

Human-like artificial creatures

6. Fuzzy approach

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Motivation

if **a** then **A**

if **b** then **B**

Can transitions be smooth?

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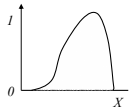
Outline

1. Fuzzy theory (introduction)
2. Fuzzy rules and state machines
 - [Champandard, 2003]
3. ASM Evaluation
4. Emotional system using fuzzy FSM

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Fuzzy logic

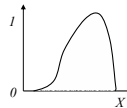


- In classical logical, all sets are "crisp" and all values are "crisp"
 - true / false
 - health = 39, ammo = 68
- Fuzzy logic address continuous gray area between black and white borders
 - p is mostly true, r is not entirely false
- Fuzzy set:
 - is defined by membership function: $m : X \rightarrow <0, 1>$
 - $A = B \Leftrightarrow \forall x: A(x) = B(x)$
 - $A \subset B \Leftrightarrow \forall x: A(x) < B(x)$
 - $\bar{C} = A \cup B \Leftrightarrow \forall x: C(x) = \max(A(x), B(x))$ (OR)
 - $\bar{C} = A \cap B \Leftrightarrow \forall x: C(x) = \min(A(x), B(x))$ (AND)
 - $A(x) = 1 - A(x)$ (NOT)

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Fuzzy variables



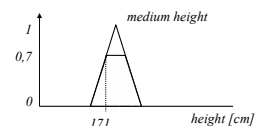
- Fuzzy values can be stored in single fuzzy variables
 - health = 0.9
 - strong = 0.7
 - moving = 0.0
- Fuzzy variables can be combined in linguistic variables
 - e.g.: **height**
 - linguistic variable is defined over base variables: **height in cm**
 - linguistic variable is a collection of membership functions, each associated with a term
 - set of terms: { **small**, **middle**, **tall** }
 - set of values: { 0, 0.4, 0.9 }
- Fuzzy modifiers

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height [cm]

Fuzzification

- Fuzzification is the process of creating a fuzzy value from a crisp value

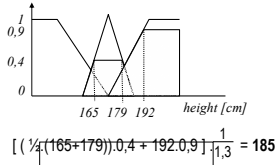


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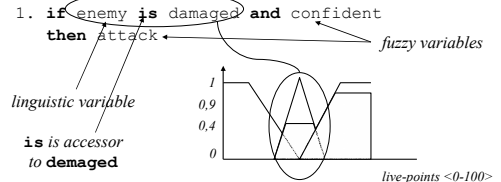
Defuzzification

- Defuzzification is the process that convert a fuzzy value to a crisp value
- Several approaches exist, they are approximate in general
 - weighted MOM:



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Fuzzy rules



- the working memory contains fuzzy values
- the inference process must determine the degree of truth of the THEN part of the rule

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The degree of truth of THEN part

1. if enemy is damaged and ammo is high then attack



- Evaluation is slower than in the case of "crisp" rules
- One possible approach is to ignore fuzzy values below certain threshold, i.e. 0.3, and rescale the values above 0.3 to <0,1>
- "lazy" evaluation: operators MIN and PRODUCT are used only for defuzzification

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Example

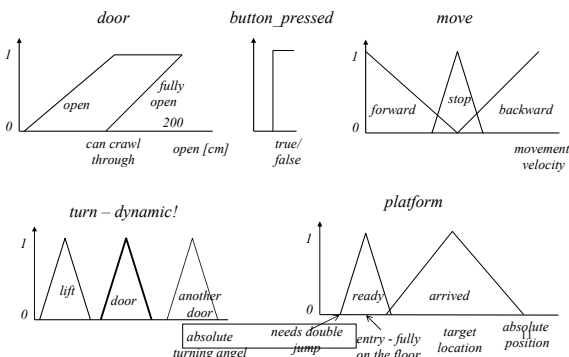
taking a lift

if not button pressed then	turn to button, move forward
if button_pressed and platform not ready then	move stop
if button_pressed and not aboard then	turn to platform
if platform is ready then	move forward
if aboard then	turn to exit
if aboard and platform has not arrived then	move stop
if aboard and platform has arrived then	move forward

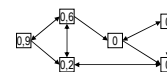
[Champandard, 2003, p. 410-414] 10

Example

fuzzy and linguistic variable



Fuzzy FSM



[Champandard, 2003, p. 541-544]

Fuzzy "finite-state machine" (FFSM) is a tuple:
 $\langle \{ \langle \text{label}, F, \text{script} \rangle \}, A^F \rangle$

- $\langle \text{label}, F, \text{script} \rangle$ is a state
 - a label is a name of the state
 - a script is a code associated with the state
 - F is a set of fuzzy-rules that trigger transition to another states
- A^F represents current degree of the activity of the states, it is a set of tuples:
 - i.e. "<shoot", 0.25>

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Fuzzy FSM

- States are fuzzy, transitions are fuzzy
- How to compute degree of activity?

– e.g. MIN-MAX method:

IF <wandering> AND [attacked] THEN <fleeing>
IF <attacking> AND [near_dead] THEN <fleeing>

$act_{\text{fleeing}} = (\text{act}_{\text{wandering}} \cdot \text{act}_{\text{attacked}}) \cdot \text{MAX}$
 $(\text{act}_{\text{attacking}} \cdot \text{act}_{\text{near_dead}})$

- Which script to perform?
 - all scripts above a threshold or a script of the most active state
 - i.e., turning right and slowing down
- Fading problem

Evaluation

- Transition
- It behaves in the same way
- Rigid
- Compromise action
- Proscription
- Modification of a behavior
- Concurrent behaviour
- Interleaving
- Sharp timeout
- Adaptive
- Time-consuming design

(authoring vs. learning)

ok?

n.a.

OK

ok?

ok?

n.a.

OK

-

ok?

-

OK, but parameterizing!

Evaluation

PROS

- Fuzzy control is very smooth
- Fuzzy rules can be created by a designer, not a programmer
- Fuzzy rules fit better to decision making, rather than to a low level control

CONS

- Evaluation is slow...
 - RETE-like evaluation is not possible
- Creation of membership functions is difficult
 - tuning must be performed

Do you see any difference between fuzzy-rules and neural networks used in Creatures?

Outline

1. Fuzzy theory (introduction)
2. Fuzzy rules and state machines
 - [Champandard, 2003]
3. ASM Evaluation
4. **Emotional system using fuzzy FSM**

Fuzzy FSM Example

modeling emotions

- A **sensation** is immediate reaction to a creature's current state
 - pain, surprise, disgust,...
 - cognitive (surprise caused by an object not being present, when a bot thought it should be) vs. external (health and armor lost, arriving lift, enemy presence,...)
- An **emotion** is a lasting characteristic of a person's state
 - they change relatively slowly in time
 - e.g. fear, anger, pride, shame
- A **mood** is the complete set of emotions that constitutes someone's mental state at a particular time
- A **feeling** is a persistent association of an emotion with a class of object
 - they are relative to an arbitrary object
 - e.g. love, cruelty, pity
- Mood, emotions etc. affect acting and perceiving
 - parameter modification, mannerism

[Champandard, 2003, chap. 39, 42]

Fuzzy FSM Example

modeling emotions

- Example 1: simple emotional model
 - first FSM models moods and emotions
 - second FSM (decision tree) models transition between moods based on external sensations
- Example 2: complex emotional model

Fuzzy FSM Example

modeling emotions

- Example 2: complex emotional model
 - a set of FSMs models feelings based on past experience
 - feelings: attraction, pity, hatred, disgust
 - memories: damage taken and inflicted, number of shots fired and received, value and difference of the "kill counters"
 - a set of FFSM models sensations based on feelings, external stimuli and emotions (one FFSM for each sensation)
 - external stimuli: health and armor lost, explosions, arriving lift, enemy presence, blood splat, object disappears, door opening, desirable object
 - sensations: surprise, anticipation, disgust, attraction, confusion, discovery, pain, pleasure
 - a set of FFSM (linguistic variables) models complex emotions based on sensations (one FFSM for each sensation)
 - emotions: pride, shame, fear, anger, joy, sorrow, amusement, waeriness
 - a set of PFSM models mannerism based on emotions
 - e.g.: wave and happy comment, cynical comment, happy jump, stretch,...¹⁹
 - one HFSM models moods according to emotions

Fuzzy FSM Example

modeling emotions

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End.

References

- **Fuzzy rules:** Champandard, A.J.: *AI Game Development: Synthetic Creatures with learning and Reactive Behaviors*. New Riders, USA (2003), chapter 30-31
- **Fuzzy rules:** Novák, V.: *Základy fuzzy modelování*. Ben (2000)