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### A Guide to the RoboCup Virtual Rescue Worlds

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**Publication date**

2016

**Document Version**

Final published version

[Link to publication](#)

**Citation for published version (APA):**

Visser, A. (2016). *A Guide to the RoboCup Virtual Rescue Worlds*. (IRL technical report; No. 16-01). Intelligent Robotics Lab, University of Amsterdam.

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IRL technical report IRL-UVA-16-01

## A Guide to the RoboCup Virtual Rescue Worlds

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**Abstract:** Now that the Virtual Robot Competition will be based on Gazebo and ROS, instead of the USARSim protocol implemented on top of Unreal Engine, it is time to create realistic rescue worlds in Gazebo. Fortunately it is possible to port Unreal worlds to Gazebo, which means that the previous designs can be reused. To make the right choice on which worlds are the most interesting to be ported, an overview of those worlds and the challenges they provided is needed. This paper provides this overview.

**Keywords:** Robot Simulation

IRL

intelligent robotics lab

## Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
<b>2</b>	<b>Demonstrations</b>	<b>2</b>
2.1	RoboCup 2005 - Osaka . . . . .	2
<b>3</b>	<b>Competitions</b>	<b>2</b>
3.1	RoboCup 2006 - Bremen . . . . .	2
3.2	RoboCup 2007 - Atlanta . . . . .	3
3.3	RoboCup 2008 - Suzhou . . . . .	3
3.4	RoboCup 2009 - Graz . . . . .	4
3.5	RoboCup 2010 - Singapore . . . . .	4
3.6	RoboCup 2011 - Istanbul . . . . .	4
3.7	RoboCup 2012 - Mexico . . . . .	4
3.8	RoboCup 2013 - Eindhoven . . . . .	5
3.9	RoboCup 2014 - João Pessoa . . . . .	5
3.10	RoboCup 2016 - Leipzig . . . . .	6
3.11	RoboCup 2017 - Nagoya . . . . .	6
<b>4</b>	<b>Discussion</b>	<b>6</b>
<b>5</b>	<b>Conclusion</b>	<b>7</b>

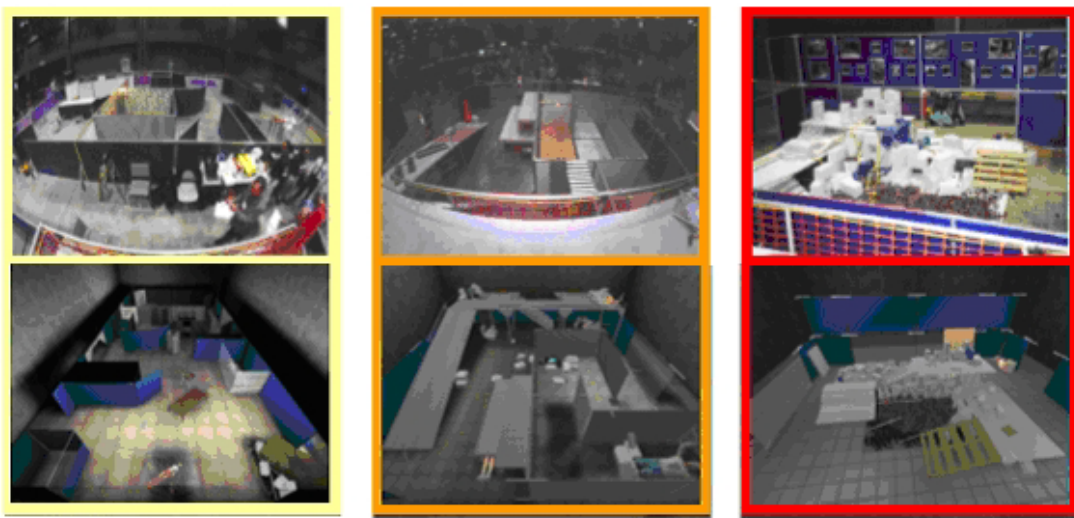
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## 1 Introduction

The challenge provided by the RoboCup Rescue Simulation League is to have a team of robots cooperate inside a devastated area. Inside this League, the Virtual Robots competition provides a realistic challenge since 2006 [6]. The important research issues related to the competition are utility-based mapping, victim detection, fused sensor data, advanced mobility and multi-robot control [1]. The simulation environment allowed teams to experiment with algorithms for cooperation between robots on a scale not easily possible in the real world [14]. However, to be useful, the simulator should provide realistic noise models for sensors and actuators; noise models which should be validated [7, 2, 13, 8, 18].



**Figure 1:** Respectively the Yellow, Orange and Red Arena (top NIST arenas, bottom simulated arenas). Courtesy Carpin *et al.* [9]

Creation of worlds large enough for teams of robots with enough detail to have realistic perspective challenges (lighting, texture, etc) and mobility challenges (tight and vast spaces, obstacle courses, tilted surfaces, etc) is an extensive work, which were performed by developers with both knowledge of robotics and game design. The creation of a typical competition world could easily consume several man-months. Reuse of this creative effort for the Gazebo platform would be beneficial.

Currently most research institutes prefer the Robot Operating System (ROS) as an open source framework for robot control [15], which allows easy exchange of modules between robot platforms. Using Gazebo, the simulator behind ROS, as the simulation engine for the Virtual Rescue competition allows to have a direct exchange between the RoboCup Rescue and Rescue Simulation League [11].



## 2 Demonstrations

### 2.1 RoboCup 2005 - Osaka

As described in [9], 3D CAD models of the real National Institute of Standards and Technology (NIST) arenas were imported into Unreal and decorated with texture maps generated from digital photos of the actual environments, resulting in the arenas of Fig. 1:



**Figure 2:** Resp. the Black Arena, the DARPA Grand Challenge and the Tall test world.

After the demonstration these worlds were extended with an even more challenging arena; the Black Arena (see Fig. 2) that depicted a scenario that was a good prediction of the situation in Fukushima [12]. Another interesting challenge, although not related to the RoboCup Rescue League, was the world created for the DARPA Grand Challenge. For the drones already a large outdoor world was created<sup>1</sup>.

## 3 Competitions

### 3.1 RoboCup 2006 - Bremen

For the first competition several variants of the same large world were used, which had for instance a street scenario, an office scenario and even a hedge maze in the garden (see Fig. 3).

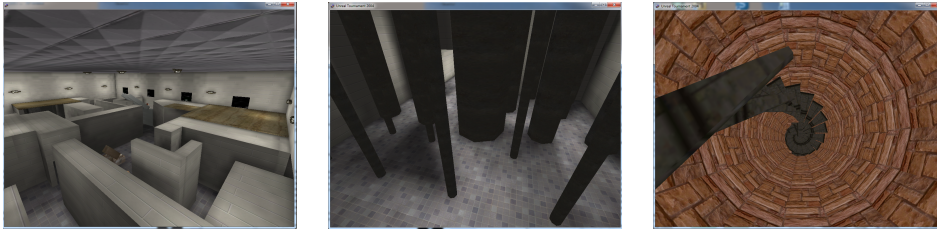


**Figure 3:** Resp. the street, the office and the maze at the RoboCup 2006 competition.

The results of the first RoboCup Rescue Virtual Robot competition were evaluated in a journal article [4].

<sup>1</sup>The worlds for the UT2004 version of USARSim were published on <https://sourceforge.net/projects/usarsim/files/Maps/>

### 3.2 RoboCup 2007 - Atlanta

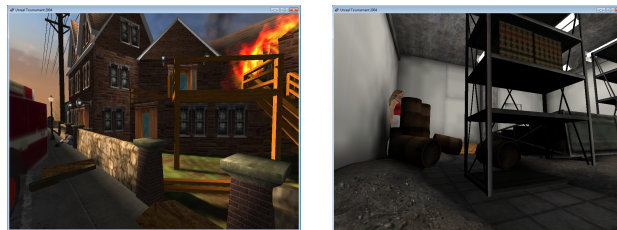


**Figure 4:** The Mobility, Mapping and Corridors world.

In preparation of the competition in Atlanta, the teams mainly trained on the Mobility and Mapping world (see Fig. 4). Contradictory to their name, the Mapping world had a considerable mobility challenge, because only half of the world had a flat floor, the other half consisted of patchwork of tilted floortiles. The Mobility map consisted of two parallel twisting corridors, which induced a considerable mapping challenge (with a small orientation error easily the mistake could be made to localize the robot in the parallel corridor). In addition, also a world with wide corridors especially designed to be navigated by drones was created.

### 3.3 RoboCup 2008 - Suzhou

In Suzhou the indoor and outdoor world introduced in Atlanta were reused. The outdoor world contained many areas not yet explored by the robot rescue teams.

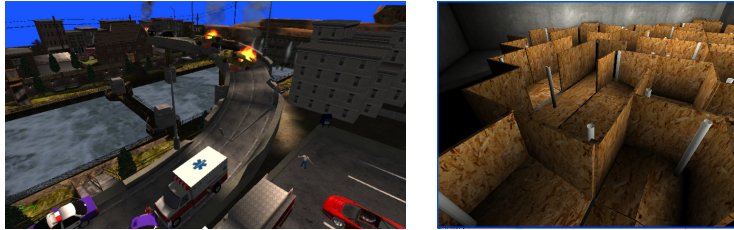


**Figure 5:** Resp. the outdoor and indoor map at the RoboCup 2008 competition.

During the preliminaries in Suzhou the teams had to set up a wireless connection between multiple robots to be able to explore a whole street (with most victims at the end, see Fig. 5) in an unexplored section the outdoor world with the bridge accident. The results of the third RoboCup Rescue Virtual Robot competition were evaluated in another journal article [3], which concentrated on the evaluation of the maps which the robots had generated indoors.

### 3.4 RoboCup 2009 - Graz

This was the last year that both the indoor and outdoor world introduced in Atlanta were reused. After the 2009 competition the worlds were published on sourceforge<sup>2</sup>, so that they could be used for training purposes.

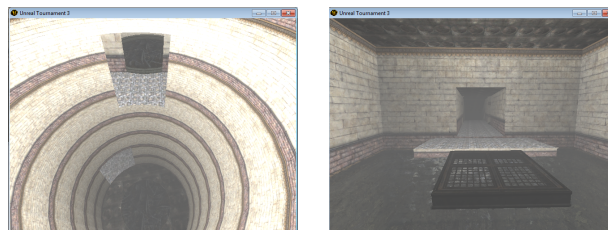


**Figure 6:** Resp. the rescue scenario and an elemental skill test at the RoboCup 2009 competition.

The indoor and outdoor worlds were used to evaluate the overall performance of the integrated team coordination systems in the finals of the competition. During the preliminaries the capabilities of the coordination systems on elemental skills were evaluated on worlds especially designed to benchmark this skill. The details of this new evaluation approach were presented at the Performance Metrics for Intelligent Systems workshop [5].

### 3.5 RoboCup 2010 - Singapore

This was the first year that the UT3 version of USARSim was used. Concerning worlds with active elements were created; not only worlds with smoke (and the correct response from the laser scanners [10]), but also with elevators and a ferry over an indoor stream.



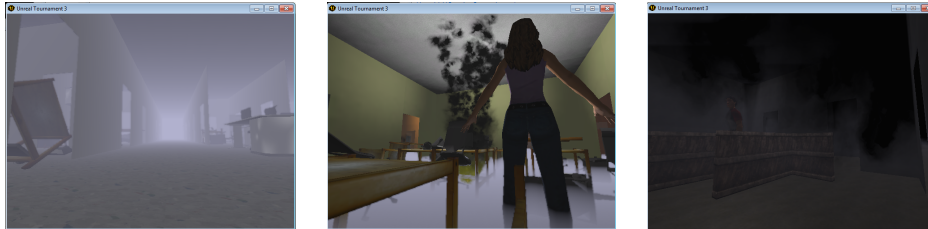
**Figure 7:** Resp. an elevator and ferry used in the RoboCup 2010 competition.

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<sup>2</sup><https://sourceforge.net/projects/usarsim/files>

### 3.6 RoboCup 2011 - Istanbul

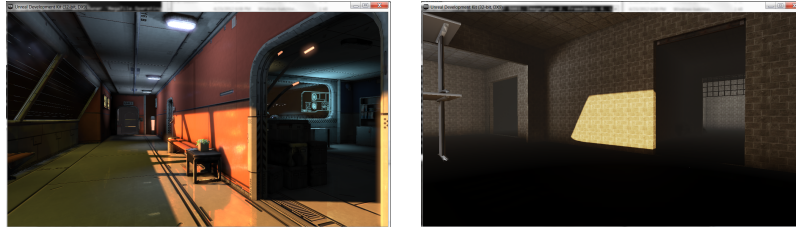
This was the last year that the UT3 version of USARSim was used. The whole competition was dedicated on how teams could battle smoke; each day the teams encountered another challenge (low hanging smoke, smoke hanging at the ceiling, smoke like mist, rolling waves of dark smoke).



**Figure 8:** RoboCup 2011 worlds with white mist, low hanging smoke and rolling waves of dark smoke.

### 3.7 RoboCup 2012 - Mexico

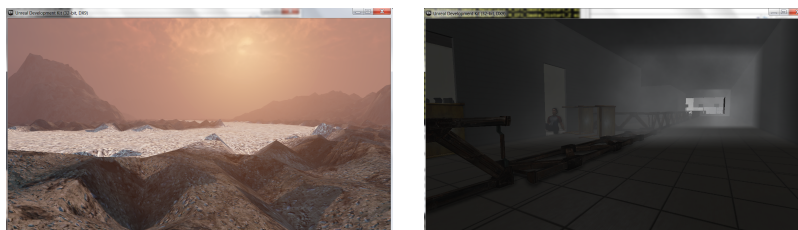
This was the first year the UDK version of USARSim was used. The environment was extensively tested in the regional games (the Dutch and Iran Open). At the Dutch Open a very nice outdoor map was introduced, but with slopes that were too challenging for the tracks as modeled at that moment. Instead, the World Cup consisted of only indoor maps, but with quite challenging lighting conditions.



**Figure 9:** RoboCup 2012 worlds with fast changing lighting conditions.

### 3.8 RoboCup 2013 - Eindhoven

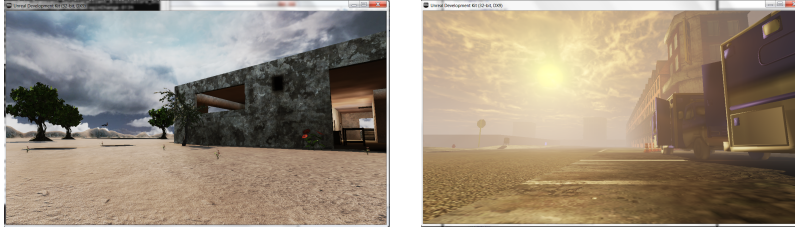
At the RoboCup in Eindhoven the size of the worlds increased so much that large robot teams became essential. The size of the outdoor was larger than one  $km^2$ . In such environments, the use of flying robots to scout large areas and avoid difficult terrain really becomes an asset.



**Figure 10:** RoboCup 2013 worlds, including a large outdoor and large indoor world.

### 3.9 RoboCup 2014 - João Pessoa

In João Pessoa the teams could show how they could use the combination of flying and ground robots on some challenging outdoor worlds.



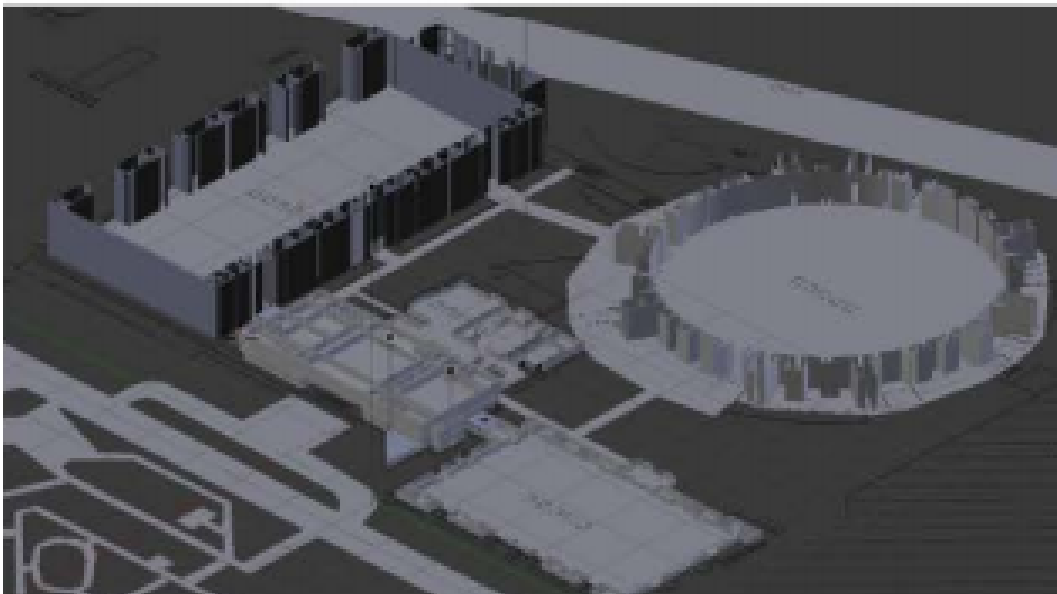
**Figure 11:** RoboCup 2014 worlds, with multiple large outdoor worlds.

### 3.10 RoboCup 2016 - Leipzig

This will be the first year that the Gazebo will be used as simulation platform for the RoboCup Rescue Simulation. Shimizu *et al* [16] have shown that porting of USARSim worlds via 3D-editing tools as Blender is possible, by converting one of the RoboCup 2012 maps. This makes it possible to include all worlds described in this paper, although this will only be done for the ones that give an interesting challenge to the robotics community.

### 3.11 RoboCup 2017 - Nagoya

Already a 3D-model of the venue in Nagoya is modeled and incorporated in Gazebo and tested at the Future of Robot Rescue Simulation workshop [17].



**Figure 12:** A 3D model of the RoboCup 2017 venue.



## 4 Discussion

The Virtual Robot competition has a long tradition in designing worlds with the right challenge. The worlds illustrated here are manually produced worlds, during the preliminaries typically automatically produced worlds were used [19]; a tool with would also be very handy for the Gazebo environment. Manually designed worlds could contain surprises which are often encountered in real search and rescue missions, but care has to be taken that the challenge remains realistic and validated (for instance, in the Dutch Open outdoor world all the robots were sliding along a slope towards a river, while in reality tracked robots should not be start sliding on such small elevation angle).

The Unreal Editor allowed to create environments which are also challenging for the perception; with rich textures and a variety of lighting conditions. Although the overall layout of an environment is easily ported from Unreal towards Gazebo, the details in texture, lighting and active elements are the first things to be lost in the conversion process.

The first ported world is an indoor map. It would be interesting to demonstrate that is also possible to port an outdoor world. The world of 2013 and 2014 are too large for such a first attempt, which makes the RoboCup 2007 bridge accident world an attractive candidate. This is also in interesting choice in historical sense, because it would give teams the opportunity to show the progress made in the last 10 years.

## 5 Conclusion

Creation of worlds large enough for teams of robots with enough detail to have realistic perspective challenges (lighting, texture, etc) and mobility challenges (tight and vast spaces, obstacle courses, tilted surfaces, etc) is an extensive work, which were performed by developers with both knowledge of robotics and game design. The possibility to port Unreal worlds to Gazebo means that the previous designs can be reused. To paper gave an overview of what was created for the previous competition, which makes the possibility to make an informed choice.

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