Poster Abstract: KinSpace: To Provide Fall Prevention Using Kinect

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ABSTRACT

Falls are a significant problem for the elderly living independently in the home. Many falls occur due to household objects left in open spaces. We present KinSpace, a system that uses real-time depth data and human-in-the-loop feedback to adjust its understanding of the open space of an environment. We present results showing the effectiveness of our underlying technical solutions in identifying open spaces and obstacles. The results for both lab testing and a small deployment in an actual home show over 80% accuracy for open space detection and 70% accuracy in obstacle detection even in the presence of many real world issues.

Categories and Subject Descriptors

C.3 [**Special-Purpose and Application-Based Systems**]: Real-time and embedded systems

General Terms

Algorithm, Design, Experimentation

Keywords

fall prevention, object detection, obstacles, safety, Kinect

1. INTRODUCTION

Falls account for a large number of the injuries sustained in the home. Various studies estimate that from 33-52% of adults aged 65 or greater have at least one fall per year[1]. It has also been shown that falls in the elderly population can largely be attributed to trips[2]. Researchers at Colorado State University estimate that about one third of falls in the elderly occur due to environmental hazards in the home, the most common of which is tripping over objects on the floor[3]. This gives clear motivation for the development of a system to assist in keeping living spaces free of obstacles in efforts to prevent falls.

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We propose KinSpace, a home monitoring system that uses the Kinect sensor to detect objects left in open spaces in a room. It uses skeleton data from the Kinect to determine where in the room users walk, and subsequently which areas to monitor for obstacles. It then processes depth data to detect objects in that space and alert the user or healthcare providers about the increased risk of falling. KinSpace also employs a feedback loop that uses detection data as well as user input to evolve its understanding of the environment over time.

Automatically determining open areas and obstacles are not easy tasks because of real world complicating factors. KinSpace addresses many complicating issues involved with real-world Kinect system deployments, including different open room formats, noisy depth data, false alarms, differences between users of the system, and various types of items that lead to different depth data patterns provided by the Kinect sensor.

KinSpace makes the following contributions:

- KinSpace, a three-part Kinect-based open space detection, obstacle detection, and alert system
- A system that addresses real-world complicating factors involved with in-home deployments
- A lab evaluation of KinSpace that fully analyzes the accuracy of both open space and obstacle detection, showing greater than 80% for each
- An in-home deployment evaluation of KinSpace that demonstrates the handling of real world issues

2. OVERVIEW OF KINSPACE

KinSpace is a system that uses a Microsoft Kinect to perform obstacle detection in a room to minimize the risk of falls. It accomplishes its purpose in two phases – a training phase and a detection phase.

During training phase, the processing unit uses skeleton data and records where users walk in the environment as well as the plane equation of the floor. When data collection process is complete, KinSpace calculates a transformation matrix based on the floor plane that is then used to transform all depth points used in the remainder of the algorithm. All foot points captured during data collection are transformed to generate a normalized training set of foot points. The system filters this set of projected points, removing any whose height is above a certain threshold. These processes give us the full training set to be used during detection.

In the detection phase, KinSpace transforms each real-world point into the floor coordinate space and computes the *lateral distance* between the projected point and its nearest neighbor in the training set. The lateral distance is computed using a simple 2D Euclidean distance calculation, ignoring the y-coordinate. This results in a distance that does not take relative height of the objects into account. Any point with a lateral distance less than the *lateral distance threshold* is considered an obstacle pixel candidate. After filtering by the lateral distance threshold, the system also filters the candidate set by the height of the pixel relative to the floor. Any pixel that has a height less than the *vertical distance threshold* is discarded to gives us a candidate set of pixels that are within a set distance of the open space and are above a certain height. The system then clusters these candidate pixels into individual obstacle objects. This allows us to estimate the size of each object as well as its location in the room.

3. EVALUATION

We briefly present several representative performance results.

3.1 Open Space Calculation

We deploy the system in an actual residence to evaluate its accuracy at automatically estimating the open space of a room using passive training. We vary the lateral distance threshold to observe the effects of this parameter on the resulting open space calculation. Figure 1 shows the portion of the true open space that is captured in the system's determination of open space. The under the optimal lateral distance threshold, the system approaches 80% of the true open space. Note that the number of considered frames includes only those in which a valid skeleton was detected.

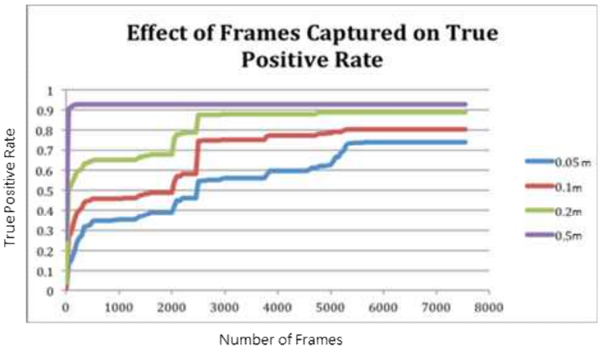

Figure 1. The portion of the true open space that is captured in the system's determination of open space.

3.2 Obstacle Detection

We also evaluate our obstacle detection system by performing a series of lab experiments as well as in-home deployment. We show that KinSpace can use the passive training from deployment to detect obstacles in various scenarios. We test multiple scripted trials while KinSpace monitors the environment and indicates the number of obstacles it detects in the scene. After running multiple trials on three different object sizes (large, medium, and small) and for different 5 trials per object size, we present the system accuracy across all frames.

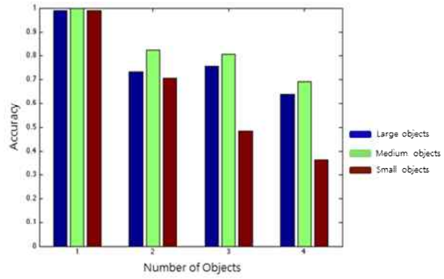

Figure 2. System accuracy as a function of the number of objects in the frame and the object size.

As shown in Figure 2, we see that KinSpace can identify the presence or absence of an object with near 100% accuracy. However, as more objects are placed in the scene, the detection accuracy decreases. This is especially prevalent with the small objects, as some of the small objects from our trials are placed far enough away that their pixel count is not high enough to consider it a true obstacle.

4. ACKNOWLEDGEMENTS

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5. CONCLUSION

We have presented KinSpace, a system that (1) observes the environment and learns what portions of the scene it should consider as open space, (2) monitors that open space for the presence of obstacles, and (3) notifies the resident if an obstacle is left in the open space. KinSpace employs a feedback loop, both with the user and with the scene itself, to allow it to accurately evolve its understanding of the objects in the scene. Our evaluation provides empirical evidence that KinSpace has high accuracy for both lab and deployment situations (80% and 70% respectively) in identifying open spaces and obstacles.

References

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