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Collision Detection Based on Augmented Reality for Construction Robot

Chun Jia, Zhenzhong Liu

***Abstract*— With the industrialization of construction, the safe and accurate task of construction robots is faced with higher requirements. Collision detection of construction robots based on human-robot cooperation has become a key technology to be solved urgently. This paper discusses a collision detection system based on augmented reality technology and applied it to tablets. The task scene of the construction robot is converted into an augmented reality (AR) environment in this system, and the user can control the virtual robot for collision detection with the interactive interface. The glass installation simulation experiment proves its effectiveness.**

I. Introduction

Different from industrial robots, construction robots, which have the characteristics of heavy load and movability, often require human-machine cooperation in construction operations, and tasks in complex construction environments can be dangerous or unaffordable [1-2]. Augmented reality (AR) uses overlay computers to generate data to sense the real world. AR aims to bridge the gap between the digital and real world. Once the robot has determined a collision-free path with the assistance of AR, human-machine collaboration will be safer and more efficient. As a result, AR has a broad application prospect in construction robots, such as material handling and teleoperation [3-4].

Along with the development of intelligent construction technology, the traditional construction operation mode is gradually being subverted by some high-tech. Chen [5] realized unmarked AR technology in the process of remote operation of the crane, and the safety performance was greatly improved by using the human attention mechanism. Wang [6] constructed a unified structure of AR-BIM (Building Information Model), which can realize the integrated model of on-site construction environment detection, current equipment status detection, construction progress management and so on. Ong [7] developed an augmented reality assisted robot programming system that improved the manipulability of welding robots by introducing Head-Mounted Display (HMD). Talmaki [8] and others used geospatial database combined with augmented reality to design a new anti-collision technology, improve the safety of underground excavation. Based on the above discussion, a manipulation system with AR indeed improves construction efficiency and reduces operator workload. However, during the process of installing heavy materials inside and outside buildings, installation is mostly done in collaboration with workers and robots, and the development of collision detection system or semi-automated systems based on human–robot cooperation has been attempted to assist this condition [9].

This paper demonstrates a robot collision detection system based on augmented reality, which applied to an Android-based tablet. The research and innovation achievements of this system are as follows: The system adds collision feedback on the basis of traditional collision detection, so that collision is easier to notice and find. rather than a fully virtual environment or simulated unit of work. Through the interactive buttons and UI interface of the system, the user can move the robot freely around the AR working environment to determine the non-collision point and path, so that the actual robot can follow.

II. System Overview

Currently, there is a limit to how much capacity the construction industry can wholly automatize or semi-automatize in assembly and installation. During the online glass installation process, the operator needs to guide the robot through the handle to carry out the movement, position adjustment and other actions to complete tasks [10-11]. In order for the actual construction robot to work safely and accurately, the main goal of the system is to control the virtual robot simulation construction tasks in the AR environment to avoid collisions and dead-end. Figure 1 shows the structure of development system process.

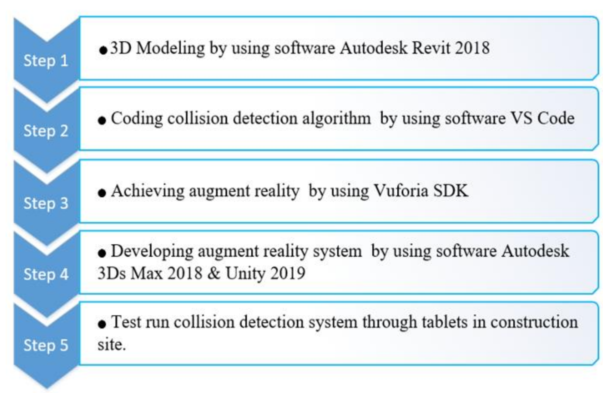

Figure 1. Structure of development collision detection system process.

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A. Achieving Augmented Reality

In this work, we have built virtual glass installation robots, workpieces and installed structures. Modeling has a much less workload than pure offline simulation. To activate the AR system, you need tags to render virtual objects of a given location in a real scene. Choosing the right marker is critical and it should have enough asymmetric features to have a higher recognition rate. Figure 2 shows a conforming tag. This selection of the marker was inspired by Su [12]. In system implementations, the Vuforia software development kit is used to implement augmented reality (AR) functionality because of its attractive features such as cloud recognition, object recognition and text recognition. Unity as a development platform to support cross-platform, real-world physics engine and graphics imaging and other functions. The tablet PC is HUAWEI BAH2-W09, which runs Android.

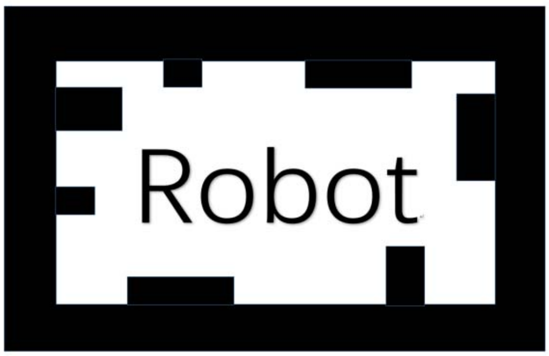


Figure 2. The marker used in the proposed system.

B. Collision Detection Technique

Collision detection technology can determine whether there is a collision of object models in the virtual world and between the object model and the virtual scene, and can provide information such as collision location and punctured depth. Therefore, applying collision detection technology to the field of augmented reality (AR) can detect the contact relationship between virtual objects, thus improving the interactivity of augmented reality systems. The system uses the AABB (Axis-Aligned Bounding Box) algorithm to detect virtual objects for preliminary collision detection, and the Mesh Collider component is added to the workpiece to accurately detect if the workpiece is intersecting. Figure 3 shows the configuration of the collider and parameters.

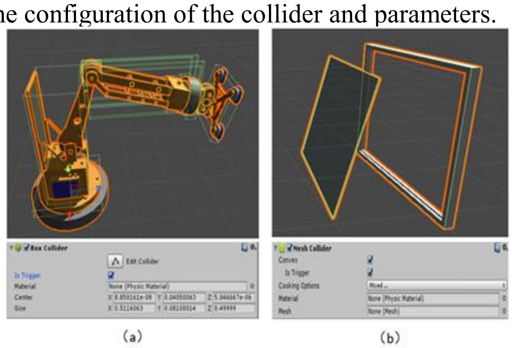


Figure 3. Collider by configuring (a) Box Collider,(b) Mesh Collider.

In order to make collisions and non-collisions more intuitive, we add trigger feedback events to the system through algorithm script. The installed construction displayed in red color indicates collision while green means non-collision. The colors of the installed construction reflect manipulability in real time. This may cause the user to enter a dead-end before the robot task is completed. In this case, the user must cancel the current task schedule or re-route. The low manipulability means that the robot may not be able to reach the next target position. Figure 4 shows the effect of triggering feedback. The collision and non-collision (a and b) of the robot visualized in the AR interface. Part of the algorithm is as follows:

```
void OnTriggerEnter(Collider collider) {
    if (collider.gameObject.tag == "obstacle")
    {
      //Chage color(collision.gameObject);
      collider.gameObject.GetComponent<Renderer>()
.material.color = Color.red;
    }
  }
  void OnTriggerExit (Collider collider){
    if (collider.gameObject.tag == "obstacle")
    {
      //Chage color (collision.gameObject);
      collider.gameObject.GetComponent<Renderer>()
.material.color = Color.green;
    }
  }
```

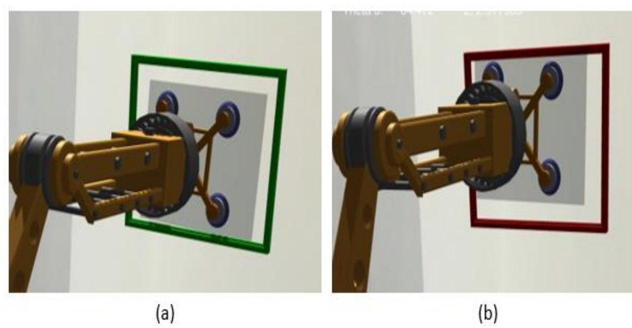


Figure 4. The collision and non-collision (a and b) of the robot visualized in the AR interface.

C. User- interaction Interface

To help users with task instruction and operation, we also designed a user interface with four functional modules, including those for configuring and displaying the virtual robot, as shown in Figure 5.

- *Operating module:* The module provides the necessary slider buttons to ensure the control of the robot arm, the user can directly control the slider to set joint angles of the robot arm, the value of θ and the coordinates of the end actuator are displayed in real time.
- *Saving module:* The user can save the current robot position or configure the robot to any position that has been saved, such as collision point and amended position.

- *Automation module:* The user can specify the coordinates of the end actuator and time duration of the desired robot position.
- *Display module:* The display of virtual models and actual environment provided by the entire screen. The user can use common gestures to control the rotation, scaling and hiding of virtual models.

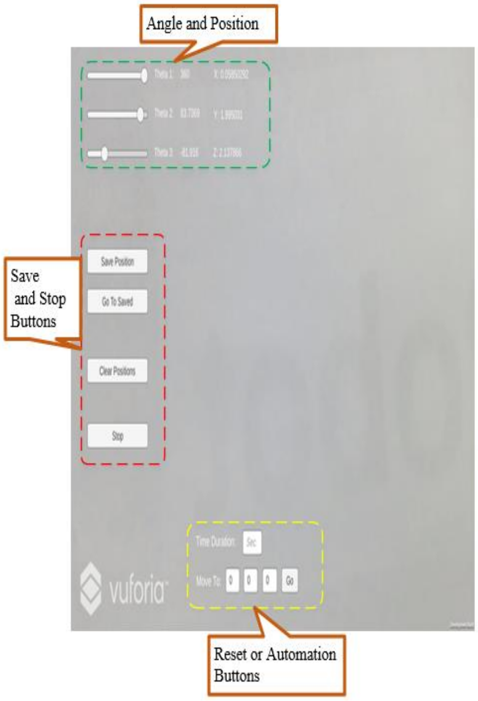


Figure 5. The AR marker used in the proposed system.

III. EXPERIMENTS

After describing the system overview, this section expounds the effect of augmented reality and experimental simulations. We planned three different paths and conducted glass installation simulation experiments to evaluate the performance of the system.

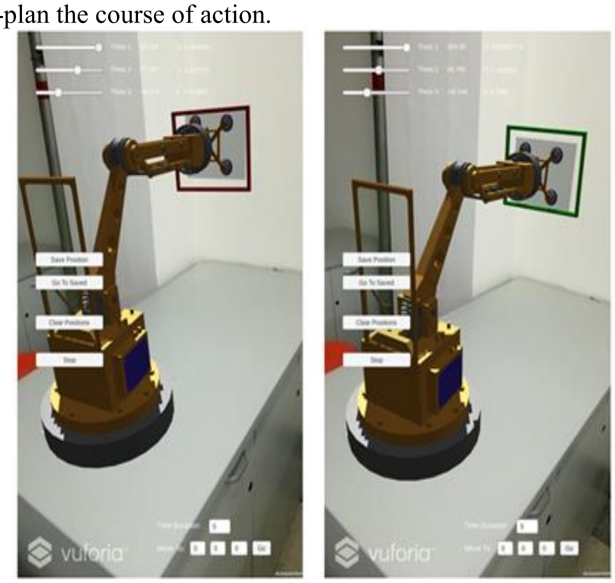
A. Augmented Reality Effect

The construction robot collision detection system based on augmented reality consists of four modules: information display, information saving, coordinate input and simulation demonstration. The task scene of the construction robot is converted into an augmented reality (AR) environment in this system, and the user can control the virtual robot for collision detection with the interactive interface. The effect and function module of the system is shown in Figure 6.

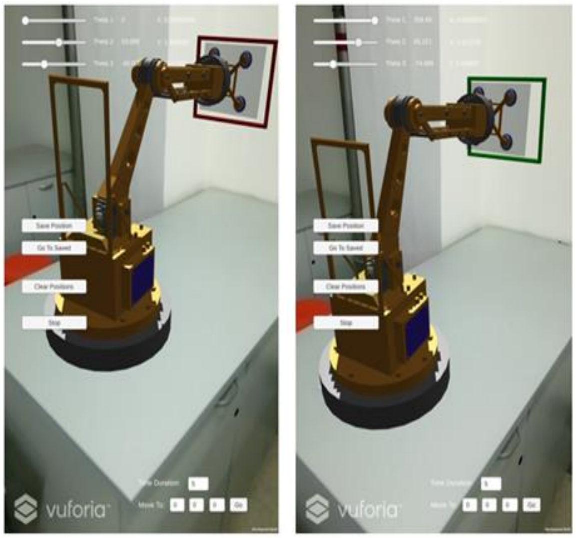
Figure 6. The AR effect of the system.

B. Simulations and Analyses

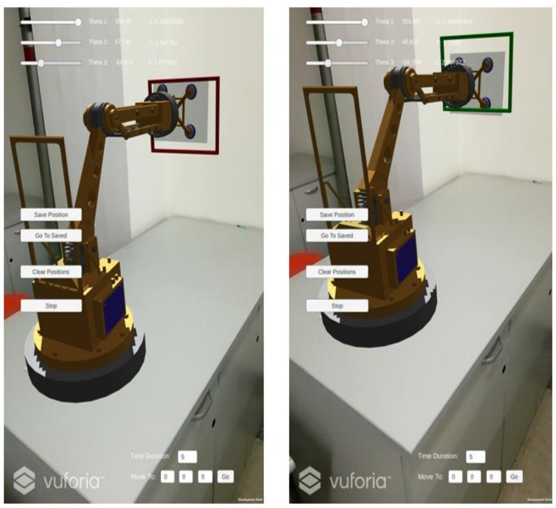
When it comes to glass installation tasks, the operator is required to determine the appropriate placement point of the workpieces. Simulation experiments are carried out according to the planned three paths. The figure 7 shows screenshots of the simulation experiment on the glass installation. With regard to each path, the task for the three participants was to control the robot in the AR environment to perform certain operations. During the simulation, the joint angles of the collision point are readjusted and saved so that the user can re-plan the course of action.



(a) Path 1



(b) Path 2



(c) Path 3

Figure 7. Screenshots of the simulation experiment (collision to non-collision from left to right).

Table I shows some joint angle data. The simulation results show that all three paths detected collisions and can be adjusted with the assistance of the system, and path 3 had the least collision and there was no dead end. Under the premise of completing the task, we recommend using readjusted path 3 to complete the glass placement.

TABLE I. EXPERIMENTAL DATA FOR THREE PATHS

Path	*Collision frequency*	*Collision position*	*Readjusted*	*Whether dead-end*
1	2	$\theta_1 = 360.00$ $\theta_2 = 57.740$ $\theta_3 = -64.742$	$\theta_1 = 360.00$ $\theta_2 = 57.740$ $\theta_3 = -74.999$	exist
2	3	$\theta_1 = 359.26$ $\theta_2 = 55.239$ $\theta_3 = -64.472$	$\theta_1 = 359.26$ $\theta_2 = 48.817$ $\theta_3 = -58.356$	no
3	1	$\theta_1 = 360.00$ $\theta_2 = 48.786$ $\theta_3 = -60.156$	$\theta_1 = 360.00$ $\theta_2 = 48.786$ $\theta_3 = -56.146$	no

IV. CONCLUSION

This paper discusses a collision detection system based on augmented reality technology and applied it to tablets. In order for the actual construction robot to work safely and accurately, the main goal of the system is to control the virtual robot simulation construction tasks in the AR environment to avoid collisions and dead-end. The task scene of the construction robot is converted into an augmented reality environment in this system, and the user can control the virtual robot for collision detection with the interactive interface. The glass installation simulation experiment proves its effectiveness. In the future, we will introduce Head-Mounted Display (HMD) into the system to alleviate the jitter of virtual models and enhance operator immersion. Another goal is to accommodate more types of construction robots and tasks by injecting more functionality into the system.

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