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ICERI2014 TABLE OF CONTENTS

INDOOR LOCATION TECHNOLOGIES FOR ASSESSING AREA OCCUPATION IN PRESCHOOL ENVIRONMENTS

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Abstract

In the field of early childhood education, some benchmarks to evaluate the quality of contexts have been developed. One of these benchmarks, developed in the scope of the Effective Early Learning Project, uses the Child Involvement Scale. The Child Involvement Scale uses a list of signals that are recorded on a five-point scale. These signals range from level 1 – 'where a child may seem absent and display no energy, activity is simple, repetitive and passive', to level 5 – 'where a child is concentrated, energetic, and persistent with intense activity revealing the greatest involvement'.

The observer records his perception about the concentration, persistence, motivation, energy, satisfaction, complexity and creativity, reaction time and language, trying to establish how the child really feels and experiences the overall learning process. The observations are performed according to a specific format and guidelines, including the definition of specific learning experiences by the teacher. The knowledge gathered from this process results in several aspects, such as in the organization of space, daily routines, and interactions.

The importance of an enabling environment is so revealing that educators devote much attention to its organization. Educators define areas of interest in sufficient number so that children have the possibility of choice. They also ensure the visibility and flow of materials between areas in order to expand the learning experiences of children. Materials are arranged in consistent places and the shelves are tagged with child-friendly labels so that children could get out and put away materials themselves. This aims at creating an intentional daily routine that provides a balanced variety of experiences and learning opportunities. Children engaged in both individual and social play, participate in small and large group activities, assisted with clean-up, and developed self-care skills.

This set-up and mechanics lead to the possibility to study the impact and interest each area has in the classroom. By constantly measuring the time each child spend in each area, the paths chosen and the number of areas visited by each of them allows the teachers to better understand the interest and success they have among children. The number of children in each classroom makes the measurements of these indicators impossible to do manually.

In this paper we assess and present a stat-of-the-art of indoor location technologies able of providing automatic measurements of area occupation in kindergarten classrooms. We focus on technologies that allow dealing with the very dynamic nature of the room environment and that can provide adequate precision and sample time for multiple children simultaneously. We consider several approaches, such as infrared or radio-frequency signals, acoustic location, GPS, trilateration of WiFi devices and mobile phone (GSM) based location.

Indoor and noisy environment present a challenging task for assessing, with precision, the location of people, in particular, children in preschool environment that we hope to solve with the combination of several techniques.

Keywords: Preschool Education; Indoor Location; Learning Experiences; Learning Areas.

1 INTRODUCTION

Early childhood education, as in many other areas, demands a constant attention and dedication in order to maintain or increase the learning process quality. The education process involves many actors and techniques, arranged in very diverse ways. One important factor is the existence of specific activity areas in the classroom, referred in the literature as influencing the quality of an early education program and contributing to the child development (Figure 1).

Figure 1 – Areas in a kindergarten room.

1	Entrance door	2	Teacher closet	3	Table with children's pictures
4	Library area	5	Writing area	6	Sciences area
7	Home area	8	Constructions area	9	Games area
10	Flip chart	11	Children's closet	12	Large group
13	Painting and plastic expression area	14	Children's closet	15	Sink dishwasher

The activity of children is an indicator of the success of these areas and how they can be optimized. The activity includes analyzing the time each child spends in each area, the sequence they follow, the colleagues with whom they usually work and even when the pattern, if any, breaks.

The number of children, which is typically 20 to 24, makes the task of maintaining a manual record of this information very difficult. The kindergarten teacher does not have the time or availability to log all the children's activity, keeping a record of time and others.

Indoor Positioning Systems allow locating and tracking each child in the classroom, constantly registering the position, time, path and nearby colleagues. There are many challenges to overcome, in particular the number of children to track, the constant and frequent movement and position accuracy and precision. However, the possibility to maintain a long-term record of activity is of the utmost importance to assess the quality of space organization and overall learning activities.

In this paper we make an exploratory approach to indoor positioning systems and automatic activity recognition models, towards defining and implementing a children's activity monitor. This system will be used to assess the relevance and organization of specific activity areas in kindergartens. It is structured in five sections, starting with this introduction. Next section focus on the importance of the areas and environment in the children's learning process. Section 3 describes some approaches and technology for indoor positioning and section 4 describe de nature of activity recognition systems. Section 5 presents some final considerations.

2 THE IMPORTANCE OF AN ENABLING ENVIRONMENT

Specialized literatures, about quality in early childhood education provide evidence that layout, size, materials and design features influence the quality of an early education program and thereby contribute to child development. Recent research about early childhood programs based on Exploratory Learning suggest that cognitive development takes place in the context of the child's interactions with others and with the environment – interactions in which the child is a very actively participant. The implications for learning opportunities and for early childhood pedagogy are substantial. In other words, young children learn through play and by exploring and interacting with their environment, both social and physical. They need indoor and outdoors play space that is markedly different from conventional elementary school classrooms and playgrounds.

Instead of filling classroom space with desks or tables, preschool programs subdivide classrooms into physically well defined activity areas – a block area, a dramatic play area, and the like. These areas permit small groups of children to engage simultaneously in different activities without interfering in each other's play. Architectural elements, such as ceiling height, lighting, corners, walls, and platforms, as well as furnishings, provide visual separation and a distinctive atmosphere appropriate to each activity. These design considerations support uninterrupted self-directed play and exploration. Achieving this type of environment requires classroom dimensions and layouts that lend themselves to these arrangements and architectural elements specifically designed and constructed to support active learning [1].

These evidence recognizes the interdependence and interaction between children and their life contexts [2], [3] and stress the importance of building complex learning environments, designed physically and socially, to respond to the plurality of actors, the diversity of learning experiences and the multiplicity of forms of expression. Building knowledge is seen as a collaborative and participatory action.

The intentional design of the environment is a "starting point that allows the development of a real sense of participation in a enabler community" ([2], p.109). The learning space is not conceived as merely physical. It depends on the interactions that take place in it. Act and build knowledge in space, implies understanding it as a cultural dimension where the definition of the areas, equipment, materials and interactions are constituted as vehicles of cultural appropriation. When children are in the paying areas they use cultural, symbolic and material instruments.

Recognize the child as an active learner who learns best from learning experiences that develop in space, implies creating conditions for their action on the objects and their interaction with people, ideas and events.

This aspect are related to the Piagetian ideas which highlight: i) that learning takes place through the direct action of the children and the materials [4]; ii) that active manipulation of objects, creates the opportunity to explore with all the senses, combining and processed its initial usefulness; iii) that the initiative and the ability to choose allows the child to decide what they want to achieve continuing his interests and goals; iv) that children should communicate their choices explaining their thoughts through language. In this perspective, the activities children do should contribute to their development and learning intellectual, social and [5].

In this sense it is expected that kindergarten teachers act with intentionality As [6] points out "being intentional means to act with a purpose and a plan to achieve it. The intentionality of the acts arises from careful reflection, considering its potential effect" (p.4). This means that Kindergarten teachers have to assess to the quality and quantity of materials and the diversity and dimensionality of the playing areas, how children interact with it and how and with whom they interact.

This assessment allows the kindergarten teacher to know what the children's preferred area is, what kind of materials interest them the most, if there are areas that do not attract their interest, know what kind of choices they make over the week, with which colleagues they often work, if there are children who often work alone, if there is diversity of choices taking into account gender or ethnicity, if the children flop around from area to area or if they keeps focused for long periods of time.

In the context of early childhood education different scales were designed, to evaluate the environment, in diverse dimensions, such as fiscal and social space, relations and daily routine, such as the Early Childhood Environmental Education Rating Scale (ECEERS) [7] and the Preschool Program Quality Assessment (PQA) [8].

The ECEERS provides a collaborative tool for educators and others to discuss their program goals, consider its strengths and areas of needed improvement, and chart a future direction for development. The ECEERS encouraging deep discussions about program philosophy, design and implementation.

The evaluation process in itself is an invaluable professional development activity. Professional development benefits include attaining knowledge about effective practices in both early childhood education and environmental education. The findings of the rating scale, on the other hand, can assist in the identification of priorities or facets of program practice that can be improved or made more effective. It can allow the kindergarten teachers to the program strengths and existing resources and talents, which can be leveraged as appropriate to bring about needed improvements or progress, are imbedded with in the process of evaluation.

The Preschool Program Quality Assessment (PQA) developed in the HighSope approach evaluates seven areas of program quality, four of which are based on classroom observation: Learning Environment (9 items), Daily Routine, (12 items), Adult-Child Interaction (13 items) Curriculum Planning and Assessment (5 items). The others two areas are about Parent Involvement and Family Services (10 items) Staff Qualifications and Staff Development (7 items) and Program Management (7 items) are based in specific program based on interviews.

However, the use of those tools requires time to observe. This activity is compromised by the interaction that educators have to keep with the 20 or 25 children who are in the room.

3 INDOOR POSITIONING SYSTEMS

Location services, such as the Global Positioning System (GPS), are widely used in several applications and scenarios. Virtually any system that requires getting a subject's current position can benefit from this technology. It is used in several areas and with several purposes, such as, but not limited to:

- fleet tracking: track or follow one or more fleet vehicles in real-time;
- geofencing: locate vehicles, persons or pets and warn when the subject leaves a pre-determined area;
- navigation: through constant measurements of velocity and direction;
- robotics: in self-navigation, autonomous systems, such as drones;
- recreation: several games and challenges based on location.

The low price and miniaturization of current GPS receivers make this technology easy to integrate in an increasingly number of devices. They are ubiquitous in mobile phones, laptops, car navigation systems, pet collars, and many others.

However, GPS does not work inside buildings or the location provided is not accurate. It depends on line of sight to four or more satellites that orbit the earth, and obstacles can block the signal and thus prevent the system to operate correctly. Indoor Positioning Systems (IPS), although providing the same service than GPS, require different technologies and approaches to work.

The existence of reliable indoor location is increasingly important, as the buildings are getting bigger and automated machines are finding their way into several indoor applications. Humans rely on their eyes to guide them inside buildings, however, as buildings start to be more complex, visual clues to positioning start to be insufficient.

This section describes some approaches to IPS, which are structured in two large groups. Wireless Systems use the strength, time and angle of radio waves to calculate the position of a subject. Non-radio-Based Indoor Positioning relies on sound (or ultra-sound), inertial navigation, infrared, magnetic fields, and others.

3.1 Wireless Systems

Wireless positioning system relies on radio waves for distance measurement and thus calculating the relative position of the subject. A common technique is to measure the time that electromagnetic waves take to travel a specific distance. Having the speed, the distance is easily calculated, considering that the precision is adequate (TOA – Time of Arrival). The location in 2D is determined with the help of an additional radio signal, giving a second distance to measure [9].

The main problem with this approach is the necessity to have all the clocks perfectly synchronized. An alternative is to use Differential Time of Arrival, which dismisses the necessity of clock synchronization with the receiver. However, the transmitters still need to be synchronized. The position is calculated by measuring the difference between all the received signals (one for each transmitter).

A similar approach is followed in the Round Trip Travel Time, in which a transmitter node A sends a packet to another node B and waits for the response. Each packet carries a timestamp, allowing A to calculate the distance between both nodes.

An alternative to the time to calculate distance is to use angles. The Angle of Arrival method of estimating the location is based on figuring out the angle between the transmitter and the receiver, with respect to a coordinate system. For 2D, two angles are necessary to calculate the position. The main inconvenient of this approach is the difficulty in measuring angles, especially when reflections are a possibility. Moreover, the error increases with the distance [10].

One of the simplest ways of estimating distance is through signal strength. The farthest the transmitter, the weaker the signal will be. However, signal strength is affected by several factors, such as interference between reflected signals, relative movement between transmitter and receiver and also movement by third party objects [11].

3.2 Non-radio Systems

Non-radio Systems rely on a different set of physical characteristics and effects to assess the location of the subject. Approaches based on sound or ultra-sound waves, for example, use the speed of propagation of mechanical waves in the air. The time of flight, in this case, is measured and compared to the speed of sound in the atmosphere, resulting in the distance between the transmitter and the receiver [12].

The advantage of sound waves to the radio waves is the slower velocity and the effective barrier that obstacles pose to the propagation. However, the velocity depends on the temperature and humidity of the atmosphere, contributing to the error in determining the position [13].

Alternatives use magnetic fields, either generated [14] or already existing [15], for positioning. The former depends on previous distribution of magnetic field generator coils, with the advantage of stronger resistance to perturbations. The later depends on geomagnetic field and on fingerprinting it inside buildings.

Following a different structure, Inertial Navigation Systems (INS) are self-contained, in the sense that they depend only on the sensors within. Usually, these sensors include accelerometers and gyroscopes, widely available in modern smartphones and other devices. Considering the data the sensors collect, it is possible to calculate direction and distance traveled, and thus the current position of the subject [16]. However, error tends to accumulate as the subject moves.

3.3 Practical approaches to IPS

Common Indoor Location Systems use WiFi hotspots in buildings to locationing. As described above, the strength of the signal (RSS – Received Signal Strength) can be used to calculate the distance to the access points and thus estimate the location of the subject. Another approach is through fingerprinting the signal strength in offline and make the database available to the subject [17]. Both are usually used in smartphones, equipped with processing power and WiFi. The smartphone will calculate the position according to the RSS and, eventually, the fingerprint of the received signals. The precision of using this approach is around 1.5 to 3m, depending on the conditions [18]. Similar approaches are also used with Bluetooth, for example, both for RSS and fingerprinting [19].

Active badges, worn by the subjects, can help increase the accuracy of the IPS. These will emit a signal (infrared, sound, radio frequency, or others) that will be used by receiving stations to calculate the position of the emitter [20].

There are several approaches and techniques for Indoor Positioning Systems. The accuracy depends on the method and on the characteristics of the environment. Cheaper or simples approaches will sacrifice accuracy, although precise system will tend to be complex or expensive.

In the kindergarten context, the purpose is to get the position of 24 moving subjects in a single room, trying to be as inconspicuous as possible. Moreover, the system has to be accurate below one meter, to allow assessing the position of each child in the room and relative to the other children.

4 AUTOMATIC ACTIVITY RECOGNITION MODELS

Kindergarten environment is very dynamic in the sense that over 24 children are constantly occupied moving, experiencing, and other learning building activities. As mentioned above, the room areas are important to define themes and experiments children use. It is important to assess when they move, where are they going, how much time they spend on each area and with whom, and many other indicators.

It is very difficult for kindergarten teachers to maintain a detailed record of all the activity of all the children at all times, so we propose using an automatic activity recognition system based on indoor positioning for gathering the information necessary to assess the kindergarten room dynamics.

Activity recognition models provide a mean to identify the actions and goals of one or more subjects, relying on data collected by sensors and on environmental conditions. In the context of kindergarten, the sensors should be as inconspicuous and simple to install as possible. Moreover, since we intend to apply the system to several children, cost is also a factor. Cameras and image processing is very difficult because of the difficulty identifying and track each child (they all have similar clothing, similar body shape and overlaps would be common).

Wearable sensors are an interesting possibility, allowing both the identification of each child as well as other data, such as position. They should be compact and light, allowing to pin to the clothes or carrying it in the pocket.

The purpose of an automatic activity recognition model is to identify patterns in the action primitives performed in the kindergarten room setting. In such tasks, features such as position, time, speed and others are extracted and used to classify the data. The approaches include data mining and probabilistic models.

These models allow mapping current data to pre-learned or pre-defined models and detect similarities or differences in activity, such as the time spent in specific areas, the colleague gender, age or even the sequence of visited areas. These allow getting the notion of the long-term evolution of interest and relevance of the areas in the room with time, as well as detect changes in children behavior. The kindergarten teacher can, then, study the activities and reflect on the changes to be made in the room areas, sequence or define new experiences for the children.

5 CONCLUSIONS

The automatic activity recognition models can be used both in research and evaluation. The results can be analyzed by kindergarten teachers and shared with colleges, administrators and staff. One of the advantages of the sistem relates to the fact that the kindergarten teacher can collect data while interacting with the children and they can analyze the data subsequently.

It could be an excellent resource for providing professional development through observation and sharing information. A kindergarten teacher can focus on one or more aspects, then he can analyze it and improve his practices and the learning experiences he provides to children. He can share the information with their colleagues, and make comparisons between classrooms. Together, they could assess strengths and areas for improvement, providing concrete examples of how implementation can progress along the rating continuum.

The findings can be used to define and illustrate best practices, to focus attention on program development issues in preservice and inservice training, to examine the relationship between program practices and children's development, to analyze questions of gender and diversity, and to improve the quality of the early childhood program.

However the design and development of an automatic activity recognition models implies consciousness of the difficulties inherent to the development of hardware and software as well as system calibration. The costs associated with sensors, is another difficulty to implement the system in large scale.

It should be noticed that this is preliminary and exploratory work although we strongly believe that the extraction and study of children activity in the kindergarten room can provide valuable insight into how to improve the areas to further improve children learning.

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