Course on Artificial Intelligence and Intelligent Systems, KIIS

Exercises on fuzzy expert systems

Henning Christiansen
Roskilde University, Computer Science Dept.
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Introduction

The theme of these exercises is driving a car on the motor way. The exercises concern the development of a fuzzy expert system whose rules determine the next action to perform. In other words, this is an application of *fuzzy control* which is not covered by our text book. The idea in fuzzy control is as follows.

1. A number of measurements are taken from the environment and perhaps converted into a different scale or format.
2. Fuzzy rules are applied to these values, leading to identify the possible action to perform.
3. The action with the highest weight is chosen (to be explained).
4. Wait a suitable time until the action has had the opportunity to affect the environment.
5. Goto 1.

We make some assumptions, some of them reflect (mostly) good behaviour in the traffic, and others are included in order to simplify these exercises.

- We consider only driving at road sections with no incoming or outgoing lanes, and precisely two lanes (in each direction).
- Our car should always drive with a highest possible and secure speed.
- In general we should stay within the speed limit 110 km/h; however, we may decide to go 15% above the limit for a short period if there is reason to do so.
- Our car can be though of as being in exactly one lane at a given point in time, Right or Left. (In other words, the time between two following measurements of the environment is longer than it takes to change lane).
- We should observe strictly the rule saying that it is not allowed to overtake another car using the Right lane.

- Keep in Right lane if no really good reason to do otherwise.
- We have only very few assumptions about the other cars behaviour; their speed may range from 60 to 200. If you need it, you may assume that most other guys drive according to roughly the same principles as we do (but you must be prepared for the madmen of different kinds).
- We make no prediction or anticipation of other drivers possible next actions.

1 Exercise: Fuzzy variables

The speed of any car can take one of the following fuzzy values:

Slow, Good-cruising-speed, Fast.

Design relevant membership function for these values and show their curves (it is recommended that you use linear segments).

Apply the so-called hedges (textbook p. 96–97) Very, Extremely, More-or-less to these values to check whether they are intuitively correct. Perhaps you may want to modify the membership functions in order to obtain this goal.

Draw some membership curves for selected fuzzy (linguistic) expressions that represent the following.

- Speed of cars that drive fast but not very fast.
- Speed of cars that you find annoying (the "madmen").

2 Exercise: More fuzzy variables

For the decisions concerning your driving, you need also to consider the behaviour of the other cars. It is assumed that you can see the following and measure their speed and distance to you:

- The car in front of you in same lane.
- The car behind of you in same lane.
- Similar two cars in the other lane.

Define fuzzy values and membership functions for distances that are relevant for rules about driving (that you have to define in next exercise). Basically you should have a collection of values that makes it possible to avoid collisions and to check whether the manoeuvre you plan is possible.

3 Exercise: Fuzzy rules for control

Based on the variables and possible values defined in the previous exercises, you should now define a set of rules to be used in a fuzzy control system, recalling the assumptions given in the introduction.

The conclusion of a rule is one or more actions chosen among those specified below.

In fact, this situation is simpler than what is described in our textbook as we avoid the steps "Aggregation of the rule outputs" and "Defuzzification" as no numerical value is to be calculated. The action with the highest score (i.e., how well the antecedents are satisfied) is the one executed.

The following actions are possible:

- Continue-with-same-speed
- Change-lane
- Accelerate (assumed to be as fast as possible under the given circumstances).
- Brake (we assume, for simplicity, an intelligent brake that finds out itself how much)
- Honk-and-flash-head-lights
- Alarm-and-manual-override (meaning that the situation is dangerous and the fuzzy control system cannot suggest a solution from the limited amount of data it has available).

Analyze a few familiar scenarios from the motor way to see how well your fuzzy control system will perform. It is recommended that you avoid detailed calculation of speeds and positions of the different cars and just indicate some roughly estimated values.

4 Optional exercise: Fuzzy rules with numerical output

Extend you model developed so far with fuzzy variables for the *amount* of breaking and acceleration, and modify the relevant rules from the previous exercise.

It is suggested that you drop the detailed mathematical calculations that provide the perfect values and just aim at results that appear to be reasonable.

Calculate for an example how the system performs using the "Aggregation of the rule outputs"[1] and "Defuzzification" in order to determine the output values.

5 Optional exercise: Discussion of problems

With the methods we have considered and which is given by our textbook, there are some problems with the fuzzy control system as we have considered above (and, in fact, any fuzzy expert system).

Obvious questions concerning the system are the following:

- If there is risk of an accident, and there is a possible sequence of actions that will avoid the accident, will the system avoid the accident?
- Are there situations in which the two highest scores for actions are very close so it is difficult to select which one to take?[2]
- How often, in average, is the action Alarm-and-manual-override suggested.

How well can you answer these questions? Consider how simulation can be used and where mathematical proof methods can be used.

[1] The book is very unclear at this particular point, so part of this exercise is to reconstruct a useable definition. You may consult other literature.

[2] You may also discuss a possible extension of the fuzzy control model, so that several actions are chosen at the same time provided they are not conflict. In this case, how should the question be raised?

6 Theoretical project

Search literature on the sort of simulation and proof techniques that were discussed in the previous exercise. Write a report that summarizes the state of the art in this field and describe central methods and existing systems.

7 Practical project

Implement the fuzzy control system that you have described above and extend it with a simulation module.