# **Disaster Management**

### A multiagent system based approach

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Img. 1: Earthquake in Italy in 2016. Source: BBC



Img.2: Great Hanshin-Awaji Earthquake in Japan in 1995. Source: iStock

# Introduction and Purpose

Natural disasters are extreme phenomena that are beyond human control

There are Social, economic and environmental impacts

There is partial and uncertain knowledge of the current state of the environment

Effective rescue enable for a greater number of survivors and less economic impact

Necessity: Better environmental exploration strategies



Img. 3: Kobe Map of RoboCup Rescue Simulation



Img. 4: Simulation entities

# Introduction and Purpose

Robocup Rescue Simulator: practical application of Multi-Agent Systems to study rescue strategies in natural disasters

Evaluation of strategies involving Ambulances, Police and Firefighters in the rescue of civilians after a disaster

Lack of a complete knowledge of the scenario is a characteristic of Multi-Agent Systems

Joint efforts of entities are optimal in the mission

Creation algorithms that implement rescue strategies

# Introduction and Purpose

Focus on the ambulances

Simulator complexity requires focus of efforts

Exploring the ambulance algorithm in a context of competitions that ended up placing more value on the performance of firefighters

Disabled fire for more precise measurement

#### Baseline

#### Autonomous tasks

Sample team provided by the development framework

Team 1 Clustering, centralized task allocation and autonomous tasks Team 2 Team 1 + restriction of tasks exclusively to the assigned cluster

# **Concepts** Classification Algorithm: K-Means



Unsupervised learning

Classification of data based on similarity patterns, without the presence of a supervisor



Img. 5: Steps of the execution of the K-Means clustering algorithm for K = 3

#### **K-Means**

Partition of K clusters where each point is assigned to the cluster with the nearest means

### **Concepts** Wilcoxon Rank Sum Test

### Nonparametric Hypothesis Test

Comparison of two unpaired groups that don't assume a normal distribution

$$z = \frac{W - \mu_W}{\sigma_W}$$
$$\mu_W = \frac{n_A (n_A + n_B + 1)}{2}$$
$$\sigma_W = \sqrt{\frac{n_A n_B (n_A + n_B + 1)}{12}}$$

# **Metrics** Total Score and rescue metrics

#### Score

Based on two main metrics: average civilian health and level of physical damage in buildings (normal simulation score)

#### **Rescue metrics:**

Civilians identified
Civilians allocated
Rescues initiated
Civilians transported
Civilian deaths
Civilian Identification Step
Task Allocation Step

Score = HPscore \* buildingScore

HPscore = agentsAlive + (hpLeft/hpMax)

 $buildingScore = \sqrt{areaLeft/areaMax}$ 

Based on two key metrics: average civilian health and level of physical damage to buildings

# **Our Contributions**

K-Means used as an algorithm in defining clusters

Greater number of ambulances allocated to regions with many buildings

# Target

Target allocation only within the same cluster as the ambulance



Target's cluster identification

Autonomous behavior in the lack of assigned tasks

Centralized partitioning

Different priority lists



# **Our Contributions** Debug Viewer

Graphical display of relevant information

Cluster buildings

Cluster buildings to be explored next (Team 2)

Civilians identified

Ambulances transporting civilians



Img. 6: Debug Viewer used on the Berlin2 map



# Our Contributions Bash Script

Automation of simulation log collection

Each simulation can generate up to 8 GB of data

Up to 45 minutes per simulation

3,5 TB of total data

#### for K in \${CLUSTERS[\*]};

#### do

# Change the K value within the code of the team
# Clean project and recompile
for MAP in \${MAPS[\*]};

#### do

for SEED in \${SEEDS[\*]};

#### do

# Change the simulation seed in the server # Create folder in the format team-name/map/k/seed # If it exists, skip simulation # Start server # If the debug flag is active, start Visual Debugger # Start team # Wait for the end of simulation # Close agent # Copy simulation output to log folder passed as a parameter # If open, close Visual Debugger if open # Extract score lines from kernel log done ; done ;

done ;

Img. 7: Bash Script to automate log collection

# **Experiments**



Team 1, Team 2 and Sample (Baseline)



4 values of K: 1, 2, 4 e 8



5 maps: Berlin, Joao, Kobe, Paris and Berlin2

#### 10 different seeds

#### 450 simulations

#### Comparison with Sample Team

[	Tim	e 1	Time 2		Sample			Total		
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мара	de Score	StuDev	de Score	StuDev	de Sco	ore	Jev	de Score	StuDev	
Berlin	698, 31	43,56	698,12	43,91	699,2	4 40,	99	698,55	42,84	
K = 1	699,00	42,23	698,04	44,22	699,2	4 40,	99	698,76	42,51	
K = 2	697,85	44,41	698,05	44,26	699,2	4 40,	99	698,38	43,25	
K = 4	698,22	43,87	697,85	44,43	699,2	4 40,	99	698,44	43,13	
K = 8	698, 15	$43,\!67$	698,53	42,72	699,2	4 40,	99	$698,\!64$	$42,\!48$	
Joao	153,28	8,00	153,03	8,29	153,8	5 9,0	)7	153,39	8,47	
K = 1	153,05	8,50	153,05	8,29	153,8	5 9,0	)7	153,32	8,64	
K = 2	153, 15	7,51	152,95	7,94	153,8	5 9,0	)7	153,32	8,21	
K = 4	153, 35	8,12	153,25	8,38	153,8	5 9,0	07	153,49	8,54	
K = 8	153,55	7,84	152,85	$^{8,51}$	153,8	5 9,0	)7	153,42	8,50	
Kobe	448,05	5,58	448,77	5,80	436,2	6,3	32	444,36	8,23	
K = 1	445,89	5,61	448,10	4,86	436,2	7 6,3	32	443,42	7,62	
K = 2	$447,\!69$	4,39	447, 49	7,04	436,2	7 6,3	32	443,82	8,05	
K = 4	449,30	5,97	449,40	5,21	436,2	7 6,3	32	444,99	8,50	
K = 8	449,30	5,48	450,10	5,46	436,2	7 6,3	32	445,22	8,57	
Paris	439,20	$14,\!64$	441,63	14,27	431,2	5 14,	82	437, 36	15,24	
K = 1	438,15	$13,\!97$	$^{442,15}$	$13,\!87$	431,2	5 14,	82	437, 19	14,92	
K = 2	440,45	16,01	441,35	$13,\!84$	431,2	5 14,	82	437,69	$15,\!60$	
K = 4	439,85	13,31	440,95	14,15	431,2	5 14,	82	437,35	14,76	
K = 8	438,35	15,01	442,05	15,14	431,2	5 14,	82	437,22	$15,\!65$	
Berlin2	761,82	30,39	$761,\!18$	30,30	755,2	28,	25	759,41	29,81	
K = 1	761,09	$31,\!19$	756,83	32,09	755,2	5 28,	25	757,72	30,66	
K = 2	760,33	30,17	761,21	28,36	755,2	5 28,	25	758,93	29,06	
K = 4	764, 18	29,18	761,52	30,26	755,2	5 28,	25	760,32	29,48	
K = 8	$761,\!67$	30,83	765, 16	29,79	755,2	5 28,	25	760,69	29,92	
Total	500,13	218,00	500,55	217,73	495,1	7 217	,33	498,62	217,70	

Table 1: Scores obtained on maps using different K values and testing different teams

Team 2 - Differential analysis of metrics between clusters - All maps





Images 8 and 9 To the left: Evaluating Rescue Metrics for Team 1 Above: Evaluating Rescue Metrics for Team 2

# Wilcoxon Rank Sum Test

Parameter	Man	Team a	Average	Team b	Average	statistic	p-value
Dead civilians	Kobe	Sample	$64,\!40$	Team 1	$51,\!92$	4,075	0,000046
Dead civinans	Kobe	Sample	$64,\!40$	Team 2	52,27	3,881	0,000104
Step of civilian death	Kobe	Sample	137,76	Team 1	127,01	2,692	0,007099
Step of civilian death	Kobe	Sample	137,76	Team 2	$127,\!13$	2,765	0,005694
Identified civilians	Berlin2	) Team 1	220,95	Team 2	$235,\!38$	-1,968	0,049091
Identified civilians	Kobe	Team 1	$191,\!38$	Team 2	202,97	-3,026	0,002476
Identified civilians	Paris	Team 1	$146,\!22$	Team 2	163,88	-3,594	0,000326
Rescued civilians	Berlin2	Team 1	38,23	Team 2	60,05	-5,398	0,000000
Rescued civilians	Kobe	Team 1	$33,\!10$	Team 2	73,95	-7,332	0,000000
Rescued civilians	Paris	Team 1	$5,\!10$	Team 2	$15,\!38$	-7,289	0,000000
Step or civilian rescue	berin12	Team 1	$132,\!43$	Team 2	$138,\!24$	-3,315	0,000917
Step of civilian rescue	Paris	Team 1	$252,\!02$	Team 2	$203,\!62$	6,795	0,000000



Dead civilians, Identified civilians, Rescued civilians, Civilians being rescued, Score

#### Kobe, Berlin2, Paris

Differences between Team 1, 2 and sample

Tabela 4: Wilcoxon tests for different teams in the same map.

	California (California)			21 - AND NOT BEEN AND A	Parameter	Map	K	Average	K	Média	statistic	p-value
Parameter	Team 1	Team 2	statistic	p-value	Dead civilians	Kobe	1	57,00	4	51,05	2,683	0,007290
Step of allocation	$108,\!44$	$116,\!07$	-3,278	0,001045	Dead civilians	Kobe	1	$57,\!00$	8	$50,\!65$	2,733	0,006280
Step of allocation	$95,\!9$	100	-2,156	0,031060	Final score	Kobe	1	$443,\!42$	4	449,35	-2,693	0,007077
Rescued civilians	$15,\!54$	30,02	-2,769	0,005628	Final score	Kobe	1	443,42	8	449,70	-2,654	0,007964
Civilians being rescued	66,03	60,72	2,841	0,004498	Rescued civilians	Berlin2	1	$44,\!50$	8	$55,\!30$	-2,380	0,017293

Tabela 5: Wilcoxon tests for Team 1 e Team 2.

Tabela 6: Wilcoxon tests for different K's.

# Conclusion

Centralized K-Means clustering algorithm showed positive impact mainly on maps with fewer blockades, like Kobe and Paris

The statistical relevance of centralizing clustering was more relevant throughout the parameters than changing the value of K

The impact of restricting ambulances to their own cluster (Team 2) was more relevant than the impact of changing the value of K

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#### Implementation of other algorithms such as DBSCAN

Advantage: it is not necessary to inform K

#### Evaluate results in different maps

Specific aspects such as spatial distribution of buildings may influence

Compare results with non-centralized algorithms

Use K-means in a supervised manner

Such as using refuges as cluster centers