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CidadeSocial: A social sensing model for urban dynamics *

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Abstract

In everyday urban life, people see and face different problems and challenges. Citizens may face criminal activity, poor public transportation, and other difficulties. If their claims were gathered and used to highlight urban problems, they could draw attention from authorities to such issues, saving time to solve the problems and thus improving their quality of life. People would behave as (very sophisticated) sensors of the urban environment. However, allowing anyone to share and interact with others about topics of interest to them is a necessary step toward such big-picture thinking. As a proposal to reach this goal, we describe CidadeSocial, a platform for participatory and passive sensing in a dynamic urban setting. Next, we describe the main features of a developed mobile client. Afterwards, we exemplify how to use the platform in two different application scenarios. The proposed platform contributes to the development of smart and participatory communities in which everyone plays an important role in the information economy.

1 Introduction

A city is defined as an "urban agglomeration" of continuous urban areas (or built-up areas) [2]. In this area, it is possible to observe activities that are performed with frequency between the geographical space and its inhabitants, like commuting to work, going to school, and getting public transport. Because of the large number of people who live in cities, these activities, known as "urban dynamics," have become even more important. Nowadays, most of the population lives in cities. For example, in Europe, more than 70 percent of people already live in urban areas [1].

In urban dynamics, residents and public organizations collaborate to address issues related to the environment that they live in. For example, people who go to similar places (such as classrooms, bus stops, or hospitals) face similar challenges in these settings. They can interact with each other (actively or involuntarily) to solve problems or simply to share information that interests them. This collaboration can take place in person or via social media (e.g., Facebook, LinkedIn, Instagram, or Twitter).

Although social media platforms facilitate remote interactions, we would like to draw attention to the fact that, on such platforms, the information generated by user interactions just flows through their pre-existing networks (a group of pre-connected users) [4]. This means that the information spreads in a connection-oriented way. So, even if someone is outside of a network where information is propagated, he will not receive it. To exemplify, we can consider a scenario where a certain public service uses a Twitter profile to share useful public information (such as schedules, alerts, and problems with a mode of public transportation). Such public

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information will only spread up to the boundary of the group of a service's profile followers. As a result, other users of the same platform won't even get information relevant to their interests.

Aside from the restrictions on information dissemination, it is possible to notice that opportunistic interactions—spontaneous interactions that do not make use of social connectivity—are not taken into account on social media platforms such as Twitter, Facebook, and so on. Their communication models are insufficient to support the day-to-day, opportunistic interactions [3, 13].

Opportunistic interaction are spontaneous interaction that occurs between strangers. In addition, the citizens' information available on the digital world could improve services in cities. When a person shares information about a problem in a city, public departments may be able to use such information. In other words, humans could provide useful information about the city.

When someone shares information related to urban dynamics, he behaves like an electronic sensor. To put it another way, everyone could utilize their five senses to record experiences and share them as data in the digital world. Citizens are indeed the most adaptable (and much smarter) sensors. They understand context well, and unlike electronic sensors, humans can go wherever they want, observe, and share information about what they deem relevant [14].

However, there are some needs to be addressed. What parts of information and communication technology can help people act as "sensors" of urban spaces (sources of information about how urban dynamics work) and help them work together in a way that allows them to share and use this information?

As a proposal, this paper presents an adaptation of a platform named CidadeSocial, which means "Social city" in free translation to English [3, 13, 10, 9]. Our proposal, which is a work in progress, makes use of mobile devices, sensors (e.g., GPS), and a recommendation system (oriented to geolocation and interests) in order to allow citizens to monitor the city at the same time that they consume information and interact with other users in a connectionless way. Then, citizens can act as "sensors" of urban dynamics and perform opportunistic collaboration by sharing and consuming as much information as they want.

Our goal is to define a system that will aid in the formation of opportunistically dispersed networks of humans acting as urban dynamics sensors. Humans can sense a lot of physical variables and deal with different contexts. The sensed information could flow beyond their already-established social connections into a different network composed by human sensors.

This paper is organized as follows: the methodology is presented in Section 2. In Section 3, we present the literature. In Section 4, we describe the proposal. In Section 5, we present possible application scenarios. Finally, we present the final considerations in Section 6.

2 Methodology

The motivation for CidadeSocial development is a lack of appropriate models that use ICT—Information and Communication Technologies—to support humans in sharing information about urban dynamics without the need to be part of a network of people. To fulfill this motivation, it will be necessary to implement an artifact that will give humans this sensing capability.

First, the research question was defined and analyzed from different perspectives in order to enhance our understanding of the problem statement. This was followed by the development of prototypes, designs, and models based on the functional requirements collected from the problem statement. The requirements highlighted the need to make solutions that focus on

people, since people are the most important part of this architecture and work as an intelligent network of human sensors.

Considering the requirements, in the second stage of the methodology, we proposed a model that combines different ICT such as mobile devices, GPS, a gamification approach, a content recommendation engine, and other minor components to address the elucidated requirements. This work divided the solution into two parts—client and server—to aid comprehension. The first is the back-end, with its services like the recommendation service. Following the description of the mobile client and its components.

3 Related Work

A city is a concept with numerous definitions that vary depending on the context and domain in which it is used. Dijkstra et al. [4] say a city may be defined based on the number of people who live in a specific area. Other countries consider factors such as the presence of public essential services—public health and education—or the number of people engaged in non-agrarian activities. In the context of this work, the main factor is the level of urban dynamics performed in these places. Urban dynamics include, among other things, commuting, migration, the formation of dynamic events like protests, and changes in population density caused by new housing or industrial developments in the city.

In this context, each city is unique in terms of characteristics, dynamics, and issues that affect its inhabitants. These differences have motivated different researchers in the last few years to understand and document these phenomena[5, 7]. In that work, their intention was to document and understand aspects of mobility, emergency events, urban violence, energy use, communications, economics, and so on. [5] referrers to these categories of dynamics as the "pulse of the city". In general, the researchers aimed to identify anomalies and identify new trends while analyzing the crowd's behaviors.

Santos et al. have evaluated the use of data in the macrourban region of São Paulo. They discovered some interoperability issues after analyzing governmental open data platforms, which may make the use of city data for understanding city dynamics difficult. The main contribution of this work was the proposal of a structure responsible for ingesting and processing this data from different sources and making it available to the public. In [6], the authors made use of passive sensing to collect data about the levels of rain in the city of Fortaleza, Brazil, in order to predict the emergence of dengue fever cases. These studies try to understand, document, and model urban dynamics in the domains of governmental data ingestion and public health, respectively. They did not propose an artifact to enhance the inhabitants' communication and collaboration in their day-to-day lives. CidadeSocial is concerned with the human exchange of information in urban areas.

Another important related concept is "passive sensoring" which refers to the capture of information that does not require users' active input while they go about their daily lives [8]. In this field, Kubicek et al. (2019) provided a case study of cellular phone information for situational awareness. Cellular phones, perhaps the most ubiquitous personal technology available to society, provide a unique platform from which people can communicate not only verbally, but also through social media. Although cellular phone data is not easy to access because of privacy concerns, this data contains a wealth of useful information for understanding the site and situation of users. In this context, CidadeSocial proposal differs from the other study because it not only focus to gather information passively from a part of the city, however, it also gives the possibility to users posts actively information.

Trivedi et al. investigated how mobile phones functioned as contact tracing sensors. In

their work, they have modeled a network-centric contact tracing method that uses enterprise Wi-Fi networks for contact tracing in office and campus settings. These models were capable of determining when a human in an office had contact with another person who was infected with another disease, using passive sensing as a tool for controlling diseases' spreading. The present work also aims to use involuntary sensing techniques, but it is not limited to the use of Wi-Fi networks to perform the data gathering.

The Stack Exchange[1] is a tool that supports the web forums creation. It proposes is that each forum had its own subject. Users can collaborate by sharing both doubts (as topics) and answers (as topic's comments). The effective management of topics to avoid repeating questions and the gamification approaches has been leading the Stack Exchange to get success. Different instances of Stack Exchange are running nowadays, each one focuses on specific subjects. The most well known by information technology professionals are the Stack Overflow[2] and the Ask Ubuntu[3]. This software application does not explore functionalities as user localization as CidadeSocial do. Besides, in CidadeSocial, the communications are based on interests related to urban day-to-day subjects.

An Instagram[4] and Foursquare[5] evaluation was made in [12]. The authors wanted to investigate these media as being participatory sensing networks, where data from sensors (e.g., GPS and barometers, etc.) captured by the mobile devices are attached to the user-provided data [12]. Then, they described Instagram as being a media focused on cultural issues, and Foursquare as being a participatory sensing network for the definition of way finding. Thus, these authors pointed out the usefulness of these media as tools to understand both the dynamics of displacement (by tourists, for example) and the acquisition of information concerning cultural events. The aim of CidadeSocial is in communication centered on user interests (which are related to city dynamics) and not only on cultural or issues of location.

4 Proposal

This proposal intends to take an important step for society to collaborate on understanding the main social demands and problems of urban centers in collaboration with CidadeSocial. We believe that it is necessary to have a means to obtain and recover information that can be useful to improve urban spaces and people's quality of life. Therefore, we would like to have and provide data in order to support (but not address) future analyses (e.g., data fusion or new scales) and get new knowledge on different urban domains (such as public transport and air pollution, among others).

Using CidadeSocial, people will be able to send data about their urban spaces. Such data could be about physical infrastructure, services, or events that happened nearby. Since humans use their senses (and even perception) to obtain information from the real world, we made an analogy using the expression human acting as a sensor. When combined with computer technology, sensors are capable of taking information from the real world and sending it (in some representation of measurements) in the digital world.

Humans are much smarter, more adaptable, and more sophisticated than electronic sensors. They can create, feel, and do not have to follow repetitive procedures [14]. They send what they want, when they want. People open up new possibilities, but they are also far more complex

[1] https://stackexchange.com/
[2] https://stackoverflow.com/
[3] https://askubuntu.com/
[4] https://www.instagram.com/
[5] https://foursquare.com/

than an electronic sensor, which brings new challenges.

CidadeSocial is a platform for exchanging information about citizens' daily lives and their surroundings. Like in a sensor network platform, people can also send messages in a distributed way. However, human nature and ability enable them to create new connections, creating new and dynamic networks according to their interests.

4.1 The CidadeSocial Description

The communication on CidadeSocial is based on users' common interests and locations. The interests are defined as the strategy to link users, their interests, and message content. All information is associated with an interest. Therefore, users receive information according to their interests. The user's interests are defined upon account creation and can be modified at any time. The set of predefined interests is shown in Table 1. In CidadeSocial, communication (the content of messages) comes before a person-to-person relationship, unlike more popular social media platforms (such as Facebook). In other words, the primary goal of CidadeSocial is to facilitate information dissemination in order to reach everyone and anybody interested in a subject (or interest), even if they are strangers to one another.

Topics can be linked to a location or an organizational unit. Places can be found in identifiable areas or regions. Places include, but are not limited to, streets, squares, bus stops, subway or train stations, beaches, tourist attractions, and so on. an organizational unit in which a unit represents an organization with several units (or departments) The City Hall of Rio de Janeiro (an organizational unit), for example, is located in Floriano Square (a place), Cinelândia, at coordinates -22°54'36.175" N -43°10'36.108" E. Administrators record places and organizational units in the database, each with a unique name and location (geography coordinates are also used, for example, to pin places and organizations on a map). The primary goals are to connect places and organizations with subjects.

The user timeline is made up of topics categorized by interests and published near the user's current geo-coordinates. The timeline appears as the user's initial screen after logging in. It is a map with icons indicating the user's timeline's subjects. Users can also view a list of recommended topics. The topic list is a custom-built object list of the data generated on the server, and there is a recommendation engine that takes care of the user's interests. Another screen is the discover screen (topic visualization), which displays all of the user's topics (topics created by the user).

Table 1: List of interests adapted from [3]

Interests			
Art	Comedy	Crime	Elections
Employment/Work	Entertainment	Event	Exposition
Fashion	Food	Government	Health
Infrastructure	Judiciary	Legislation	Mass Gathering
Mobility	Municipal Council	Music	Politics
Protest	Recreation	Security	Service
Social Network	Sport	Trade	Transport
Violence	Other		

Table 2: Topic Types adapted from [3]

Topic Types			
Complaint	Denouncement	Disclosure	Lament
Joke	News	Praise	Other

Due to external factors, users' access to the Internet might be lost during the day; however, there is an offline mode that enables usage of some features without the Internet, and as a result, there is a client sync component. A user can create topics, view their timelines (limited to the content currently there), rate topics, and comment on subjects that have become accessible since the last synchronization while in offline mode. When an Internet connection is or becomes accessible, synchronization invariably takes place. To ensure that the user will have access to updated information, the mobile device automatically initiates an update with the server (for instance, every 30 seconds). When the connection to the Internet is restored, the data that were generated while it was disconnected and are delivered to the server.

Every time the user utilizes the system, the system may record his geocoordinates. When it becomes available, the GPS will be used to determine the coordinates. When a user conducts a search for information, the coordinates are used. The data will be arranged in accordance with how near the user is to the location where the messages retrieved by the search were published. There are other search options available, including searches by interests, locations, or organizational units. A system for gamification was created. It is thoroughly explained in [12]. Its goal is to motivate users to collaborate. The user's actions within the application result in points and level advancement. There is a ranking that is dependent on user progress.

4.2 CidadeSocial Architecture

The distributed system CidadeSocial has a client-server architecture. To construct the application over HTTP, we use the Representational State Transfer (REST) architectural style. Every communication is conducted over HTTPS in secure channels. User authorization was controlled using the OAuth2 protocol. The distributed model of the CidadeSocial is shown in Fig. 1. Both client and server are essentially made up of components, and each has a unique interface that enables communication between them. The client-side components offer user interfaces for tasks like syncing, logging in, and signing up. The server side, on the other hand, will set up and offer end destinations for web requests.

4.2.1 Client-side components

The client-side of CidadeSocial is currently a mobile application that runs on top of the Android operating system. The client, as previously stated, is an offline-first application. To accomplish this, it includes data management components that allow the app to keep all data on the mobile in case of an internet connection failure. Furthermore, the mobile software includes components aimed at determining the client's geolocation. These components update the app based on the geo-location, allowing it to construct a feed of topics based on interests and proximity.

The components of participatory sensing are in charge of topic posting, timeline processing, and evaluation registration. They work together to let users share information like text to express thoughts, pictures, or videos from the real world and to rate how useful a topic is.

There is also a component specialized in implementing gamification to help engage users

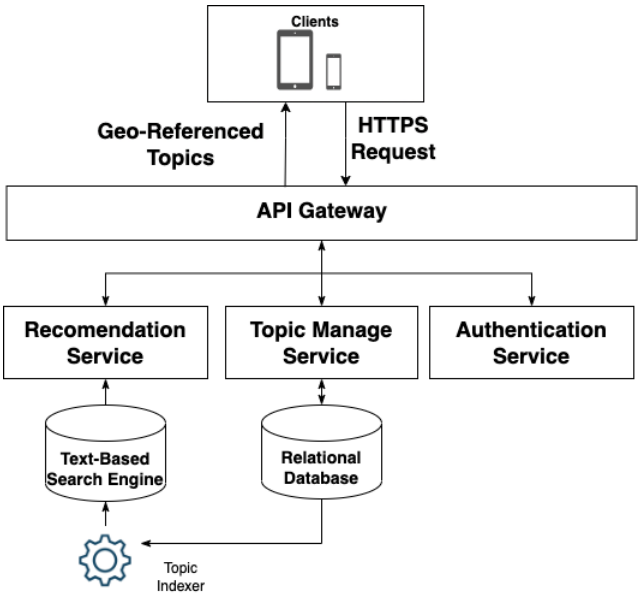

Figure 1: High-Level Overview of CidadeSocial architecture

in the task of actively contributing to the platform by posting or commenting on topics. The gamification component awards points to users based on their actions. This score is used to rank CidadeSocial users. For example, if a user posts a topic and it is evaluated 100 times, the user should be rewarded with points and a badge. [11] contains more information on CidadeSocial Gamification. Also, a more detailed explanation about the client side can be found in [3].

4.2.2 Server-side components

In this application architecture, the server is responsible for acting as a single source of truth. As this work is describing a distributed system that aims to gather and process data coming from the physical world, due to consistency purposes, all messages (or evaluations) published by clients are sent to the server, which registers the activities and stores the data in a database.

The API Gateway is the component that acts as a gateway to all other components via the web. It is called CidadeSocialAPI and is built on REST principles. All HTTP requests for each service (resource) offered by the server are received by the CidadeSocialAPI. Based on the REST principles, all resources have at least one URL. Table 4 depicts some URL examples.

All requests rely on the authorization component to obtain the client application's credentials. This component is in charge of handling client credentials. To authorize access, the OAuth2 protocol is used. The authorization is defined by the component using the client's credentials (which are associated with their level of permission for each server resource). The client must send the credentials associated with each request. Because the application has no state, all requests must be self-contained (they must have all the information necessary for its processing).

The Topic Manage Service contains all of the logic for performing operations such as timiline building operations, data CRUD (create, read, update, and delete), user ranking based on gamification techniques, and information retrieval. This service is also in charge of processing

Table 3: Example of URLs of CidadeSocial API. Adapted from [3]

Request Method	Path	Description
POST	/users	Send the new user JSON representation to create a new user
PUT	/users/{user_id}	Send the JSON user representation with new data to update the logged user
GET	/topics/timeline/{user_id}	Topics recommended to a user
GET	/topics/{user_id}	A list of 20 first topics of a user

and responding to API Gateway requests. It is built on a relational database that stores all information about topics, places, users, and interests. Correa et al. [3] previously explained specific details about this service.

Finally, the recommendation service is used to generate personalized topic recommendations based on the users' ratings, interests, favorite locations, and current location. This service uses the user's latitude and longitude to perform geo-queries against a text-indexed repository of topics and interests. A process called ETL (extract, transform, load) is used by this base to index data from the Topic Manage Service.

4.3 The CidadeSocial Implementation

A solution for a real-world problem must be developed and validated, as described in the methodology session. To accomplish this, the proposal described in the architecture section was implemented to test its viability. To accomplish this, both the Topic Manage Service and the Recommendation Service were built on the server side with Java and the SpringBoot[6] framework. The Hibernate Object-Relational Mapping framework was used to connect Topic Manage Service and PostgresSQL[7].

Elastic Search[8], a search engine based on the Lucene library, was also used to implement the recommendation service. It provides a multitenant, distributed full-text search engine. The need to perform geo-queries based on user location was the motivation. In addition, Logstash[9] was used as an ETL tool to index data from the relational database.

The client was built with React Native with Platform Expo in order to generate the app in the future for IOS. This paper presents the main flows of use of CidadeSocial as an app in order to better understand the app. The topics-geolocation features are connected to the use cases. Along with this description, the client's user interfaces will be presented as usage flows.

The first use case is the sign in, where the user could insert his personal information and select his interests from a list of interests. Fig. 2 shows the sign in flow. After completing the sign in, a user could access a map with topics published by other users in the same region (defined by a radius size of 1 km).

[6]https://spring.io/projects/spring-boot
[7]https://www.postgresql.org/
[8]https://www.elastic.co/elasticsearch/
[9]https://www.elastic.co/logstash/

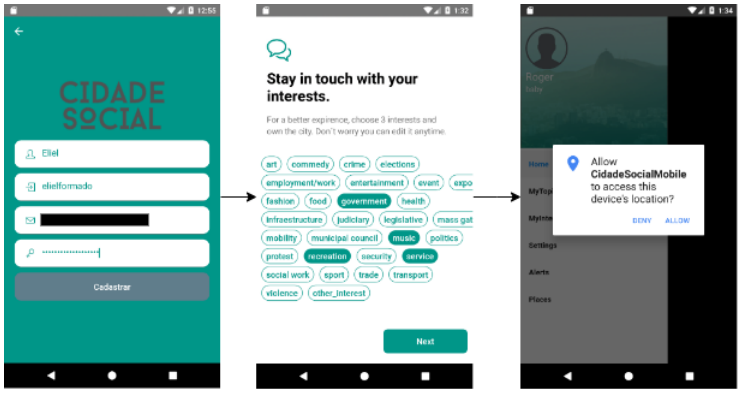

Figure 2: The Flow of a sign in CidadeSocial

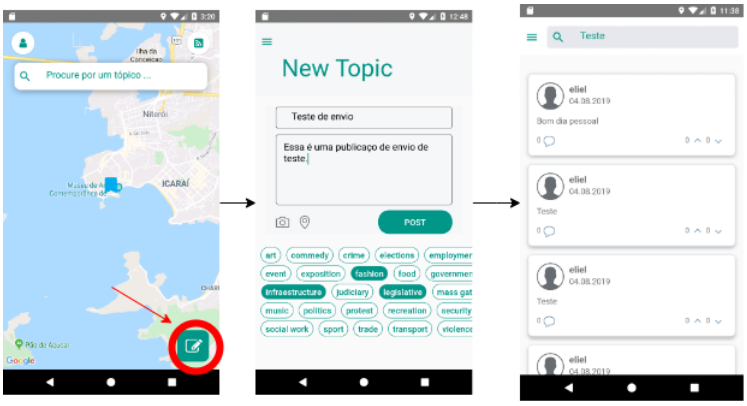

Figure 3: Publish Topic Flow

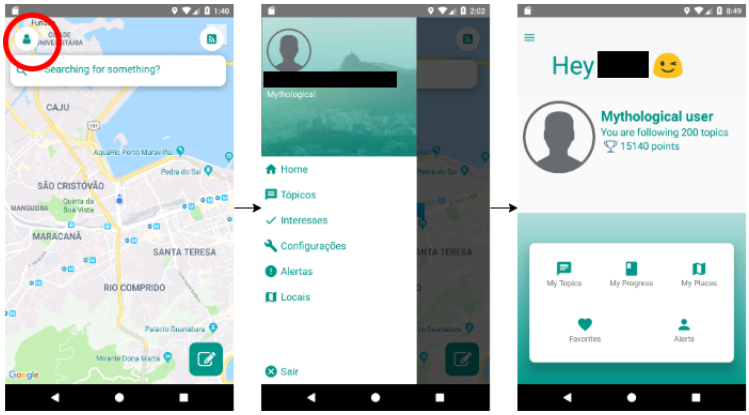

Figure 4: CidadeSocial Gamification Flow

As shown in Fig. 3, the main application's screen shows a map in which the user can see the nearby topics according to his or her interests. Other important screens related to the user's timeline enable users to just list the topics. The topics that will compound the user timeline are returned as pageable responses that enable users to get more and more topics up to the end of available data.

The user could also navigate using other functionalities. As shown in Fig. 3, a user posted a topic from the main screen. The right button on the first screen will give them access to the form to publish a topic. The user enters the title and text and then proceeds to select interests related to the topic. At the end of this flow, the user would see his topic on the screen of topics. That screen also shows some elements of the gamification approach.

Gamification is the strategy used to encourage users to use CidadeSocial, by given then the feeling of progress while using the plataform. People tend to feel motivated by actions that bring a direct reward, like when they interact with game like elements (gamefulness) [11].Users receive insignias according to the comments they receive and publish topics. The insignias are bronze, silver, gold, and platinum. Other activities contribute to the user experience, and they receive titles on the app. The user starts as a baby and grows in experience until he reaches a mythological level (see the last screen in Fig. 4). Gamification provides the user with a sense of evolution and significance. The evaluation of topics and messages allows other users to identify the best answers (comments) to a question and the top topic evaluated by people.

4.4 Application Scenarios

The major motive for this proposal and its implementation is to give people the ability to act as sensors and report problems and ideas connected to their reality and community. In this context, we discovered that citizens may desire to communicate and exchange information in cities on a daily basis in a variety of settings. As a result, we've identified two scenarios in which the CidadeSocial may be useful.

4.4.1 Sensory Participation and Passive Sensing in Urban Mobility

Consider the following scenario: the government invests heavily in a new bus model (bus rapid transit) and heavily in new autos. The bus service has been adjusted in the hopes that the new transportation service will improve people's journeys. However, in a large city, it may be difficult to track which routes have buses in bad condition or if drivers are driving dangerously. CidadeSocial encourages people's engagement in this scenario by making it simple to speak with others, even strangers. They can upload articles with pictures showing that a certain car is not well taken care of, and CidadeSocial can passively collect GPS data to see if the bus is taking the right route.

4.4.2 Engage pople by making easy get and share information

CidadeSocial helps people get information from others or find the information they need because others have had the same problems. In a previous experience, CidadeSocial was instantiated as "CampusSocial" [13]. In this use case, the academic community of the Federal University of Rio de Janeiro was able to share information based on their interests and get answers to daily questions like "Where are the libraries located on the campus?" "Is the university open 24 hours a day?" or "When is the university restaurant less crowded?" At this scene, the academic. The community was a human network sensor, sharing knowledge that machine sensors wouldn't be able to do.

5 Final Considerations and Future Works

This paper presented a platform of opportunistic collaboration that results in networks of information produced by humans about urban dynamics. This platform is named CidadeSocial. CidadeSocial is a model that employs participatory and passive sensing. Humans are capable of detecting and measuring events in urban dynamics. CidadeSocial supports the sharing of human-produced data and combines it with others produced by the electronic sensors of mobile devices. Furthermore, the application may offer content depending on the user's interests and location, as well as provide gamification approaches to engage and motivate users. The goal is to support the broad spread of information in urban areas, as the city could be sensored and the new information could be useful for improving the lives of citizens.

The primary purpose of this research was to create and implement a model that would aid in the establishment of opportunistically distributed networks of individuals acting as urban dynamics sensors. This goal was accomplished through the design of the "CidadeSocial" architecture and the deployment of both the backend service and the mobile client, which have the ability to help gather, process, and generate information derived from urban dynamics. CidadeSocial's methodology differs in that by using humans as active and passive sensors, the platform may transform itself into a powerful network of sensors.

5.1 Challenges to the Validity of the Proposal

The effectiveness of CidadeSocial is dependent on widespread adoption and use because all information and its validity are dependent on human usage. Even the proposed gamification approach may not be sufficient for this purpose. Besides, important issues such as fake news or rumors were outside the scope of this paper.

5.2 Future Works

There is the interest of evaluating and aligning CidadeSocial with the content-based publish-subscribe communication paradigm because of its characteristic of proactive distribution of interest-based content, as we intended for CidadeSocial. Furthermore, in the future, it will be necessary to address the adoption and engagement of CidadeSocial's users (experience, acceptance, and intent to use). The evaluation may be made through the application of well-known models of adoption of new technology. We hope to do that in alignment with the real use on Brazilian university campuses, since some of them are managed as cities. The real and free use and adoption of a social sensor platform could increase our knowledge of it.

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