Situation-aware System using RGB-D Camera, Spatial Knowledge Graphs and Situation Database
—Empowering caregivers to take better decisions and prevent child injuries —

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Unintentional injuries are one of the most common injuries among children below the age of 5 years. Although the concern about the need for injury prevention is raising among caregivers, preventable injuries are still the 3rd leading cause of death among children aged 0-14 years. Hence, there is a need for an effective system that can empower caregivers, parents, or schoolteachers in taking the right and faster decisions to protect the lives of children. In this paper, we propose a situation-aware system for unintentional injury prevention with the integration of image processing using RGB-D camera, spatial knowledge graphs and an accident database. This paper describes an implementation of the system and the advantages that it can offer in understanding the possible dangerous situations in the indoor environments like homes or classrooms and provide alternative suggestions on what kind of preventive measures be taken to minimize such injuries.

Key Words: Image Processing, Augmented Reality, Knowledge Graphs, Situation Recognition, Injury Prevention

1 Introduction

In Japan, for the children aged below 5 years, accidents and injuries are prevalent not just in the outdoor environments but also in the indoors like homes or preschools. Use of technology in the field of healthcare or danger detection systems in public environments are increasing. However, indoor environments like homes or preschool classrooms are also an important place to be monitored for the safety of children **[1]**. Camera-based monitoring is getting common even at indoor environments like homes and preschools due to the recent development of object recognition technology. Thus, we believe that it can be helpful in predicting the possible dangerous situations for children in their daily life activities.

In this study, we propose a situation-aware system that can be implemented in homes and preschools to monitor and inform carer such as caregivers, parents, and schoolteachers of the plausible dangerous situations in their own classrooms or surroundings and empower them in taking necessary actions. The proposed system consists of a real-time surveillance part performed with the help of RGB-D camera and spatial knowledge graphs are utilized for generating and obtaining the semantics between the objects and its position in a real environment.

2 Overview of the Situation-Aware System

In the following sections, we will discuss fundamental functions of situation-aware system and its related works.

2.1 Object recognition with RGB-D Camera system

In recent years, object recognition technology has been used in numerous applications to help improve the quality of life. As technology progressed, various research is performed in not just object recognition but also understanding a scene **[2]** or recognizing a situation from a 2D/3D image just like how a human would perceive the visual information. In our previous work **[3]**, we proposed an online learning system through which both parents and lecturer are empowered on the injury prevention education. In this case, we could only work on processing 2D image data obtained via communication tools like Skype and provide an overview of possible dangerous situation along with knowledge graphs.

With the raise in affordable and powerful cameras that could be installed in indoor environments like homes or preschools, we expect that this could help in overcoming the challenges faced in predicting dangerous situations from 2D images and instead directly access the real-world information (RGB and Depth values) from a camera installed in local environment.

2.2 Spatial Knowledge Graphs for Dangerous Semantic Information

When working with image recognition in the field of computer vision, use of graph networks has become popular among researchers to understand more meaningful information about the recognized image. In a knowledge graph, the vertices or nodes denote the graphs of objects, and the edges are relations between objects **[4]**.

In a spatial knowledge graph, following are some of the relations that can take different forms.

- spatial (front/back, right/left, above/below, inside/outside)
- comparative (bigger, same, smaller);
- part-whole (to have/include, to be a part of);
- or have other specific semantics (hold, ride on, play on). Etc..

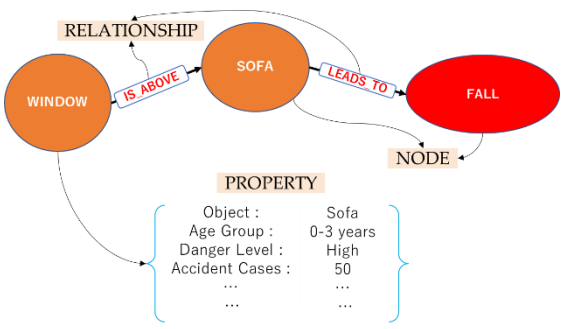

Fig. 1 An example of knowledge graphs that consider the semantics between the objects

In this study, we apply knowledge graph to dangerous situation recognition. Figure 1 shows an example of how knowledge graph can be used in the child injury prevention. The nodes refer to the dangerous objects (Orange) or an injury/accident (Red) that could occur. Each node could also contain properties like age group prone to injuries, severity of the danger or past injury/accident count that can be obtained from an accident database (Explained in the following section 2.3). As per Fig. 1, for example, when a window is detected above a sofa, this resulting relation between the object could be dangerous as it can lead to the child falling off the window or from the sofa. This relation here is a spatial relation that says window "is-above" sofa. Further, we can also include a causal relation that includes the effect of such spatial relation: window is-above sofa "leads-to" fall.

2.3 Accident Database from Japan Sport Council

To provide an understanding of the past accidents that has occurred in indoor environment like preschools and homes, we used the open-source database provided by Japan Sport Council (JSC) **[5]**. Details like place of accident, timing, location, and specific cause of such accidents are tracked on a yearly basis from many homes and preschools around Japan.

3 Details of Implementation

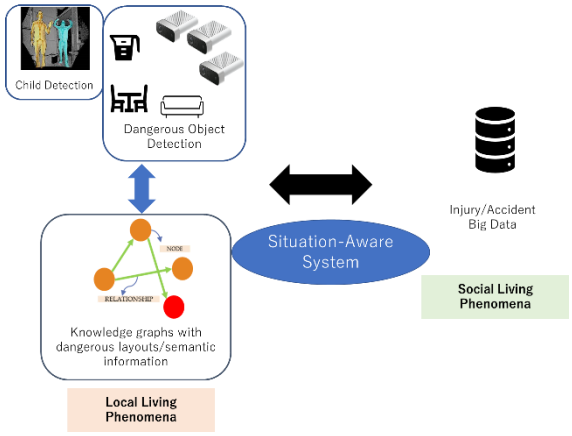

Fig. 2 Image describing the system overview

Figure 2 explains how we implemented a situation-aware system for injury prevention in preschools and homes. First, on the local living phenomena (for a particular home/preschool), we integrate the information obtained by the dangerous object detection from the RGB-D camera and the relations between the object and accidents as maintained in a knowledge graph database. We use Microsoft's Azure Kinect camera to obtain the depth information from the environment that can help us understand how close a child gets to a certain object and what possible dangerous layouts it can lead to. The obtained information is processed with the help of a pre-trained neural network called YoloV3**[6].** In this study, we predefined the following set of 16 objects that are commonly found in homes or preschools as dangerous objects. These include Sofa, TV Monitor, Bed, Backpack, Cup, Chair, Dining Table, Bench, Bottle, Vase, Refrigerator, Fork, Knife, Wine, Glass, and Potted Plant.

The Knowledge graphs are helpful in considering the following two situations which is difficult to achieve with object detection alone.

- **Collocation:** Multiple objects and their mutual spatial relations are considered to define the overall danger level of a particular situation and not just with mere object detection (As explained in Fig. 1).
- **Inclusion:** Sometimes, there are parts which are not detected easily even with the current state-of-the art object detection techniques. For example, a blind in a normal household can contain cords that are not visible even to naked eyes from a distance, and the cords can get strangulated on the neck of a child if ignored. Hence, knowledge graphs serve as great tool in considering such possibilities beforehand and warn about the situation to the caregivers.

So, there is a mutual exchange of information between the detected dangerous object via Kinect Camera and then verifying whether the identified set of objects fall under a certain dangerous layout with the help of knowledge graphs.

Second, we consider the social living phenomena, where we use the data provided by databanks in Japan like Japan Sport Council (JSC) on the large-scale prevalent injuries that occur throughout Japan. We integrate this accident big data in our system to help caregivers understand the specific scenarios and details of how a particular injury/accident has occurred in the past and then propose a possible set of preventive measures that can be taken to avoid such injuries in future.

Hence, the situation-aware system acts as a bridge for dealing with both local-living and social living phenomena.

4 Experimental Results

4.1 Spatial Information from RGB-D Camera

We conducted an experiment in our living room-like laboratory to simulate the indoor environment of home as shown in Fig. 3. A Kinect camera is placed on one side of the room to monitor the area near dining table. We then used a dummy child and placed in on top of a moving robot to simulate the movement of a child in a living room. In this experiment, we demonstrated how our system would respond to when a child gets closer to the dangerous objects and in a certain dangerous layout.

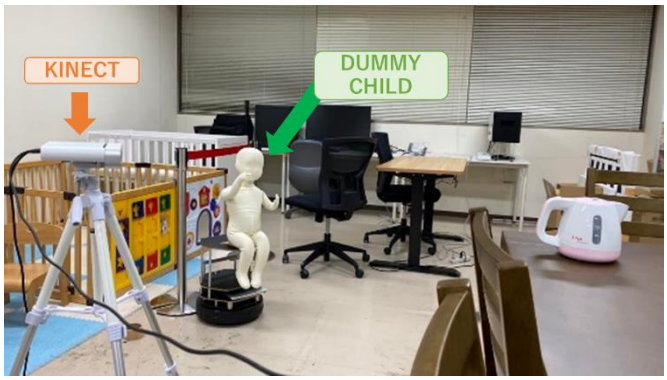

Fig. 3 Experiment Setup in a living room-like environment

Figure 4 shows an example of the dummy child approaching near a dining table who wants to grab the glass cup kept on top of dining table. The situation-aware system predicts here that child is within a certain range from the dangerous object, glass, and based on the

dangerous layout obtained from the knowledge graphs, it predicts that glass "is-on" the dining table that can "lead-to" sharp cut on the child's fingers.

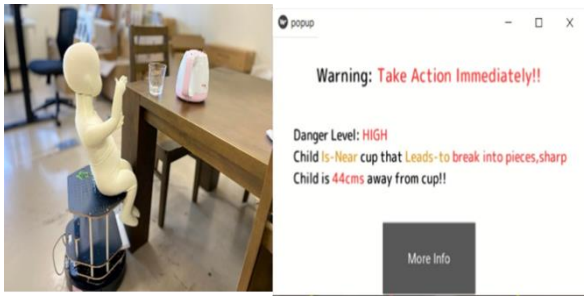

Fig. 4 Alert provided by the system

4.2 Dangerous Situation Information Presentation

Figure 5 shows the results of how our system provides the information on the possible dangerous situations. The system detects the possible dangerous objects with a bounding box and shows an i-button(top-left) and pink circles(top-right) to indicate the severity of the dangerous objects (On a scale of 1-5 with 1: least priority and 5: highest priority). When the i-button is clicked, a detailed information regarding TV as a dangerous object as an example is presented in 3 parts as shown in Fig. 6. These include an illustration explaining how exactly the object poses danger, what are the possible solutions or safety goods that are available in the market and then provide a QR code of e-commerce site of where such goods can be purchased.

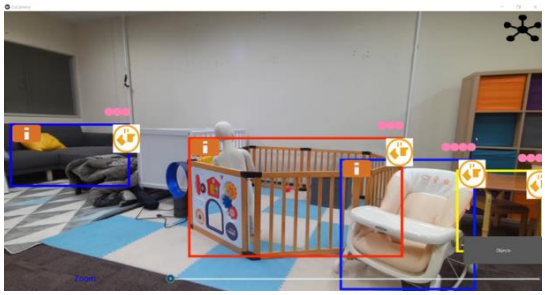

Fig. 5 An example of how the dangerous layout detected by the system is presented

Fig. 6 Detailed information provided by the system when i-button is clicked

Figure 7 shows an example of some specific cases of situations that led to an injury that is obtained from the accident database. In this case, some specific examples of how sofa as a dangerous object has caused injuries to children at homes are presented. This can help caregivers provide a better understanding on the dangerous situations that can occur even in their own living environment and motivates them to take better decisions.

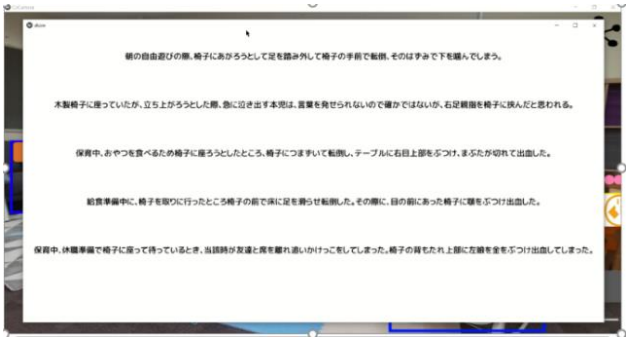

Fig. 7 Typical accident situations obtained from the accident database

5 Conclusion

In this paper, we proposed and demonstrated how a situation-aware system can help caregivers understand more about how their living environment can be potentially dangerous that can cause unintentional injuries at homes and preschools. Use of knowledge graphs along with object detection serves as an effective way in recognizing the severity level of a dangerous situation. This research is still under progress and as a next step, we would work on how to exploit the information obtained with a depth camera to consider complex scenarios (for instance, not just above/below or left/right directions but other arbitrary directions also). Also, the specific scenarios differ with a home and preschool environment as the number of objects and their interference with the child and environment may differ which can lead to further challenges. This study shows that effective integration of the explained technologies can empower the caregivers and take right and faster decisions to minimize the child injuries.

Acknowledgements

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