tool, to the extent that it will allow mapping problematic places that need attention using a crowdsensing-based strategy (Figure 3). Moreover, it could also help with dissemination and monitoring of educative campaigns.

Aiming to provide rich experiences with low-cost and arouse users’ interest and motivation, more immersive features are offered in special modules. For instance, users will be able to see and better understand the vector and its life cycle through augmented reality. Some realistic 3D models of different phases of the ecology of Ae. aegypti (egg, larva, pupa, adult) and also some playful models (Figure 3), are being developed and made available to users.

The virtual reality module will offer an immersive experience at a low cost, using Google Cardboard. In this module, players may face dengue in a 3D environment, having to act against vector in several stages of its life cycle (e.g. eliminating a potential breeding site, as illustrated in Figure 5).

B. X-Dengue: development and evaluation process

To evaluate and validate ideas, document the project and guide the development, several prototypes of low and high fidelity were developed and evaluated. An example created to specify features related to ranking of users is presented in Figure 6. Quick and dirty evaluations [85] were performed aiming to collect fast and useful feedbacks to support the game design and development. Some prototypes and demos were informally presented and assessed by specialists and potential users in events such as the IV Symposium on Dengue Control Modeling and the Latin American Game Symposium.

This approach based on short cycles with rapid feedbacks worked well, enabling achievement of good results in reason-
able time. The next steps include evaluation by public health agents to design and develop the features related to vector surveillance and educational campaigns.

C. X-Dengue: 2D-based demo version

In the first and second modules, in his home, the player will directly face the adult mosquito and eliminate vector breeding sites. A set of artifacts such as his hands, electric racket, insecticide, and sand can be used for this purpose. Initially, users will act mainly against adult mosquitoes. However, to advance in the game, they will have to accomplish different tasks (e.g. eliminating vector breeding sites) in so far as mosquitoes become more numerous, resistant and aggressive. Each module has some levels, and each level corresponds to a part of the house, such as TV room, kitchen, baby’s bedroom and laundry area (Figure 7).

In each level, the user has to accomplish different types of tasks, which require different actions such as killing a certain number of mosquitoes, eliminating vector breeding sites, closing windows to prevent entrance of mosquitoes (Figure 8), making use of nets and repellents. At the end of each level, the player will still face a ‘big boss’ - one of the strategies used to make the game more playful and challenging for users.

In addition, several informative and good behavior messages are displayed during the game. Besides that, some challenges (e.g. quiz, Figure 9) are proposed for players to test their knowledge about dengue.

The 2D demo version was publicly released on Google Play in September 2016. Since then, it reached about 200
installations and 40 reviews. Currently, the game is only available in Portuguese. Releasing it in other languages and publicizing it with promotional campaigns will help to reach new users and to expand the sample of testers.

V. Final Remarks

The use of games and gamification have shown to be useful tools to promote education, motivate and engage a particular target audience around a specific purpose. The project X-Dengue proposes the use of games and gamification techniques as an alternative strategy for vector surveillance and control, by promoting awareness and behavior changes in population and serving as a medium for data gathering by voluntary contributions.

A serious game aimed at awareness people about dengue (including its transmission dynamics and vector life cycle) has been designed and is under development. Among the results obtained, we have the game design, low and high fidelity prototypes, and demo versions, which were informally assessed by dengue specialists and potential users. The next steps include: 1) perform a formal evaluation of the game (gameplay, usability and user experience); 2) design and conduct an empirical study to assess its effectiveness regarding knowledge, attitude and practice regarding dengue.

Faced with an ambitious project which aims to influence people behavior and support public health activities, we are aware that this is a complex and long-term challenge. Moreover, we know that even achieving a high number of regular users and promoting changes in their behavior, the dengue problem is too complex to be solved by one isolated approach. Instead, many coordinated efforts are required. However, it is thought-provoking and motivating inquire if and how we can deal with complex problems and change our world by using games. The game is available at https://play.google.com/store/apps/developer?id=LEDS.

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