

List of fuzzy variables used in the case study

Supplementary data to the paper: Dynamic mathematical models of theory of mind for socially assistive robots

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1 Fuzzy Variables

This document includes a description of the fast-dynamics state variables, slow-dynamics state variables, and auxiliary variables of the cognitive module that was used in one of the scenarios of the case study. The variables are given in Table 1. For each variable, its type, name, range, and linguistic terms are given.

In this scenario, one dependent being (e.g., a cat) and a personal belonging (e.g., a wallet) are present, as to give a complete overview of the fuzzy variables used in the case study. The human colleague is not present in this scenario. Nevertheless, the fuzzy variables associated with the human colleague are identical to the ones associated with the dependent being.

2 Fuzzy Rules

All the rules are presented as follows:

IF <variable name of the antecedent>[<verbal term of the antecedent>] THEN [<variable name of the consequent>[[<verbal term of the consequent>] @maximum-rule-firing%],

where the maximum-rule-firing is a percentage that describes the maximum value that the rule can be fired with.

All the rules that have a certain fuzzy variable as the consequent are grouped together. The list of rules follows the same order as the list of variables in the first section.

1. Variable: Belief - in danger cat

1.1. Antecedent: Perceived Knowledge - in danger cat

1.1.1. IF in danger cat[no danger] THEN [in danger cat[no danger]]

Type of Variable	Name	Range	Linguistic terms
Belief	in danger cat	[-0.25 , 1]	['no danger', 'do not know', 'low danger', 'danger', 'high danger', 'extreme danger']
Belief	in danger wallet	[-0.25 , 1]	['no danger', 'do not know', 'low danger', 'danger', 'high danger', 'extreme danger']
Belief	injured cat	[-1 , 1]	['not injured', 'do not know', 'injured']
Belief	picked up cat	[0 , 1]	['not picked up', 'picked up']
Belief	picked up wallet	[0 , 1]	['not picked up', 'picked up']
Belief	near fire agent	[0 , 1]	['no fire near', 'fire in diagonal', 'near fire', 'on top of fire']
Goal	save cat	[-1 , 1]	['do not save at all', 'do not save', 'neutral', 'save', 'save more than anything']
Goal	save wallet	[-1 , 1]	['do not save at all', 'do not save', 'neutral', 'save', 'save more than anything']
Goal	go to exit	[-1 , 1]	['do not exit at all', 'do not exit', 'neutral', 'exit', 'exit more than anything']
Emotions	fear for cat	[0 , 1]	['null', 'light', 'moderate', 'intense', 'extremely intense']
Emotions	fear for wallet	[0 , 1]	['null', 'light', 'moderate', 'intense', 'extremely intense']
Emotions	fear for agent	[0 , 1]	['null', 'light', 'moderate', 'intense', 'extremely intense']
Bias	bias in danger cat	[-0.25 , 1]	['no danger', 'do not know', 'low danger', 'danger', 'high danger', 'extreme danger']
Bias	bias in danger wallet	[-0.25 , 1]	['no danger', 'do not know', 'low danger', 'danger', 'high danger', 'extreme danger']
General Preferences	relationships cat	[0 , 1]	['neutral', 'a bit close', 'close', 'very close', 'extremely close']
General Preferences	relationships wallet	[0 , 1]	['neutral', 'a bit close', 'close', 'very close', 'extremely close']
Perceived Knowledge	in danger cat	[-0.25 , 1]	['no danger', 'do not know', 'low danger', 'danger', 'high danger', 'extreme danger']
Perceived Knowledge	in danger wallet	[-0.25 , 1]	['no danger', 'do not know', 'low danger', 'danger', 'high danger', 'extreme danger']
Perceived Knowledge	injured cat	[-1 , 1]	['not injured', 'do not know', 'injured']
Perceived Knowledge	picked up cat	[0 , 1]	['not picked up', 'picked up']
Perceived Knowledge	picked up wallet	[0 , 1]	['not picked up', 'picked up']
Perceived Knowledge	near fire agent	[0 , 1]	['no fire near', 'fire in diagonal', 'near fire', 'on top of fire']

Table 1: List of fuzzy variables used in the case study.

- 1.1.2. IF in danger cat[do not know] THEN [in danger cat[do not know]]
- 1.1.3. IF in danger cat[low danger] THEN [in danger cat[low danger]]
- 1.1.4. IF in danger cat[danger] THEN [in danger cat[danger]]
- 1.1.5. IF in danger cat[high danger] THEN [in danger cat[high danger]]
- 1.1.6. IF in danger cat[extreme danger] THEN [in danger cat[extreme danger]]
- 1.2. Antecedent: Bias - bias in danger cat
 - 1.2.1. IF bias in danger cat[no danger] THEN [in danger cat[no danger]@0.70%]
 - 1.2.2. IF bias in danger cat[do not know] THEN [in danger cat[do not know]@0.70%]
 - 1.2.3. IF bias in danger cat[low danger] THEN [in danger cat[low danger]@0.70%]
 - 1.2.4. IF bias in danger cat[danger] THEN [in danger cat[danger]@0.70%]
 - 1.2.5. IF bias in danger cat[high danger] THEN [in danger cat[high danger]@0.70%]
 - 1.2.6. IF bias in danger cat[extreme danger] THEN [in danger cat[extreme danger]@0.70%]
- 2. Variable: Belief - in danger wallet
 - 2.1. Antecedent: Perceived Knowledge - in danger wallet
 - 2.1.1. IF in danger wallet[no danger] THEN [in danger wallet[no danger]]
 - 2.1.2. IF in danger wallet[do not know] THEN [in danger wallet[do not know]]
 - 2.1.3. IF in danger wallet[low danger] THEN [in danger wallet[low danger]]
 - 2.1.4. IF in danger wallet[danger] THEN [in danger wallet[danger]]
 - 2.1.5. IF in danger wallet[high danger] THEN [in danger wallet[high danger]]
 - 2.1.6. IF in danger wallet[extreme danger] THEN [in danger wallet[extreme danger]]
 - 2.2. Antecedent: Bias - bias in danger wallet
 - 2.2.1. IF bias in danger wallet[no danger] THEN [in danger wallet[no danger]@0.70%]
 - 2.2.2. IF bias in danger wallet[do not know] THEN [in danger wallet[do not know]@0.70%]
 - 2.2.3. IF bias in danger wallet[low danger] THEN [in danger wallet[low danger]@0.70%]
 - 2.2.4. IF bias in danger wallet[danger] THEN [in danger wallet[danger]@0.70%]
 - 2.2.5. IF bias in danger wallet[high danger] THEN [in danger wallet[high danger]@0.70%]
 - 2.2.6. IF bias in danger wallet[extreme danger] THEN [in danger wallet[extreme danger]@0.70%]
- 3. Variable: Belief - injured cat
 - 3.1. Antecedent: Perceived Knowledge - injured cat
 - 3.1.1. IF injured cat[not injured] THEN [injured cat[not injured]]
 - 3.1.2. IF injured cat[do not know] THEN [injured cat[do not know]]
 - 3.1.3. IF injured cat[injured] THEN [injured cat[injured]]
- 4. Variable: Belief - picked up cat
 - 4.1. Antecedent: Perceived Knowledge - picked up cat
 - 4.1.1. IF picked up cat[not picked up] THEN [picked up cat[not picked up]]
 - 4.1.2. IF picked up cat[picked up] THEN [picked up cat[picked up]]
- 5. Variable: Belief - picked up wallet
 - 5.1. Antecedent: Perceived Knowledge - picked up wallet

- 5.1.1. IF picked up wallet[not picked up] THEN [picked up wallet[not picked up]]
- 5.1.2. IF picked up wallet[picked up] THEN [picked up wallet[picked up]]
- 6. Variable: Belief - near fire agent
 - 6.1. Antecedent: Perceived Knowledge - near fire agent
 - 6.1.1. IF near fire agent[no fire near] THEN [near fire agent[no fire near]]
 - 6.1.2. IF near fire agent[fire in diagonal] THEN [near fire agent[fire in diagonal]]
 - 6.1.3. IF near fire agent[near fire] THEN [near fire agent[near fire]]
 - 6.1.4. IF near fire agent[on top of fire] THEN [near fire agent[on top of fire]]
- 7. Variable: Goal - save cat
 - 7.1. Antecedent: Belief - in danger cat
 - 7.1.1. IF in danger cat[no danger] THEN [save cat[do not save]]
 - 7.1.2. IF in danger cat[do not know] THEN [save cat[neutral]]
 - 7.1.3. IF in danger cat[low danger] THEN [save cat[neutral]]
 - 7.1.4. IF in danger cat[danger] THEN [save cat[save]]
 - 7.1.5. IF in danger cat[high danger] THEN [save cat[save more than anything]]
 - 7.1.6. IF in danger cat[extreme danger] THEN [save cat[save more than anything]]
 - 7.2. Antecedent: Belief - injured cat
 - 7.2.1. IF injured cat[not injured] THEN [save cat[do not save]]
 - 7.2.2. IF injured cat[do not know] THEN [save cat[neutral]]
 - 7.2.3. IF injured cat[injured] THEN [save cat[save more than anything]]
 - 7.3. Antecedent: General Preferences - relationships cat
 - 7.3.1. IF relationships cat[neutral] THEN [save cat[do not save at all]]
 - 7.3.2. IF relationships cat[a bit close] THEN [save cat[do not save]]
 - 7.3.3. IF relationships cat[close] THEN [save cat[neutral]]
 - 7.3.4. IF relationships cat[very close] THEN [save cat[save]]
 - 7.3.5. IF relationships cat[extremely close] THEN [save cat[save more than anything]]
 - 7.4. Antecedent: Belief - picked up cat
 - 7.4.1. IF picked up cat[picked up] THEN [save cat[do not save at all]@1.50%]
 - 7.5. Antecedent: Belief - picked up wallet
 - 7.5.1. IF picked up wallet[picked up] THEN [save cat[do not save at all]@1.50%]
- 8. Variable: Goal - save wallet
 - 8.1. Antecedent: General Preferences - relationships wallet
 - 8.1.1. IF relationships wallet[neutral] THEN [save wallet[do not save at all]]
 - 8.1.2. IF relationships wallet[a bit close] THEN [save wallet[do not save]]
 - 8.1.3. IF relationships wallet[close] THEN [save wallet[neutral]]
 - 8.1.4. IF relationships wallet[very close] THEN [save wallet[save]]
 - 8.1.5. IF relationships wallet[extremely close] THEN [save wallet[save more than anything]]
 - 8.2. Antecedent: Belief - picked up cat

- 8.2.1. IF picked up cat[picked up] THEN [save wallet[do not save at all]@1.50%]
- 8.3. Antecedent: Belief - picked up wallet
 - 8.3.1. IF picked up wallet[picked up] THEN [save wallet[do not save at all]@1.50%]
- 9. Variable: Goal - go to exit
 - 9.1. Antecedent: Emotions - fear for agent
 - 9.1.1. IF fear for agent[null] THEN [go to exit [neutral]@0.50%]
 - 9.1.2. IF fear for agent[light] THEN [go to exit [neutral]@0.50%]
 - 9.1.3. IF fear for agent[moderate] THEN [go to exit [exit]@0.50%]
 - 9.1.4. IF fear for agent[intense] THEN [go to exit [exit more than anything]@0.50%]
 - 9.1.5. IF fear for agent[extremely intense] THEN [go to exit [exit more than anything]@0.50%]
 - 9.2. Antecedent: Belief - picked up cat
 - 9.2.1. IF picked up cat[not picked up] AND picked up wallet[not picked up] THEN [go to exit [do not exit]]
 - 9.2.2. IF picked up cat[picked up] THEN [go to exit [exit more than anything]]
 - 9.2.3. IF picked up wallet[picked up] THEN [go to exit [exit more than anything]]
 - 9.3. Antecedent: Belief - picked up wallet
 - 9.3.1. IF picked up cat[not picked up] AND picked up wallet[not picked up] THEN [go to exit [do not exit]]
 - 9.3.2. IF picked up cat[picked up] THEN [go to exit [exit more than anything]]
 - 9.3.3. IF picked up wallet[picked up] THEN [go to exit [exit more than anything]]
- 10. Variable: Emotions - fear for cat
 - 10.1. Antecedent: Belief - in danger cat. These rules are regulated by the general preferences.
 - 10.1.1. IF in danger cat[no danger] AND relationships cat[neutral] THEN [fear for cat[null]]
 - 10.1.2. IF in danger cat[no danger] AND relationships cat[a bit close] THEN [fear for cat[null]]
 - 10.1.3. IF in danger cat[no danger] AND relationships cat[close] THEN [fear for cat[null]]
 - 10.1.4. IF in danger cat[no danger] AND relationships cat[very close] THEN [fear for cat[null]]
 - 10.1.5. IF in danger cat[no danger] AND relationships cat[extremely close] THEN [fear for cat[null]]
 - 10.1.6. IF in danger cat[do not know] AND relationships cat[neutral] THEN [fear for cat[null]]
 - 10.1.7. IF in danger cat[do not know] AND relationships cat[a bit close] THEN [fear for cat[null]]
 - 10.1.8. IF in danger cat[do not know] AND relationships cat[close] THEN [fear for cat[light]]
 - 10.1.9. IF in danger cat[do not know] AND relationships cat[very close] THEN [fear for cat[moderate]]
 - 10.1.10. IF in danger cat[do not know] AND relationships cat[extremely close] THEN [fear for cat[moderate]]
 - 10.1.11. IF in danger cat[low danger] AND relationships cat[neutral] THEN [fear for cat[null]]
 - 10.1.12. IF in danger cat[low danger] AND relationships cat[a bit close] THEN [fear for cat[light]]
 - 10.1.13. IF in danger cat[low danger] AND relationships cat[close] THEN [fear for cat[light]]
 - 10.1.14. IF in danger cat[low danger] AND relationships cat[very close] THEN [fear for cat[moderate]]

- 10.1.15. IF in danger cat[low danger] AND relationships cat[extremely close] THEN [fear for cat[intense]]
- 10.1.16. IF in danger cat[danger] AND relationships cat[neutral] THEN [fear for cat[light]]
- 10.1.17. IF in danger cat[danger] AND relationships cat[a bit close] THEN [fear for cat[light]]
- 10.1.18. IF in danger cat[danger] AND relationships cat[close] THEN [fear for cat[moderate]]
- 10.1.19. IF in danger cat[danger] AND relationships cat[very close] THEN [fear for cat[intense]]
- 10.1.20. IF in danger cat[danger] AND relationships cat[extremely close] THEN [fear for cat[intense]]
- 10.1.21. IF in danger cat[high danger] AND relationships cat[neutral] THEN [fear for cat[light]]
- 10.1.22. IF in danger cat[high danger] AND relationships cat[a bit close] THEN [fear for cat[moderate]]
- 10.1.23. IF in danger cat[high danger] AND relationships cat[close] THEN [fear for cat[intense]]
- 10.1.24. IF in danger cat[high danger] AND relationships cat[very close] THEN [fear for cat[intense]]
- 10.1.25. IF in danger cat[high danger] AND relationships cat[extremely close] THEN [fear for cat[extremely intense]]
- 10.1.26. IF in danger cat[extreme danger] AND relationships cat[neutral] THEN [fear for cat[moderate]]
- 10.1.27. IF in danger cat[extreme danger] AND relationships cat[a bit close] THEN [fear for cat[moderate]]
- 10.1.28. IF in danger cat[extreme danger] AND relationships cat[close] THEN [fear for cat[intense]]
- 10.1.29. IF in danger cat[extreme danger] AND relationships cat[very close] THEN [fear for cat[extremely intense]]
- 10.1.30. IF in danger cat[extreme danger] AND relationships cat[extremely close] THEN [fear for cat[extremely intense]]
- 10.2. Antecedent: Belief - injured cat. These rules are regulated by the general preferences.
 - 10.2.1. IF injured cat[not injured] AND relationships cat[neutral] THEN [fear for cat[null]]
 - 10.2.2. IF injured cat[not injured] AND relationships cat[a bit close] THEN [fear for cat[null]]
 - 10.2.3. IF injured cat[not injured] AND relationships cat[close] THEN [fear for cat[null]]
 - 10.2.4. IF injured cat[not injured] AND relationships cat[very close] THEN [fear for cat[null]]
 - 10.2.5. IF injured cat[not injured] AND relationships cat[extremely close] THEN [fear for cat[null]]
 - 10.2.6. IF injured cat[small size] AND relationships cat[neutral] THEN [fear for cat[null]]
 - 10.2.7. IF injured cat[small size] AND relationships cat[a bit close] THEN [fear for cat[null]]
 - 10.2.8. IF injured cat[small size] AND relationships cat[close] THEN [fear for cat[light]]
 - 10.2.9. IF injured cat[small size] AND relationships cat[very close] THEN [fear for cat[moderate]]
 - 10.2.10. IF injured cat[small size] AND relationships cat[extremely close] THEN [fear for cat[moderate]]
 - 10.2.11. IF injured cat[injured] AND relationships cat[neutral] THEN [fear for cat[null]]
 - 10.2.12. IF injured cat[injured] AND relationships cat[a bit close] THEN [fear for cat[light]]
 - 10.2.13. IF injured cat[injured] AND relationships cat[close] THEN [fear for cat[moderate]]
 - 10.2.14. IF injured cat[injured] AND relationships cat[very close] THEN [fear for cat[intense]]
 - 10.2.15. IF injured cat[injured] AND relationships cat[extremely close] THEN [fear for cat[extremely intense]]

11. Variable: Emotions - fear for wallet

11.1. Antecedent: Belief - in danger wallet

- 11.1.1. IF in danger wallet[no danger] THEN [fear for wallet[null]]
- 11.1.2. IF in danger wallet[do not know] THEN [fear for wallet[null]]
- 11.1.3. IF in danger wallet[low danger] THEN [fear for wallet[null]]
- 11.1.4. IF in danger wallet[danger] THEN [fear for wallet[null]]
- 11.1.5. IF in danger wallet[high danger] THEN [fear for wallet[null]]
- 11.1.6. IF in danger wallet[extreme danger] THEN [fear for wallet[null]]

12. Variable: Emotions - fear for agent

12.1. Antecedent: Belief - near fire agent

- 12.1.1. IF near fire agent[no fire near] THEN [fear for agent[null]]
- 12.1.2. IF near fire agent[fire in diagonal] THEN [fear for agent[moderate]]
- 12.1.3. IF near fire agent[near fire] THEN [fear for agent[intense]]
- 12.1.4. IF near fire agent[on top of fire] THEN [fear for agent[extremely intense]]

13. Variable: Bias - bias in danger cat

13.1. Antecedent: Emotions - fear for cat

- 13.1.1. IF fear for cat[null] THEN [bias in danger cat[do not know]]
- 13.1.2. IF fear for cat[light] THEN [bias in danger cat[low danger]]
- 13.1.3. IF fear for cat[moderate] THEN [bias in danger cat[danger]]
- 13.1.4. IF fear for cat[intense] THEN [bias in danger cat[high danger]]
- 13.1.5. IF fear for cat[extremely intense] THEN [bias in danger cat[extreme danger]]

14. Variable: Bias - bias in danger wallet

14.1. Antecedent: Emotions - fear for wallet

- 14.1.1. IF fear for wallet[null] THEN [bias in danger wallet[do not know]]
- 14.1.2. IF fear for wallet[light] THEN [bias in danger wallet[low danger]]
- 14.1.3. IF fear for wallet[moderate] THEN [bias in danger wallet[danger]]
- 14.1.4. IF fear for wallet[intense] THEN [bias in danger wallet[high danger]]
- 14.1.5. IF fear for wallet[extremely intense] THEN [bias in danger wallet[extreme danger]]