Comparison of Crisp and Fuzzy System in Agent-Based Simulation: A Case Study of Soccer Penalty

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Outline

- Agent-Based Simulation
- Case study of "Soccer Penalty"
  - Crisp
  - Fuzzy
- Game theory of "Soccer Penalty"
- Discussion

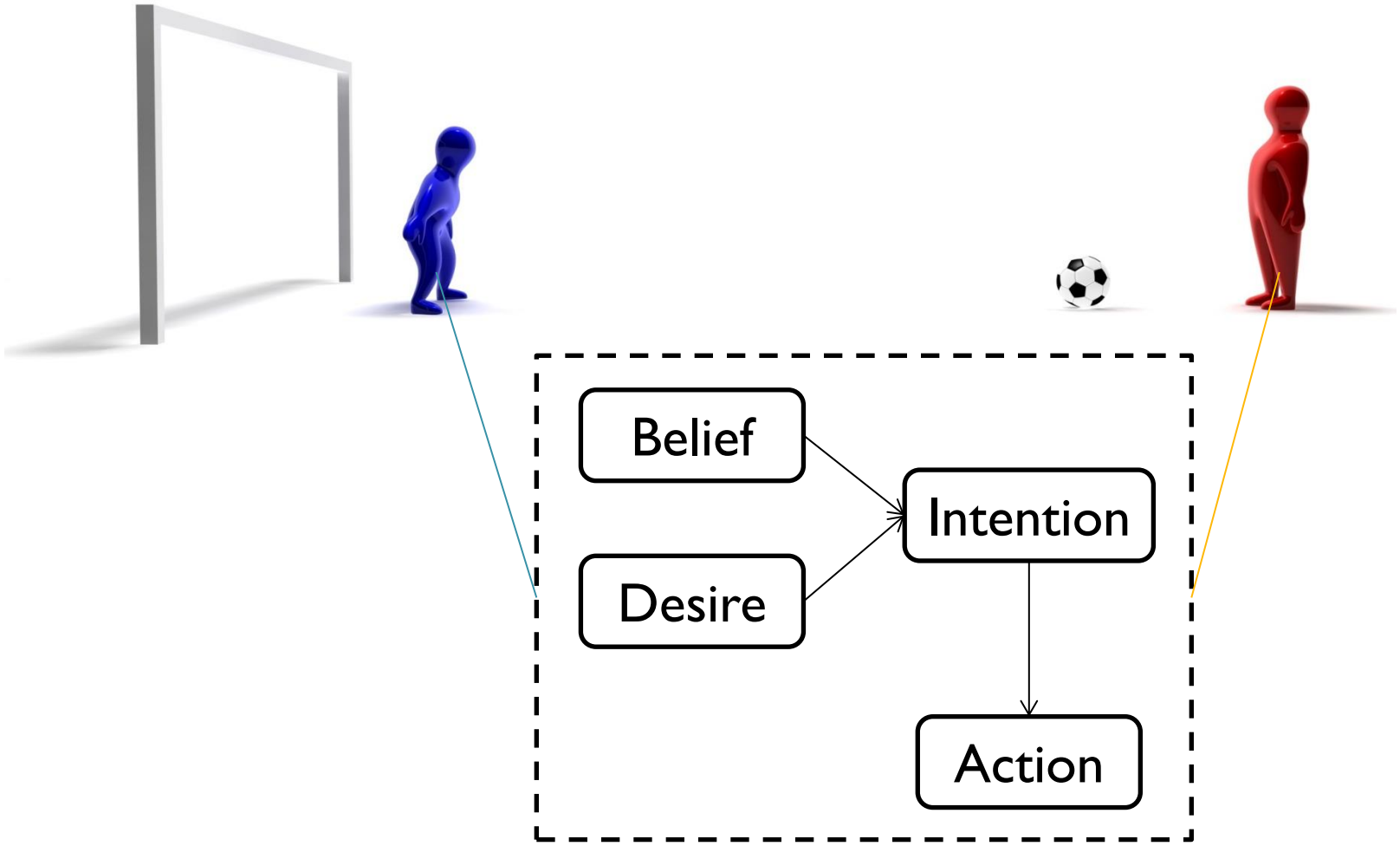
Introduction

- The Belief-Desire-Intention (BDI) model is a reasoning architecture for a bounded rational software agent.
- Expand the application of the BDI software model to the area of simulating human behaviour.
- This paper explores the differences in using a classical *crisp* rule-based approach and a *fuzzy* rule-based approach for the reasoning within the BDI system.

Agent-Based Simulation?

- Simulation is an imitation of a system, which involves designing the model and performing experiment to have better understanding of the system.
- An agent is a very good representation for a human, because agents have following properties:
  - Discrete entities: with their own behaviour, goals, thread of control.
  - Autonomous: be able to adapt and modify their behaviour.
  - Proactive: adjust action depending on agent's internal state.

A case study of "soccer penalty"



From Intentions to Actions

Generate decision list

- Gaze direction
- Target location
- Anxiety

Evaluate each risk following "rule tables" with either:

- Crisp system
- Fuzzy system

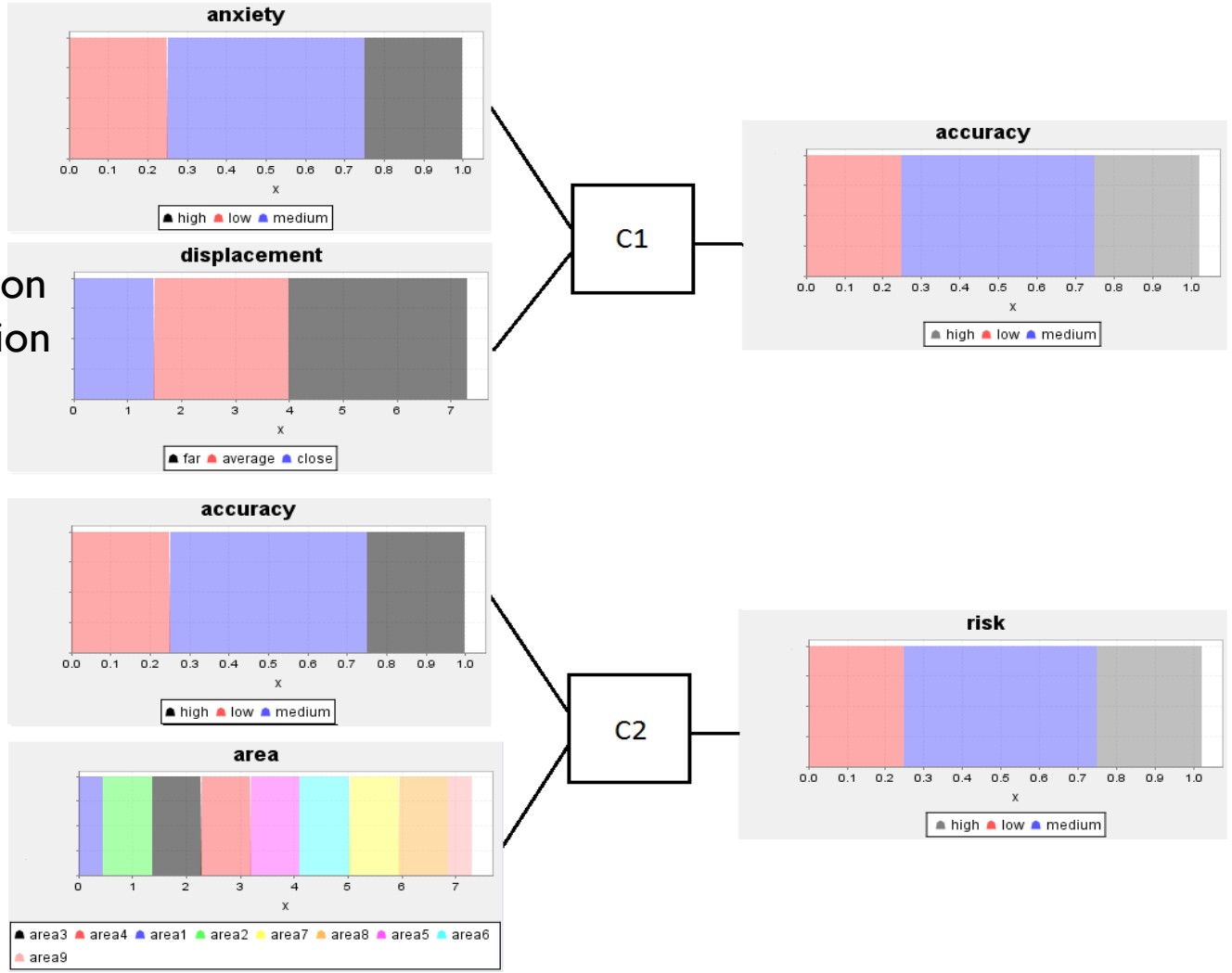
Roulette wheel selection

- One final decision

Crisp System

Inputs:

- Gaze direction
- Target location
- Anxiety



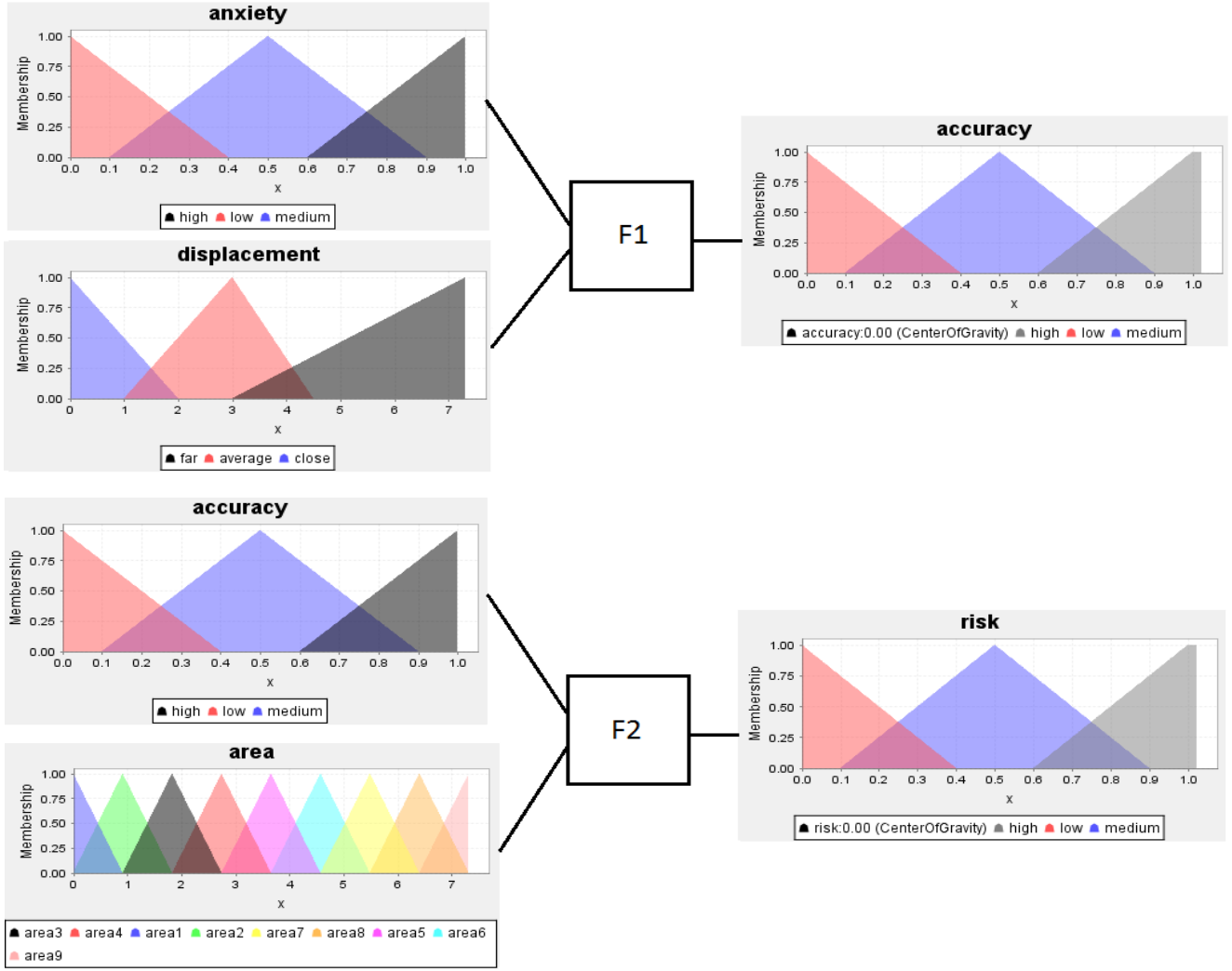
Rule table 1

Displacement	Anxiety	Accuracy	Overall accuracy (1=highest)
Close	Low	High	1
Close	Medium	High	
Close	High	Medium	
Average	Low	Medium	2
Average	Medium	Medium	
Average	High	Low	
Far	Low	High	3
Far	Medium	Medium	
Far	High	Low	

Rule table 2

Target area	Accuracy	Risk	Overall risk (1=highest)
Area1	Low	High	1
Area1	Medium	High	
Area1	High	Medium	
Area2	Low	High	3
Area2	Medium	Medium	
Area2	High	Low	
Area3	Low	High	3
Area3	Medium	Medium	
Area3	High	Low	
Area4	Low	High	2
Area4	Medium	Medium	
Area4	High	Medium	
Area5	Low	High	1
Area5	Medium	High	
Area5	High	Medium	

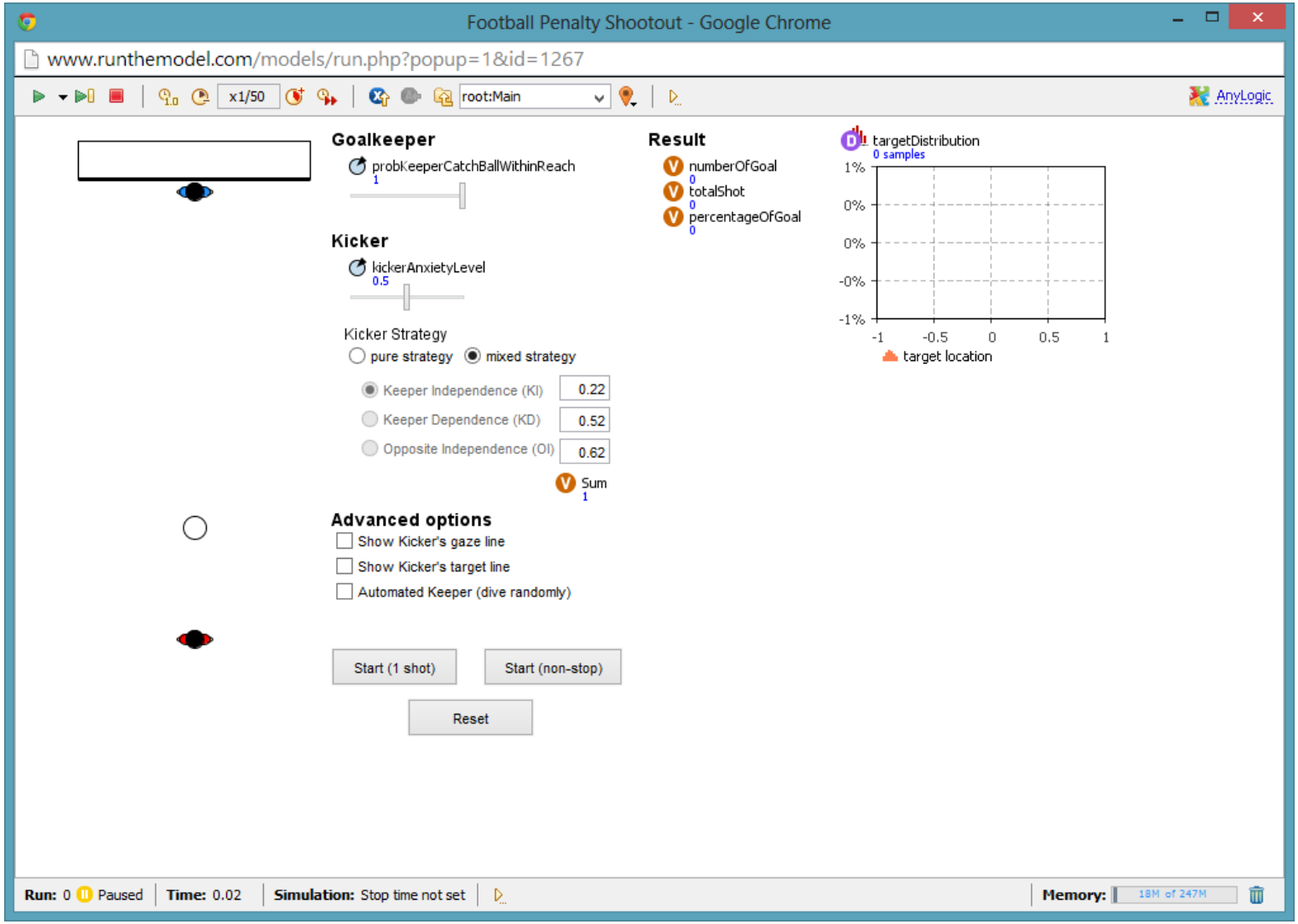
Fuzzy System



Implementation

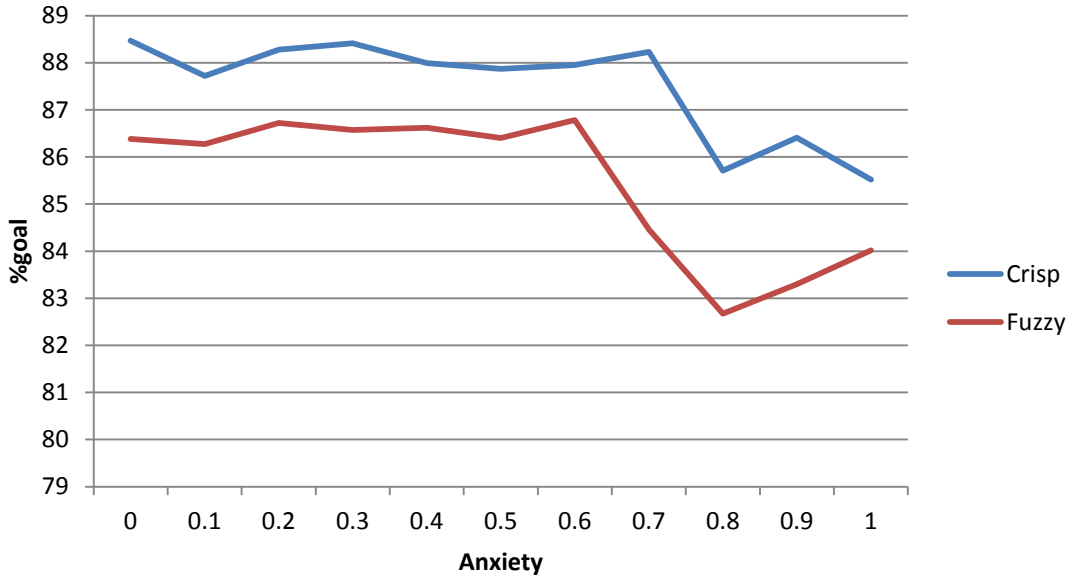
- The model, implemented in AnyLogic
- 2D simulation with bird's eye view
  - two BDI agents (one kicker, one goalkeeper)
  - a ball
  - a goal.
- Available online at RunTheModel

Screenshots



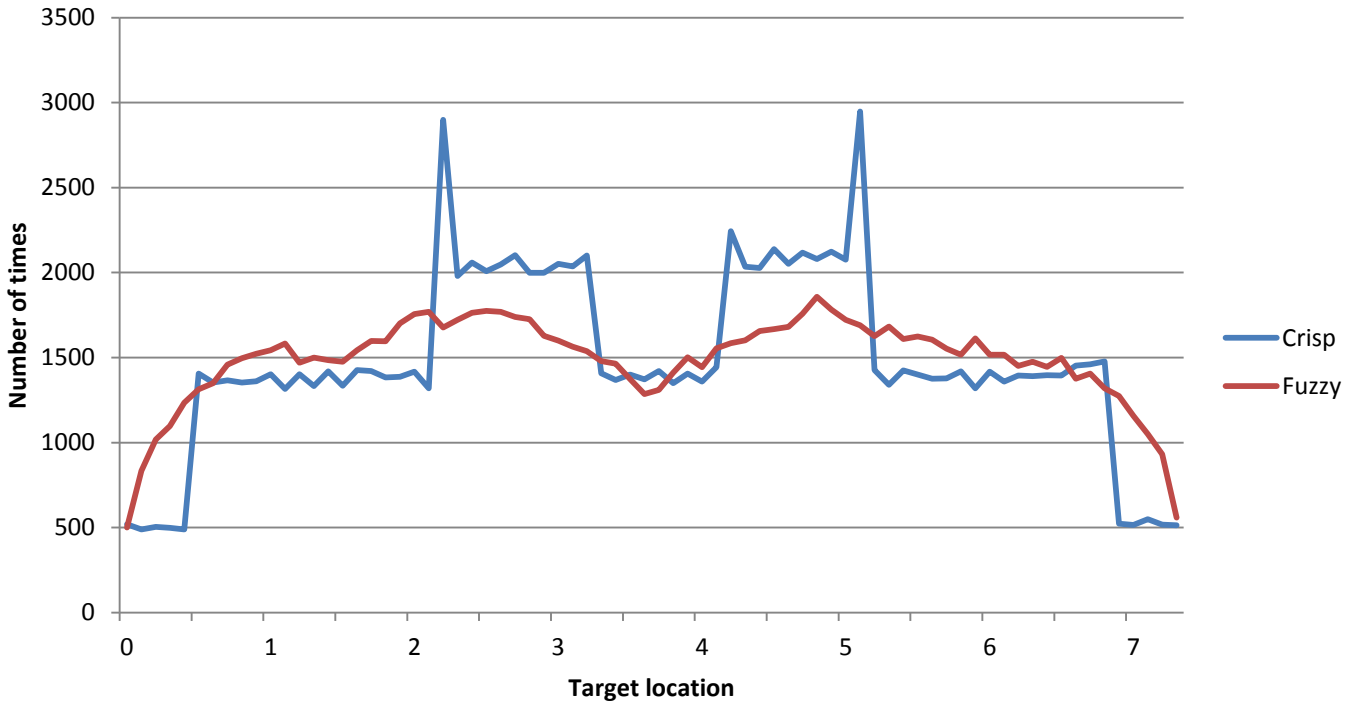
Experimentation 1

- How the percentage of successful shots of both systems vary according to the anxiety variable.
  - Crisp system: a sudden change when the anxiety variable is changing from one category/range to another.
  - Fuzzy system will be affected by how fast the degree of a membership function changes.

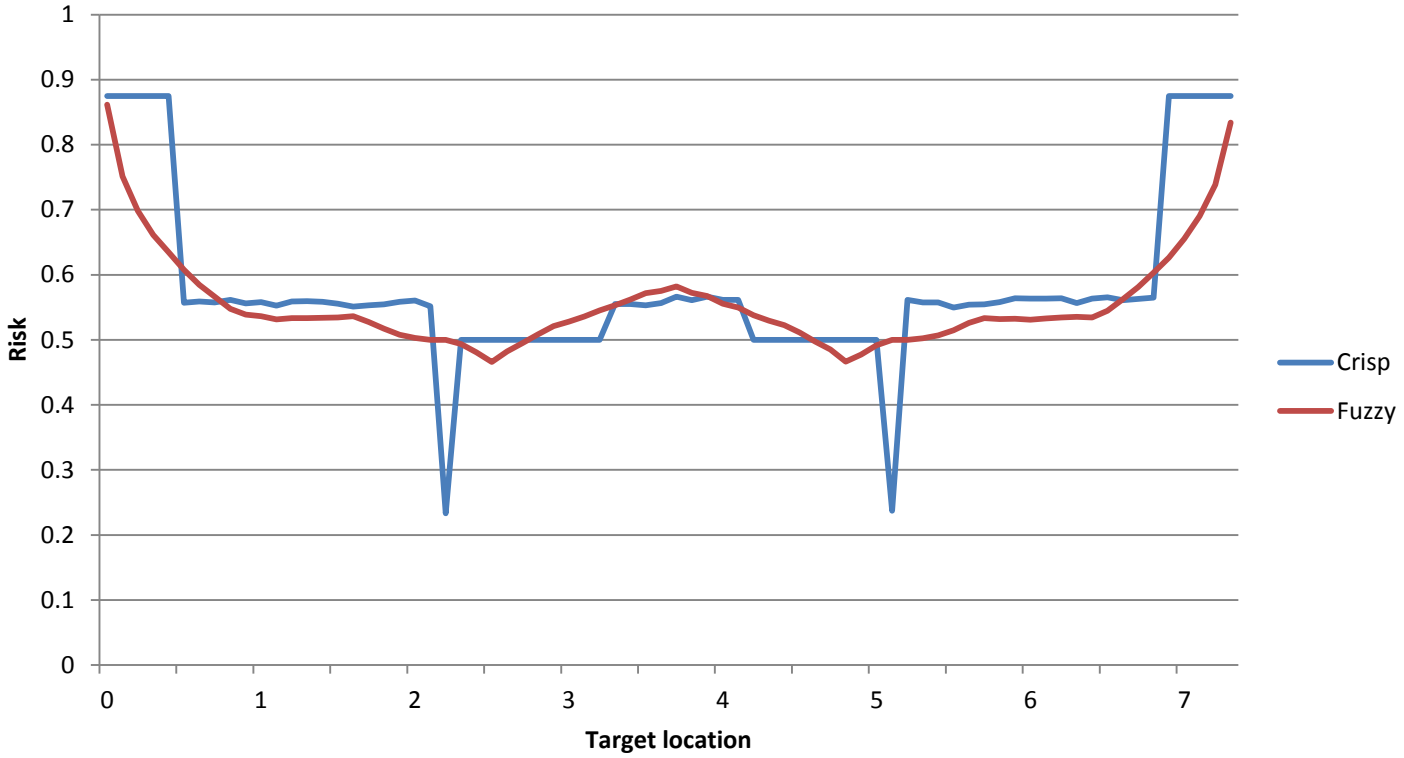


Experimentation 2

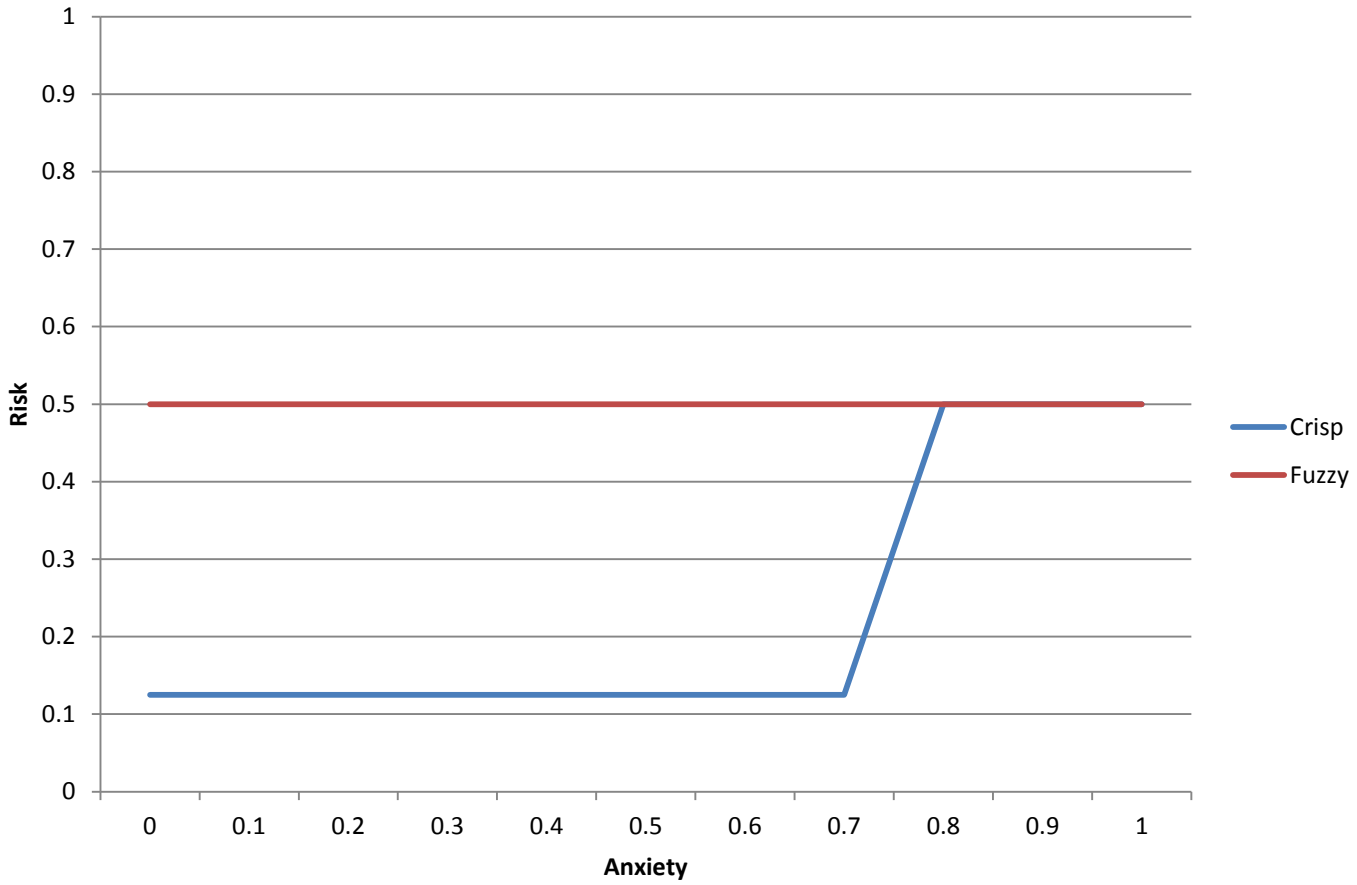
- The distribution of kicker's target locations over the 7.32m width of the goal.



Risk


1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Risk
0
1
2
3
4
5
6
7
Target location
Crisp
Fuzzy

Risk at peak positions



Conclusion (UKCI paper)

- Demonstrate the openness of BDI framework in embedding other models within its components.
- Crisp system can result in unwanted "preferred" actions because of sudden leaps or drops between different ranges of decision variables.
- Fuzzy system results have smoother transitions which results in more consistent decisions.
- A change from crisp to fuzzy rule based systems as the underlying reasoning model in BDI systems can provide the path to a superior approach for the simulation of human behaviour.

Game theory

		Goalkeeper		
		Left	Center	Right
Kicker	Left	45	90	90
	Center	85	0	85
	Right	95	95	60

p_L
p_R
$p_c = 1 - p_L - p_R$

Against goalie pure strategies, the mixture gives payoffs:

Left: $45p_L + 45p_c + 45p_R$

Center: $90p_L + 0p_c + 95p_R$

Right: $90p_L + 85p_c + 60p_R$

$p_L = 0.355$
$p_R = 0.561$
$p_c = 0.113$

Payoff: 75.4

Interpret the GT finding

- Kicker does better with pure Right than pure Left.
- Kicker should not choose pure Right strategy (60 < 75.4).
- Kicker choose Right with highest probability.
- To counter, Keeper choose Right with highest probability.