RubberBand: Augmenting Teacher's Awareness of Spatially Isolated Children on Kindergarten Field Trips

Hyukjae Jang[1], Sungwon Peter Choe[1], Inseok Hwang[1], Chanyou Hwang[1], Lama Nachman[2], and Junehwa Song[1]

[1]Korea Advanced Institute of Science and Technology
Daejeon, 305-701, Republic of Korea
{hjjang, sungwon, inseok, chanyou, junesong}@nclab.kaist.ac.kr

[2]Intel Corporation
Santa Clara, CA 95052 USA
lama.nachman@intel.com

ABSTRACT

On school field trips, chaperoning teachers' foremost concern is the safety of the children, particularly ensuring that none of them go missing. However, they have limited attention resources and face many challenges in keeping track of their charges. We present RubberBand, an assistive application that helps alleviate the teacher's burden. Our approach adapts to diverse field trip environmental and child behavioral dynamicity, utilizing observations of the relative dispersion of children and their tendency to form sub-groups.

Author Keywords

Relative group dispersion, spatial isolation, field trips, missing children, assistive application

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Design, Experimentation, Human Factors

INTRODUCTION

In childhood education, field trips such as exploring nature or visiting interactive museums are very special moments for young children, though they comprise only a tiny fraction of a school's annual programs. Getting out of the classroom routines and having new and hands-on experiences bring highly positive benefits to the children, stimulating self-motivation, creativity, and long-lasting memories [10].

With little doubt, keeping track of each and every child is the primary responsibility of the teacher chaperoning a field trip. We observe that this responsibility, preventing a single child from being lost, is nontrivial and challenging, requiring a teacher's complete and focused attention. The teacher should not only keep her eyes on every child, but simultaneously put consistent effort into maintaining the dynamic balance of managing the children's highly curious and impulsive natures, achieving situation-specific educational goals, and making proper interventions for children in need. Even the temporary disappearance of a child would be a serious failure of the teacher, causing panic and possible legal responsibility. Despite their utmost care and effort, teachers' attention resources are limited; they are outnumbered by the children and face many challenges in keeping track of their charges.

Figure 1. Diverse situations in a kindergarten field trip showing the variety of spatial dispersion in the child group

We designed RubberBand, an assistive application deployed on off-the-shelf smartphones and a fleet of wearable sensors, in order to alleviate the teachers' cognitive and emotional burden in keeping every child within their awareness. We utilized the following observations based on our 6 month collaboration with a local kindergarten in our approach:

- The occasional spatial isolation of a few children is a potential precursor to missing children.
- The spatial dispersion of a field trip group is dependent on many situation-specific diversities (See Figure 1).
- The spatial dispersion of a field trip group is not simply linear over scale, due to the tendency of children to cluster into sub-groups of close friends.

In order to reveal the spatial isolation of children, RubberBand leverages the child group's spatial dispersion as a relative frame of reference while considering the above non-linear characteristic. Our approach adapts to the diverse and dynamic situations of field trips and child behavior in

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determining the spatial isolation of children. From our experiences deploying RubberBand on multiple real field trips, we report on not only its effectiveness in discovering and notifying chaperoning teachers of isolated children while considering the teachers' limited attention resources, but also its rich implications for further benefits in the teachers' understanding of the educational interests, sociability and health and safety issues of their charges.

KINDERGARTEN FIELD TRIP PRELIMINARY STUDY

To understand school field trips and the challenges faced by teachers in managing the children, we collaborated with a local kindergarten for 6 months. We participated in and observed a total of 11 field trips with classes of 10~40 children 3 to 6 years of age. We also conducted interviews with 9 teachers for 1.5 hours each after each field trip.

The Teacher's Burden

The results from the post-field trip interviews and our direct observations confirmed that teachers spend most of their attention safeguarding their students. One teacher stated that, *"[A]fter a field trip, I hardly remember anything except accidents or critical events."* Teachers often sacrifice their personal comfort to keep track of the children. One teacher commented that she does not even have time to visit the bathroom until the field trip is finished. Teachers rely on ad-hoc techniques to address their attention limitations, such as frequently taking head counts to make sure no child is missing. Even so, children were sometimes temporarily lost. We observed the cost for teachers in terms of emotional distress and time and effort spent in searching for missing children. In addition, the other children lose valuable field trip time while the missing children are searched for.

Sub-grouping Behavior of Children

We observed, and teachers confirmed in interviews, that children do most things together in sub-groups of 2 or 3 friends. As shown in Figure 1(b), children explore an interactive science exhibition in groups of friends. These *buddy groups* play together with an exhibit before running over to another one. Children almost always are in buddy groups. They naturally cluster into small groups with nearby classmates. We observed children staying in close groups across all kinds of situations, from confined rooms to wide open spaces (though the distance between groups increased).

Spatial Isolation in Dynamic Field Trip Environments

A field trip group typically visits several locations during the course of a single field trip. The group formation varies according to these environments, as well as to the teacher's instruction. For example, in one field trip to a scientific exhibition complex, we observed the children walking in single file in a botanic garden, and then running freely through a large, outdoor exhibit and finally exploring in dispersed groups within an indoor exhibit (see Figure 4).

Most field trip environments are full of stimulating sensory information that captures the children's interest. They rush to play with exhibitions, stare at exotic animals and get deeply involved in play with each other. Such immersive environments distract children's attention away from their field trip group as it moves to another area. Additionally, field trip environments are often crowded with other school groups. As a result, children can be confused as to what group they belong to and can follow the wrong class. These environmental characteristics and behaviors of the children in such situations can lead to isolated children and the possibility of children going missing.

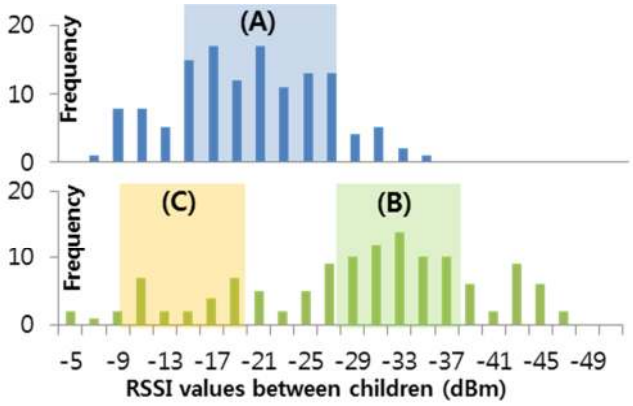

Figure 2. Histogram of RSSI values between children in different situations; the top graph corresponds to Figure 1 (a) and the bottom to Figure 1(b).

CHALLENGES AND SOLUTION APPROACH

Our observations of isolated children as described above provided hints as to how we could help teachers prevent missing children. Because isolation precedes a child going missing, it can be used as an indicator of at-risk children. In order to find isolated children, we focused on spatial isolation from the other children of the group. Spatial isolation from the teacher could be an alternative approach, but we have observed that the teacher is not in the center of the child group in most situations; e.g. she is leading the group of children or helping a specific child.

The challenges in discovering the spatial isolation of children are due to the dynamic characteristics of field trips. To adapt to diverse situations, the group's current dispersion can be used as a frame of reference for deciding if a child is spatially isolated. But as noted above, children have a tendency to move and play in buddy groups, complicating the problem. Figure 2 shows the distributions of the radio signal strength indication (RSSI) values between every pair of children collected on a field trip to a museum in two different situations, allowing proximity to be estimated between children [2]. The topmost histogram shows the RSSI values for children sitting close together on couches while watching an educational movie (see Figure 1 (a)). It has a high frequency peak around -18 dBm (A) which represents close proximities. However, the histogram below shows the RSSI values for children freely interacting with exhibits in a science exhibit (Figure 1 (b)). The histogram shows a high frequency peak around -33 dBm (B) for proximities between far-separated buddy groups and also includes two smaller frequency peaks around -11 and -18 (C), corresponding to the close proximities between the buddy group members. Here, we can find that group dispersion is not

(a) (b) (c)

Figure 3. (a) A teacher with a Bluetooth headset and a smartphone running RubberBand (b) a teacher evaluating an isolation notification (c) a screenshot of the RubberBand feedback interface

simply scaled in a linear fashion. Dispersion within buddy groups (C) is situation-invariant while dispersion between buddy groups (B) largely scales up or down depending on the situation. Thus, without considering the children's behavioral tendency of staying in buddy groups, a naïve approach would yield lower quality results, possibly not discovering many instances of isolated children.

Considering this we take a two-step approach for finding isolated children. First, we find buddy groups. We detect buddy groups by applying a spectral clustering algorithm [7] to the RSSI values which represent the proximity between every pair of children. Second, we calculate the dispersion norm between buddy groups. We then determine isolated children (buddy groups) by comparing each buddy group's average proximity from other buddy groups and the overall dispersion norm. This technique enables RubberBand to automatically adapt to diverse field trip environments.

FIELD STUDY DEPLOYMENT

We developed RubberBand and deployed it on 2 different field trips lasting about 2 hours each. One trip was to a national science exhibition complex and the other was a hiking trip to a local mountain. 12 children (4~5 years old) participated on each field trip. We distributed sensor-equipped backpacks, used in our prior work [6], to the children. An Android phone running RubberBand and a Bluetooth headset were given to a teacher (Figure 3 (a)). RubberBand collects RSSI values from each child's backpack sensor. Each sensor measures RSSI values every second by broadcasting beacons between sensors over 801.15.4 Zigbee. This allows Rubberband to be usable in diverse situations without any infrastructural support. When RubberBand detects isolated children, it notifies the teacher with an audio notification using the headset.

Our application is designed for children and thus requires careful design considerations to respect the children's safety and comfort. In our pre-deployment phase, we received confirmation from teachers and parents that the equipment was comfortable, not burdensome and not distracting for the children. In our deployment phase, we mostly focused

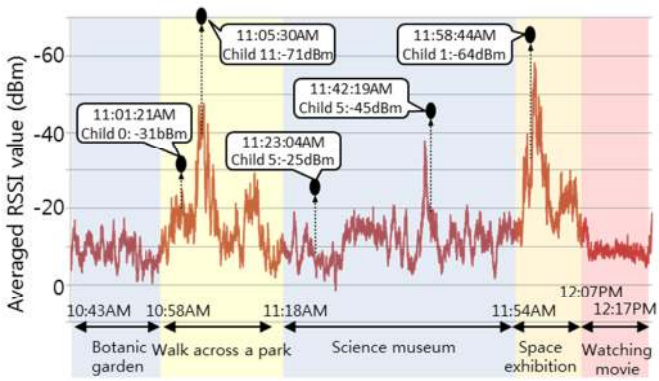

Figure 4. The averaged RSSI values between every pair of children and selected examples of detected isolated children.

on designing the runtime interface for teachers to be minimally obtrusive, such as using a Bluetooth auditory interface for notification purposes not to distract the teacher's visual attention from the children. More importantly, to evaluate RubberBand, we asked an additional teacher to take part in the experiment, who duplicated the primary teacher's tasks while using and evaluating RubberBand at the same time. The primary teacher did not use RubberBand in order to cope with any unexpected situations during the experiments. Note that we used a secondary teach for our initial deployment of our experimental application so as not to endanger the easily vulnerable, young children.

Figure 3 illustrates RubberBand being used on a field trip. RubberBand remains silent unless an isolation event is detected, so that the teacher can pay attention to the children and take care of them as in a usual field trip. On detecting an isolation event, RubberBand gives an auditory notification to the teacher, verbally stating the names of isolated children. The teacher then immediately begins looking for them. Note that, for this whole cycle, RubberBand does not require the teacher to divert her visual attention from the children nor use her hands for tactile controls. The only exception is that, when the isolation situation has been resolved, RubberBand asks the teacher whether she agrees or not that this notification was valid, as shown in Figure 3(c).

RESULTS AND DISCUSSION

We analyzed feedback results from teachers about the appropriateness of the notification as well as event logs. Interviews were conducted with the teachers to get an overall impression of RubberBand and their experiences of field trips with RubberBand. Teacher answered that 86.5% of the notifications were appropriate over 37 detected events. As shown in Figure 4, isolated children were detected in diverse situations with respect to the current group dispersion.

The teachers reported that their overall impression about the isolated children detection was good and that it helped them manage their children. One teacher commented, *"[With RubberBand]…I didn't feel as stressed out…Like when I count the children…When there's no [isolated child] notification, it gives me more confidence in my count…that no child is missing."* Even though teachers received some false

notifications, since a false notification means that the children were nearby they could be easily found, minimizing the extra cost in their attention. They reported that the value of receiving the many accurate notifications far outweighed the cost in attention of the few false notifications. Finally, they remarked that the auditory notifications did not overly distract their attention away from the children.

We found 2 common cases in which isolated children were detected by our system: when they *break away* from or are *left behind* by the group. However, we also noted an interesting instance in which the notifications helped the teacher gather all the children before moving on. While playing at a park, the children were freely running around for several minutes. When the teacher called the children together to move on to the next place, notifications for some children who had not joined the gathering group and were still at a distance were received. This was because as the density of the children becomes less dispersed, children who stand still are recognized as being isolated from the others.

We further observed that isolated children cases often provide additional information worthy of the teacher's attention. Identification of isolated buddy groups playing together as well as isolated children playing alone are valuable to teachers in understanding the sociability of children. We envision that future implementations of RubberBand could track the sociability and buddy groups of children providing teachers with data about the friendships of the children. Additionally, an isolated child captivated by an exhibit often indicates a child's educational interest. Most importantly, an isolated child lagging behind the group could be indicative of health issues such as exhaustion or injury. In one instance when the group was walking towards the next location, one girl's walking pace was a little bit slower than the others. She fell behind the group because she was more tired than the others due to her relatively small frame. Once the teacher received a notification and was made aware of the situation, she slowed down the group to an easier pace.

Although our approach offers the many benefits discussed above, it also has some limitations. Since we use a relative group dispersion approach, if children were to fan out over a very large area beyond the teacher's range of vision at a relatively even dispersion, our approach could fail to detect the many isolated children. Although this case is unlikely, it may be possible if the children are playing a game like hide-and-seek. Our RSSI implementation also has some inherent limitations. For instance, radio signals can be blocked by walls and other large obstacles. The human body itself can cause some signal attenuation as well. For these and other reasons, RSSI cannot be used to measure distances with high accuracy. However, since we use relative proximity among the children this is not a problem except in the rare cases that the signal is severely degraded or completely lost. In such cases, the teacher was alerted immediately of the system failure

RELATED WORK

Due to the potential benefits of assistive technology in education, ubiquitous technologies have supported diverse situations such as kindergarten outdoor field trips [11, 3], student with autism in classroom situations [4], and teachers and students in collaborative learning [9]. Missing children is another issue that is extremely important to not only not only academia [12], but also industry [8]. However, most existing approaches consider individual children and do not consider cases of groups of children nor dynamic and diverse environments such as in field trips. We assist teachers leading kindergarten field trips by finding and providing notifications of the spatial isolation of children. Relative approaches [1,5] for peer positioning and other aspects of system performance and energy consumption give us fundamental insights for developing our application in considering dispersion, while we further consider the subgrouping behavior characteristics of children and its implications for the dispersion and isolation results.

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