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APPLICATION OF THE INTERNET OF THINGS CONCEPT TO INFORM PEOPLE WITH DOWN SYNDROME

Dragan Peraković, Marko Periša, Ivan Cvitić, Petra Zorić
University of Zagreb, Faculty of Transport and Traffic Sciences,
dragan.perakovic@fpz.unizg.hr, marko.perisa@fpz.unizg.hr,
ivan.cvitic@fpz.unizg.hr, petra.zoric@fpz.unizg.hr

Abstract: *Assistive technology promotes greater independence for people with disabilities by enabling them to perform everyday tasks while providing improvements or changing the methods of interacting with the technology required to perform such tasks. The cognitive and physical characteristics of people with Down syndrome are usually characterized by some form of difficulty in communication and learning and unique physical characteristics, which makes performing daily activities challenging and often require the help of an assistant. For this paper, the authors conducted a survey, and the collected data served as a basis for understanding the development of people with Down syndrome, movement in traffic and the environment, and the frequency and knowledge of information and communication technologies. The paper aims to propose CAT assistive technology model and conceptual system architecture for delivering information services based on the Internet of Things concept to increase the independence and mobility of people with Down syndrome.*

Key words: *Assistive Technology, Traffic Network, Persons with Developmental Disabilities*

1. Introduction

Developmental disabilities are any mental or physical condition that limits a person's cognition and activity, and can be divided into those that occur at birth or later in life, or can be cyclical. According to [1], developmental disabilities include communication disorders, autism, neurological impairments, and visual and hearing impairments. The difficulties are mostly biological in nature.

Down syndrome (DS) is a genetic disorder caused by a copy of chromosome 21. On average, one in 650 newborns is born with this syndrome [2]. It affects the developmental abilities of affected individuals and often leads to impaired cognitive and physical functioning. The cognitive and physical characteristics of DS can vary widely. However, in most cases, they are characterized by some form of communication and learning difficulties, as well as specific physical characteristics. Learning disabilities can be caused by the linguistic, cognitive, and executive effects of DS and enriched by the effects of sensory and motor skills. Because of the above symptoms, performing activities of daily living (such as navigating the traffic network, cooking, and cleaning) can be challenging and often requires the assistance of a caregiver. Planning, self-management, maintaining task flow, and memory are some of the most common problems for people with DS [3].

Assistive technologies include devices, services, and systems that help promote, maintain, or improve the functional abilities of people with disabilities [4]. The research [5] focused on the use of assistive technologies in teaching students with DS in inclusive schools and rehabilitation centers. The main findings of the research show that, according to the teachers, the main problems of people with DS are lack of concentration and comprehension, difficulties in speech and language, and communication with others. On the other hand, families of people with DS cite a lack of focus as one of the biggest problems. The biggest challenges and barriers teachers face in implementing assistive technology are the high cost of such devices and applying the appropriate assistive technology in the appropriate situation.

Technology enables people with DS, to enjoy themselves and participate in various recreational activities that do not require the assistance of a caregiver. People with DS can use various devices to watch movies, play music, view photos, and listen to music. 78% of people with DS use technology at school for about two hours and twenty minutes per day, while 95% of people with DS use technology in the home environment for about three and a half hours per day [6]. Research [7] confirms that mobile technology, as an example of assistive technology, can help people with DS perform daily activities. The outcome of the research is to identify barriers and user requirements in order to develop solutions for independent travel applications. Several innovative technological solutions for people with DS have been developed as part of pilot research funded by the European Commission [8], and the research has been conducted in three countries. The subject of the research is the use of virtual and computer technologies in stimulating children with DS [9]. The contribution of technology is visible in teaching children with DS through electronic games. However, there is a lack of research and investment in games and applications that can stimulate the neurological, psychomotor, and cognitive development of children with DS.

The research to date provides insight into the daily functioning of individuals with DS and the adoption of technologies they encounter. It is also evident that research on assistive technologies for people with DS is current. One of the biggest challenges in using assistive technologies for people with DS is the price, complexity, and lack of customization of the solution. This has motivated the authors of this paper to propose a conceptual system architecture for providing information services to people with DS, based on the concept of the Internet of Things (IoT), that provides accurate, real-time information as they move through the traffic network. Along with the system conceptual architecture proposal, the CAT (Comprehensive Assistive Technology) model of assistive technology is proposed.

2. Methodology

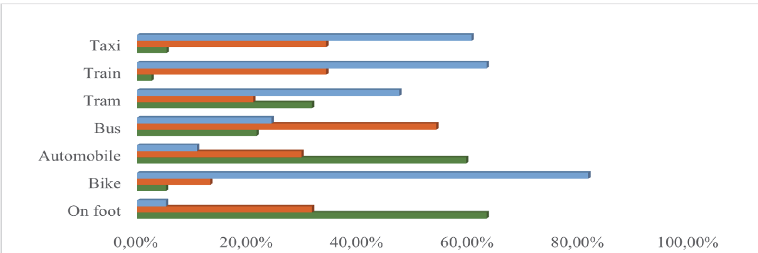
The proposal for the conceptual architecture of the system for providing information services to people with DS is based on a survey conducted, the aim of which is to collect information about the needs and limitations of people with DS. It also defines the functionality of mobile applications for providing information services that meet the needs of people with DS. The needs refer to functioning in everyday activities and availability and knowledge of new solutions and services based on modern information and communication technologies. Data on their health and social life will be considered, as well as information on moving around the traffic network and their daily needs. Based on the results obtained through surveys, the functionality of mobile applications that should be used to provide information services to end users (people with DS and their caregivers) is proposed.

2.1. Analysis of user requirements

The survey was conducted in 2022 in various associations supporting people with developmental disabilities in the Zagreb region, and 38 people with DS participated. No minors participated in the survey, and all age groups from 21 to 66 years were represented (the largest percentage of respondents was 29 years old, 10.5%). Most of the respondents live in the city of Zagreb, where public transportation is a part of everyday life and where there are different types of roads.

Respondents were asked about the type of difficulties. 100% of respondents have intellectual difficulties, 44.7% have language difficulties and 36.8% have motor difficulties. 44.7% of the respondents use a smartphone on a daily basis. Half of the respondents use the call service on the smartphone, and 33.3% of the respondents use the ability to write text-type messages on the smartphone by themselves. Respondents reported being familiar with Google Maps, which can help them navigate daily traffic. 20.6% of respondents know how to use Google Maps.

Regarding determining the time needed to get to the desired location, 60.5% of respondents cannot independently determine the time needed. Most of the respondents reach the desired place with the help of someone, and 26.3% of the respondents answered that they travel with the help of one of the smartphone applications. When they go to places they have never been before, the largest percentage (92.1%) of respondents are accompanied by a caregiver. Figure 1 shows the respondents' mode of transportation, which shows that most respondents walk and drive to get around the transportation network, while very few use the tram as a means of transportation.



	On foot	Bike	Automobile	Bus	Tram	Train	Taxi
Never	5,20%	81,60%	10,80%	24,30%	47,40%	63,20%	60,50%
Sometimes	31,60%	13,20%	29,70%	54,10%	21,00%	34,20%	34,20%
Often	63,20%	5,20%	59,50%	21,60%	31,60%	2,60%	5,30%

Figure 1. Way of travel of respondents

The survey examined respondents' ability to navigate traffic. The results show that 65.8% of respondents do not know what to do if something unexpected happens in traffic (e.g., a tram breaks down, a car crashes, or the respondent gets lost). In addition, respondents indicated that their most frequent means of payment is cash (36.8%). However, the number of those who use a combination of cash and bank card (13.2%) is also not negligible. The opinion of respondents regarding the use of a mobile application that can help them move around the traffic network is positive, as 39.5% of respondents believe that this type of service would be helpful, while 23.7% are undecided.

2.2. Defining the functionalities of information service

Based on the results of the questionnaire, challenges were identified in the form of difficulties in moving around the traffic network for people with DS, which require specific treatment of the problem. From the processed data of the questionnaire, user requirements were defined, which serve as a basis for defining the functionality of mobile applications that provide information services for people with DS and their caregivers.

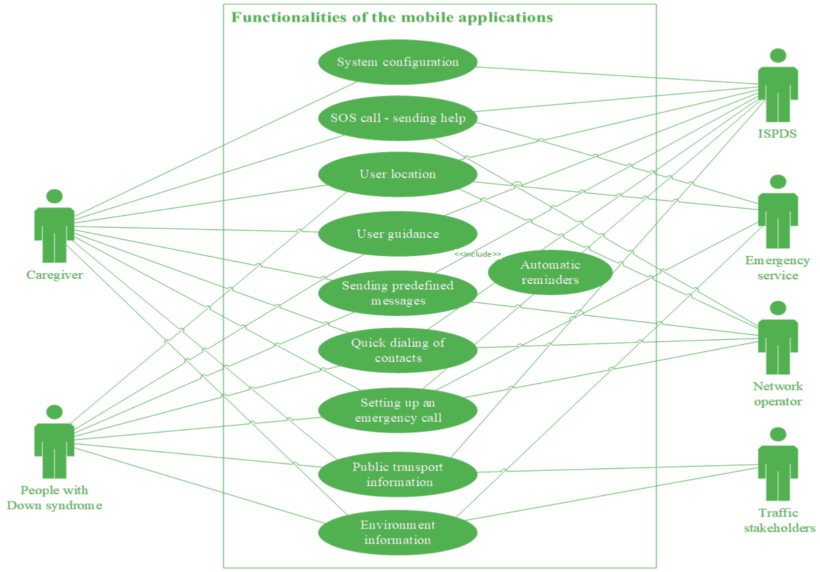


Figure 2. Functionalities of the mobile applications that provide information service

Functionalities aimed at efficient delivery of information to end users are illustrated in the use case diagram in Figure 2, which shows the interaction of a person with DS and a caregiver (assistant) with the stakeholders involved in the delivery of the information service. The functionalities differ depending on whether the user of the information service is a person with DS or a caregiver. For this reason, the caregiver mobile application has two more functionalities than the mobile application of a person with DS: *system configuration* and *SOS call-sending help*. The first functionality allows caregivers, among other things, to register users and select information that is important for a person with DS, because the survey shows that a large number of people with DS have intellectual difficulties, so it is possible that such actions are complicated for them. If a person with DS suffers some kind of accident while moving through the traffic network and is in a state of shock and does not know what to do, the caregiver has the option of *SOS call - sending help*, i.e., call directly and send help to the person with DS. Other functionalities of mobile applications for providing information services to people with DS include locating the user, user guidance with automatic reminder function, environmental information, public transportation information, setting up an emergency call, quick dialing of contacts, and sending predefined messages.

Table 1. Explained the defined functionalities of mobile applications for the caregiver and for the person with DS

Functionality	**Description of the functionality for the people with DS**	**Description of the functionality for the caregiver**
User location	Know your location at all times for easier navigation	Know the location of the people with Down syndrome at all times
User guidance	Routing with automatic reminders to keep the people with DS focused on the destination location	Ability to create automatic reminders using your own voice or personalized messages
Environment information	Street names, possibilities of redirections, traffic intersection configuration	Street names, possibilities of redirections, traffic intersection configuration
Public transport information	Line number, vehicle arrival, vehicle direction, stop configuration	Line number, vehicle arrival, vehicle direction, stop configuration
Setting up an emergency call	Use in case of danger, accident, or fear	Providing notification when functionality is used by people with DS
Quick dialing of contacts	Pre-saved contact numbers such as caregivers or friends	Saving and managing important contacts for display in the mobile application of people with DS
Sending predefined messages	Messages such as "I have arrived at my destination" sent by the user to caregivers (assistants)	Designing, writing, and receiving predefined messages
SOS call – sending help	-	If a person with DS is in danger, the caregiver can request and send help himself
System configuration	-	The caregiver adjusts the system configuration (information that is important to display) for the person with DS

Table 1 explains the individual functions of mobile applications for providing information services depending on the end user (person with DS or caregiver). From the table, it can be seen that although the person with DS and the caregiver have the same functionalities, their mobile applications are used differently for providing information depending on the request. At the same time, some of the information obtained by performing one functionality is logically related to another. For example, information about the user's location is necessary to make an emergency call if the user is in an accident, to guide the user in navigating the traffic network using automatic reminder functionality, and to obtain information about the surrounding area if there is a possibility of rerouting the user.

3. Solution proposal

When designing a system of assistive technologies, it is necessary to know the basic modeling frameworks of assistive technologies, namely HAAT (Human Activity Assistive Technology) and CAT models [10]. They simplify the representation of the connection of the four main elements and position the assistive technology in relation to them. In this research, the authors used the CAT model for a more understandable and detailed representation of assistive technology design, as shown in Figure 3. The structure of the model is in the form of a tree with a limited number of variables on its branches. The top level consists of four components that define the assistive technology system: the user (the center of the system), the context (the environment in which the assistive technology is used), the activities (performed using the assistive technology), and the assistive technology (an open framework for the delivery of information service).

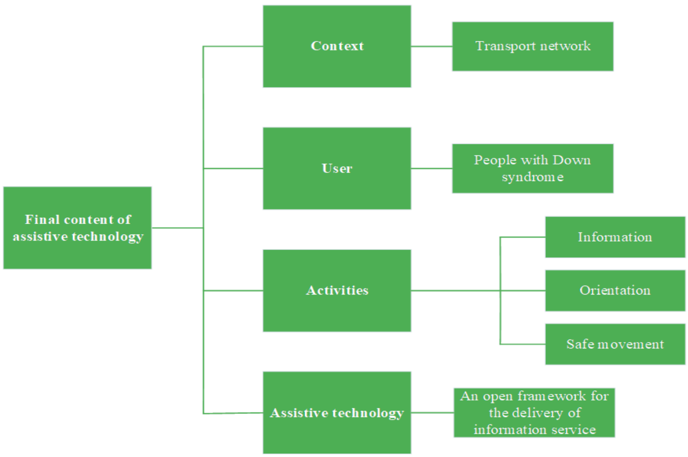


Figure 3. Presentation of the CAT model

Based on the results of the survey proposing the functionalities of the mobile applications for the caregiver and the person with DS, the elements of the conceptual architecture (Figure 4) of the system were defined. The elements of the conceptual architecture based on IoT communication technology are smartphones of caregivers and people with DS with associated application solutions, databases (user data and system data), sensors, and stakeholders (service provider (ISPDS), emergency service, network operator, and traffic stakeholders - *Croatian Automobile Club (HAK)*, the *City of Zagreb (Center for Automatic Traffic Control - AUP* and the *Zagreb Municipal Transit System - ZET*) and *Croatian Railway Infrastructure (HŽI)*). To provide the information service, the end user uses their smartphone and the proposed application solution. Appropriate means for informing users include audio, text, and visual information. Table 2 lists all elements of the proposed information service delivery system and compares the use of mobile application functionality according to each element.

Table 2. Display of system elements that use certain functionality of mobile applications that deliver information service

System element	**Functionalities of the mobile applications that provide information service**								
	User location	User guidance	Environment information	Public transport information	Setting up an emergency call	Quick dialing of contacts	Sending predefined messages	SOS call – sending help	System configuration
User phone	✓	✓	✓	✓	✓	✓	✓		
Caregiver phone	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sensors		✓	✓						
Users database	✓	✓			✓	✓	✓	✓	✓
System database			✓	✓					
Emergency service	✓				✓				
Network operator	✓				✓	✓	✓	✓	
Traffic stakeholders			✓	✓					
ISPDS	✓	✓	✓	✓	✓	✓	✓	✓	✓

The solution proposed in this research is based on the SaaS (Software as a Service) model of Cloud Computing (CC). The access to the information service consists of two basic levels: User and Data Provider. The user level is associated with the end users (person with DS and caregiver). The user level provides access to the functionality of the service through the application solution. The data provider level is further divided by stakeholder, depending on the needs and requirements of each stakeholder. For example, the stakeholder ISPDS has a data provider level with administrative powers and has the role of an information service provider in this research.

Sensor in this research proposal means beacon BLE (Bluetooth Low Energy), camera sensor and sound sensor. They are installed at traffic intersections, bus and tram stops, and train stations. Traffic stakeholders are responsible for their installation, maintenance and the data collected with them. The city of Zagreb is responsible for sensors at bus and tram stops, and traffic intersections, while HŽI is responsible for sensors at train stations. The detection of the mentioned places leads to an improvement of the accessibility of passenger transport and ensures the development of a transport system that meets the needs of its users, as well as the social integration of all users of the transport system. In addition, the installation of sensors at the mentioned locations will lead to an increase in the quality and reliability of the services currently offered by the mentioned traffic stakeholders, thereby fulfilling certain objectives of the Transport Development Strategy of the Republic of Croatia (2017 - 2030) [11]. The beacon sensor is used to detect traffic stops so that a person with DS could receive dynamic information about their movement. This sensor was chosen because there is a possibility that the GPS, which is built into the smartphone and is responsible for locating the user, is not always completely accurate. In this case, the user would not receive completely accurate information about his location. The camera sensor is located at bus and tram stops and train stations and is used to detect the arrival of vehicles at the stop (e.g., reading the line number). The sound sensor is located at all of the above locations and uses a characteristic sound to maintain the attention of individuals with DS as they move through the traffic network. As shown in Figure 4, additional sensors could be added depending on the user's needs and requirements. The sensors are connected via appropriate technologies, such as Zigbee, Sigfox, Bluetooth, and Wi-Fi. The data collected from the sensors are transmitted through the appropriate hub to the CC environment, where are customized, validated, and merged, and the data are stored and transmitted to the end user.

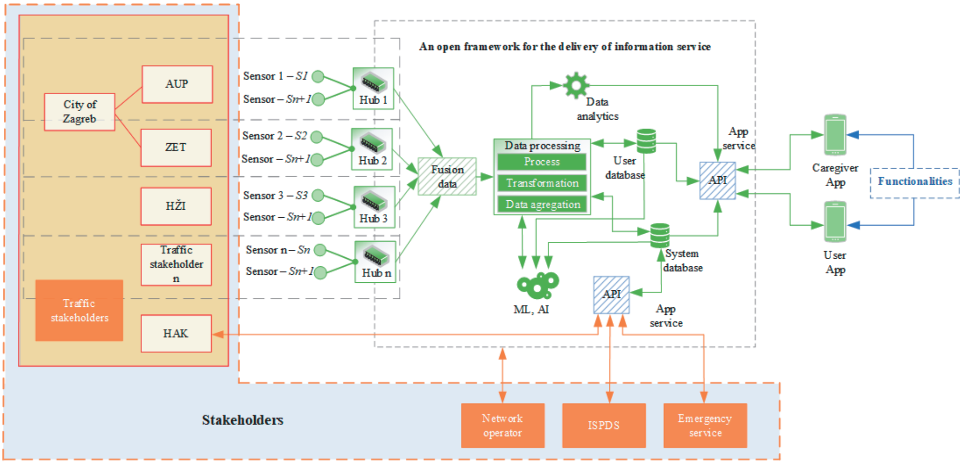


Figure 4. Conceptual system architecture for providing information to people with Down syndrome

Artificial Intelligence (AI) and Machine Learning (ML) in the proposed open framework facilitate the analysis of the collected sensor data. They can be used to identify the behavioral patterns of people with DS as they move through the transportation network and offer them alternative routes based on the data obtained and processed. The data is made available to the end user through the user database. API (Application Programming Interface) is used to provide specific data to the end user based on their needs and to the specific stakeholder. Depending on their role in the environment, the stakeholders provide specific information to the system database, and the data analytics analyzes the data received from the sensors and stakeholders. Functionalities are reflected in the mobile applications of people with DS and caregivers who access the system via 4G, 5G/6G, and Wi-Fi communication technologies to provide information services. Mobile application design should consider elements of universal design, such as availability of information, flexibility of use, visibility of information, and low physical effort to use.

In addition to user requirements, some specific user characteristics were considered when creating a proposal for the system's conceptual architecture, namely:

- Delayed responses - may occur if a person with DS experiences a drop in concentration while travelling to the desired destination. For this reason, a notification system was developed in the user's mobile application to keep the person's attention on the road.
- Recklessness - depending on the person's cognitive abilities, a person with DS may make a reckless movement while moving through the traffic network (e.g., running a red light at a crosswalk when the person is in a hurry). Such situations can be controlled with the possibility of monitoring by a responsible person who keeps track of the person's current location with DS.
- Fear of the unknown - as the survey results showed, people with DS go to places they have never been before, so a particular fear may arise. To reduce the fear as much as possible, the application solution introduced a system of instructions when moving and the possibility of an emergency call.

4. Conclusion

In this research, in addition to proposing the conceptual architecture of the system for providing information services to people with DS, the functionalities of mobile applications for end users were also proposed. The planning and presentation of routes in the proposed system are specially designed and maximally simplified for the needs of these people. The solution also supports text or sound notifications to inform the user of the current location and draw attention to a specific target, which is a new design approach than is currently offered by standard commercial mobile applications.

The models, tests, and tools used to evaluate assistive technologies are not standardized, and the evaluation and selection of the most appropriate solution is often based on subjective opinions. The selection of the assessment model for assistive technologies should be based on research, best practices, or the experience of experts in the field. It is necessary to draw attention to the need for standardized tools to ensure effective delivery of information and communication services. In the case of the proposed solution from this work, there is a possibility to introduce additional personalization of the solution in the future, as the needs of people with DS are often very different.

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Sadržaj: *Asistivna tehnologija promoviše veću nezavisnost za osobe sa invaliditetom na način da im omogućuje izvršavanje svakodnevnih zadataka, istovremeno pružajući poboljšanja ili menjajući metode interakcije s tehnologijom potrebnom za izvršenje takvih zadataka. Kognitivne i fizičke karakteristike osoba sa Daunovim sindromom obično se odlikuju nekim oblikom poteškoća u komunikaciji i učenju i specifičnim fizičkim karakteristikama, zbog čega obavljanje svakodnevnih aktivnosti može biti izazovno i često zahteva pomoć asistenta. Za potrebe ovog rada autori su sproveli anketno istraživanje, a prikupljeni podaci poslužili su kao temelj za razumevanje razvoja osoba sa Daunovim sindromom, načina na koji obavljaju svoje svakodnevne aktivnosti, kretanje u saobraćaju i okruženju, učestanosti i poznavanju informaciono-komunikacionih tehnologija. Cilj rada je da predloži CAT model asistivne tehnologije i konceptualne arhitekture sistema za pružanje usluga informisanja bazirane na konceptu Interneta stvari u svrhu povećanja samostalnosti i mobilnosti osoba sa Daunovim sindromom.*

Ključne reči: *Asistivna tehnologija, saobraćajna mreža, osobe sa poteškoćama u razvoju*

PRIMENA KONCEPTA INTERNET STVARI U SVRHU INFORMISANJA OSOBA SA DAUNOVIM SINDROMOM

Dragan Peraković, Marko Periša, Ivan Cvitić, Petra Zorić