FUZZY LOGIC - ASSIGNMENT

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INTRODUCTION

We have decided to study fuzzy-logic rice cooker. Indeed, when you are cooking rice, you can be easily distracted by a call or your children, and so your rice will be totally burned. However, with a fuzzy rice cooker, you won't have to be worried about anything : the rice cooker will automatically cook perfectly for you. While rice is prepared, you could attend to your business.

According a certain amount of rice and the kind of rice, the machine will choose the perfect temperature. If the cooking of rice is over, the machine could also choose to keep the rice warm (so you won't have to reheat the rice when you will choose to eat). In more developed fuzzy rice cooker, you can also precise what kind of texture you wish (soft, hard, sticky, wet). It can also be even more powerful than humans and makes up for any error : for example, if you have added too much water, fuzzy rice cooker will adjust temperature to give you a consistent and perfect rice. To summarize, a fuzzy logic rice cooker will be able to make a decision similar to yours, sometimes it will be even a better one.

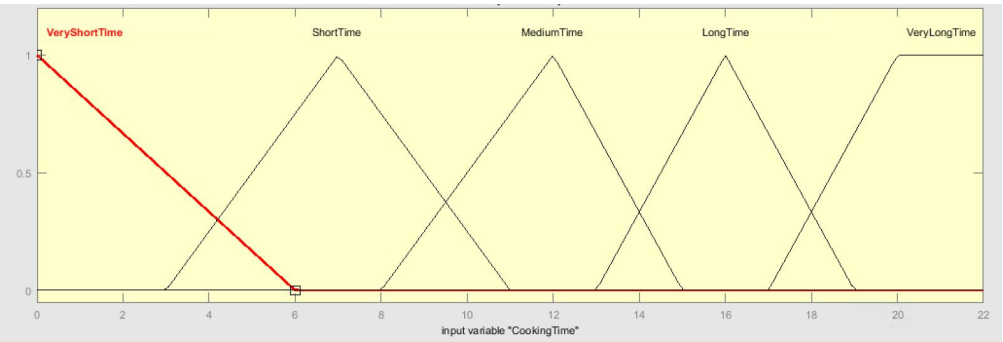
MODEL

Variables Input: Time elapsed in the rice cooker / Quantity of rice / Length of grain rice
Variable Output: Temperature

Fuzzification :

Input Variables:

- Time elapsed:
  The rice needs less than 25 minutes to cook then we focus the time elapsed between 0-22 minutes. We split it in 5 fuzzy sets:
  - Very_Short_Time: ~0-6 minutes represents more or less the time water needs to boils when we cook by ourselves.
    - Max(Min((x-0)/(0-0), (6-x)/(6-0)) , 0)
  - Short_Time: ~3-11 minutes
    - Max(Min((x-3)/(7-3), (10-x)/(10-7)) , 0)
  - Medium_Time ~8-15 minutes
    - Max(Min((x-8)/(12-8), (15-x)/(15-12)) , 0)
  - Long_Time ~13-19 minutes
    - Max(Min((x-13)/(16-13), (19-x)/(19-16)) , 0)
  - Very_Long_Time ~17-22+ minutes
    - Max(Min((x-17)/(20-17), 1, (23-x)/(23-22)) , 0)



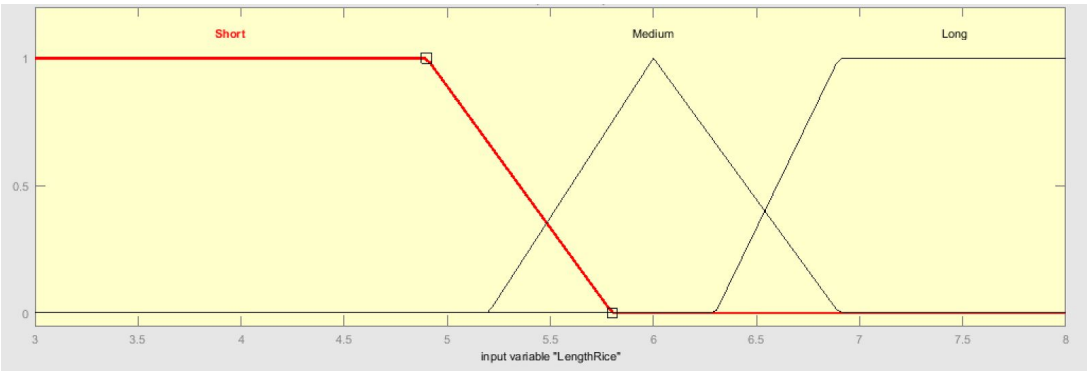
Extract of Matlab simulation representing "Time elapsed in the rice cooker"

- Length of grain rice:
  The length of the rice varies between 2 and 8 mm. It is split in three categories, which we have found on websites. The length will influence time of cooking. The guide of the rice cooker will explain to choose a length depending of the type of the rice (example:Basmati).

Grain type	Length (mm)
Long-grain	6.61 to 7.5
Medium-grain	5.51 to 6.6
Short-grain	up to 5.5

Picture 1 : Array from https://en.wikipedia.org/wiki/Grain_quality

  - Short-Grain
    - Max(Min((x-1.2)/(2.167-1.2), 1 , (5.8-x)/(5.8-4.9)) , 0)
  - Medium-Grain
    - Max(Min((x-5.2)/(6-5.2), (6.9-x)/(6.9-6)) , 0)
  - Long-Grain
    - Max(Min((x-6.3)/(6.9-6.3), 1 , (16-x)/(16-15)) , 0)



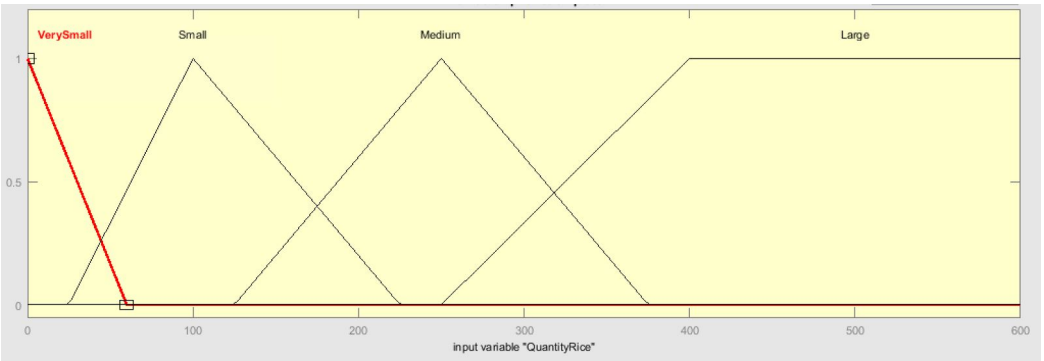
Extract of Matlab simulation representing "Length of grain rice"

- Quantity of rice:

The rice cookers represent the amount of rice by a number of cups. Each rice cooker has his maximum number of cups. We have chosen that our cooker can not exceed 600 grams of rice (6 cups), hence 1 cup=100 grams.
We have 4 fuzzy sets of Quantity of rice:

  - Very small ~0-60 g
    - Max(Min((x-0)/(0-0), (60-x)/(60-0)) , 0)

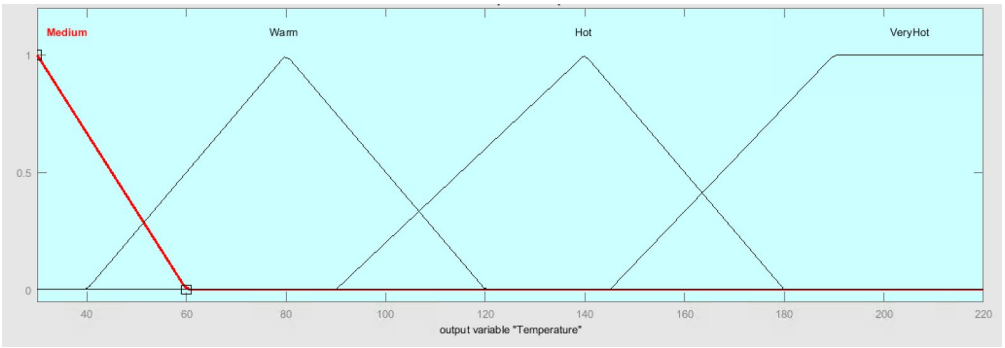
- Small ~25-225 g
    - Max(Min((x-25)/(100-25), (225-x)/(225-100)) , 0)
- Medium ~125-375 g
    - Max(Min((x-125)/(250-125), (375-x)/(375-250)) , 0)
- Large ~250-600 g
    - Max(Min((x-250)/(400-250), 1 , (800-x)/(800-600)) , 0)



Extract of Matlab simulation representing “Quantity of rice”

Output Variables:

- Temperature:
  We have defined four fuzzy set temperatures:
    - Medium : 0-60 degrees.
      This temperature allows to keep the food at a reasonable temperature (if you forgot you rice after its cooking, you don’t need to reheat thanks to this temperature set).
        - Max(Min((x-30)/(30-30), (60-x)/(60-30)) , 0)
    - Warm : 40-120 degrees.
      This temperature is to decrease the temperature but to continue to cook.
        - Max(Min((x-40)/(80-40), (120-x)/(120-80)) , 0)
    - Hot : 90-180 degrees.
      This temperature allows to cook the rice.
        - Max(Min((x-90)/(140-90), (180-x)/(180-140)) , 0)
    - VeryHot : 145-220 degrees.
      This temperature is to raise the cooker really fast.
        - Max(Min((x-145)/(190-145), 1 , (221-x)/(221-220)) , 0)



Extract of Matlab simulation representing “Temperature into the rice cooker”

For each linguistic variable, we have drawn membership functions such as they all overlap sufficiently.

Rules evaluation :

There are 4 stages of cooking rice : Stands in water / Boils / Absorbs / Rests. For our fuzzy logic rice cooker, we have written 30 fuzzy rules based on our knowledge of 4 stages of cooking rice. We are going to present you the most important rules :

- IF Very_Short_Time THEN Very_Hot

Firstly, we have a cold water. Here, doesn't matter the quantity or the kind of rice, we are wishing to enter in a boiling situation. So it seems logical to put a very high temperature in the rice cooker: in that way, we could reach a water at 100°C in a short time. When you are not anymore in a "Very_Short_Time", you can think your rice is in the stage "Boils" (=stage 2).

- IF Short_Time AND Very_Small_Rice AND (Short_Grain OR Medium_Grain) THEN Warm
- IF Short_Time AND Very_Small_Rice AND Long_Grain THEN Hot

For a very small quantity of rice, we can say that after the period of "Very_Short_Time", you already moved up into the stage "Absorbs" (=stage 3).

So the next step is to pass in the stage "Rests" (=stage 4), and so lower the temperature to a "Warm" situation. However, according the kind of rice, you could pass more quickly to stage "Rests" : it's the case for short and medium grain rice. But for long grain rice, it takes more time to cook the rice, so you are still to the stage "Absorbs" during "Short_Time". So the adequate temperature should be "Hot".

- IF Short_Time AND Small_Rice AND Short_Grain THEN Warm
- IF Medium_Time AND Small_Rice AND Short_Grain THEN Medium_Temperature

When you are in the stage of "Rests" for a time, your rice is ready. Nevertheless, the next process in a fuzzy rice cooker, it's to keep the rice in a medium temperature (so you won't need to reheat the food). Here, after a short-time (so for a medium, long and very long time), your small and short grain rice is ready and the temperature applied will be a "Medium Temperature".

SIMULATION - With an example

Fuzzification :

We are taking 300g of rice : so it belongs to the fuzzy set "Medium quantity" with a degree of membership equal to 0.6 and it also belongs to the fuzzy set "Large quantity" with a degree of membership equal to 0.33 (using previous formulas).

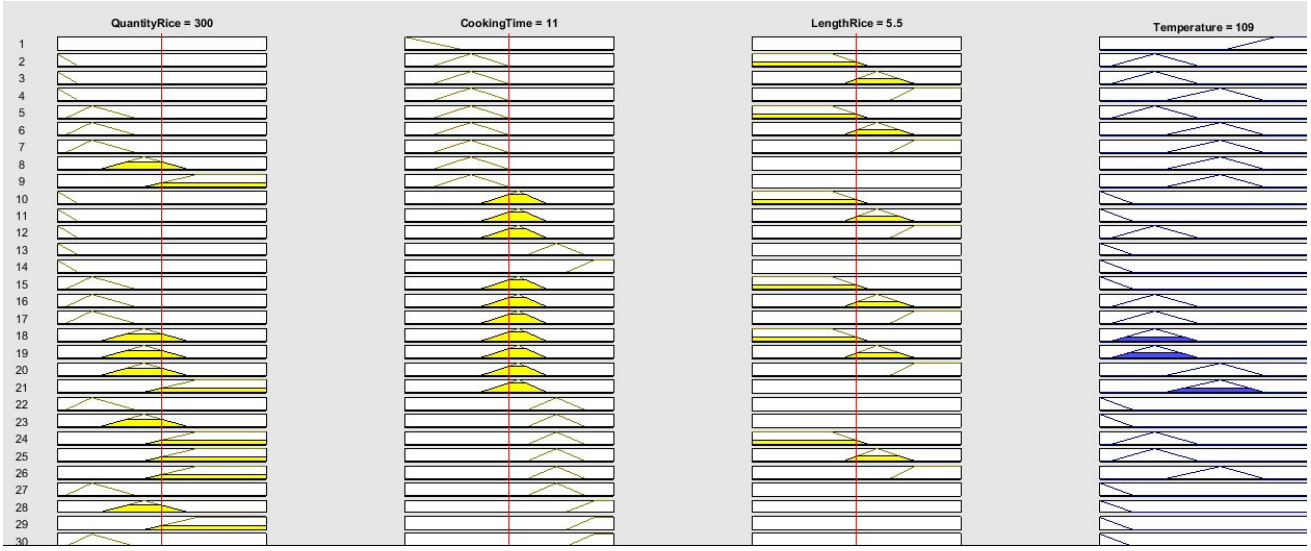
Our rice is a Swastik rice, so in average, the length of our grain rice is 5.5 mm. So it belongs to the fuzzy set "Short grain rice" with a degree of membership of 0.33. And it also belongs to the fuzzy set "Medium grain rice" with a degree of membership equal to 0.23.

We chose to examine what happens when the cooking have begun 11 minutes ago. So it belongs to the fuzzy set "Medium time" with a degree of membership equal to 0.75.

Inference :

Concerning the inference, the rules 18, 19 and 21 are fired.

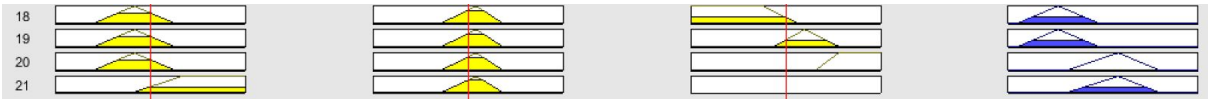
- IF Medium_Rice AND Medium_Time AND Short_Grain THEN Warm
- IF Medium_Rice AND Medium_Time AND Medium_Grain THEN Warm
- IF Large_Rice AND Medium_Time AND THEN Hot



Extract of Matlab simulation representing the rules being fired.

At the end of inference, we have 3 plots for the output variable. For example, the rule 18 give us one diagram where we applied a level cut on the fuzzy set “Warm_Temperature” at the level 0.33 (= minimum of the degree of memberships between fuzzy sets “Medium_Quantity”, “Medium_Time” and “Short_Grain”).

Composition :



Extract of Matlab simulation representing the rules being fired.

For the composition, we use the level-cut executed on the inference step. We keep the maximum degree of membership of the output fuzzy-sets 0.33 for Warm_Temperature ad 0.3 for Hot_Temperature. With our new shape, we have a degree of membership at 0.33, then 0.3.

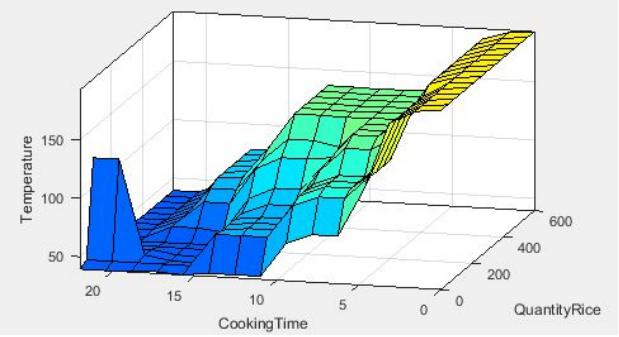
Representation of the composition giving the diagram for the output temperature.

Defuzzification :

We have selected the “centroid” method for defuzzification. In fact, that corresponds to the center of area under the curve. So, according our MATLAB simulation, we should apply a temperature of 109°C into the rice cooker.

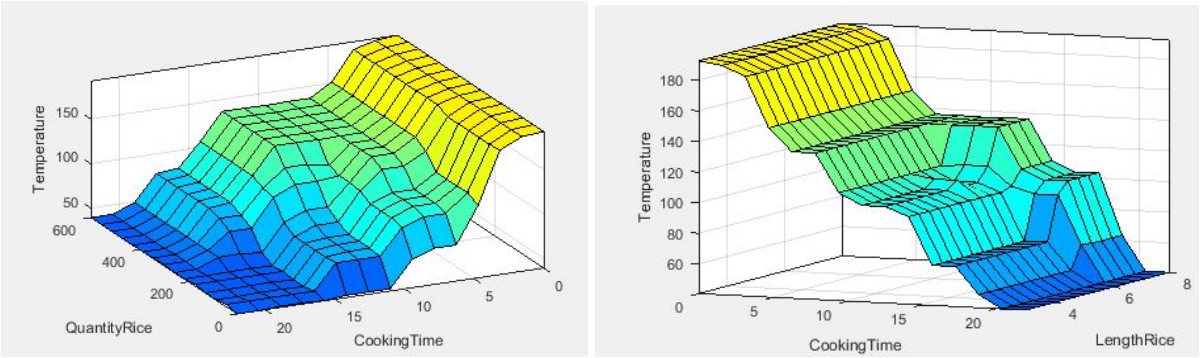
RESULTS / ANALYSIS

First time we launched a simulation, we could see a odd peak for a small quantity of rice and a very large time of cooking. In fact, we had forgotten to apply one rule :
IF Very_Long_Time AND Small_Rice THEN Medium_Temperature.



Extract of Matlab simulation representing an error.

Then for a Mandani inference with a centroid method for defuzzification, we could see:



Extract of Matlab simulation : it looks consistent.

CONCLUSION

The problem of rice cooker, with the input variables Length_Grain, Time_Elapsed, Quantity_Rice, is complicated. Fuzzy logic has been a good tool to simplify the problem of rice cooker. In our case, this system allows us to use the rice cooker with a lot of different configurations. For example, if you are cooking for two people a honey rice or for six people an ashoka rice, the fuzzy rice cooker will adapt automatically to give you the best cooking.

We have chosen to apply a Mandani inference rather than a Sugeno inference. Indeed, a Mandani describe the expertise in a more intuitive and human-like manner while a Sugeno is more efficient with control problems like a dynamic nonlinear systems.

APPENDIX

30 Fuzzy Rules :

IF Very_Short_Time THEN Very_Hot

IF Short_Time AND Very_Small_Rice AND Short_Grain THEN Warm
IF Short_Time AND Very_Small_Rice AND Medium_Grain THEN Warm
IF Short_Time AND Very_Small_Rice AND Long_Grain THEN Hot

IF Short_Time AND Small_Rice AND Short_Grain THEN Warm
IF Short_Time AND Small_Rice AND Medium_Grain THEN Hot
IF Short_Time AND Small_Rice AND Long_Grain THEN Hot
IF Short_Time AND (Medium_Rice OR Large_Rice) THEN Hot

IF Medium_Time AND Very_Small_Rice AND Short_Grain THEN Medium_Temperature
IF Medium_Time AND Very_Small_Rice AND Medium_Grain THEN Medium_Temperature
IF Medium_Time AND Very_Small_Rice AND Long_Grain THEN Warm
IF Long_Time AND Very_Small_Rice THEN Medium_Temperature
IF Very_Long_Time AND Very_Small_Rice THEN Medium_Temperature

IF Medium_Time AND Small_Rice AND Short_Grain THEN Medium_Temperature
IF Medium_Time AND Small_Rice AND Medium_Grain THEN Warm
IF Medium_Time AND Small_Rice AND Long_Grain THEN Warm

IF Medium_Time AND Medium_Rice AND Short_Grain THEN Warm
IF Medium_Time AND Medium_Rice AND Medium_Grain THEN Warm
IF Medium_Time AND Medium_Rice AND Long_Rice THEN Hot
IF Medium_Time AND Large_Rice THEN Hot

IF Long_Time AND Small_Rice THEN Medium_Temperature
IF Long_Time AND Medium_Rice THEN Medium_Temperature
IF Long_Time AND Large_Rice AND Short_Grain THEN Warm
IF Long_Time AND Large_Rice AND Medium_Grain THEN Warm
IF Long_Time AND Large_Rice AND Long_Rice THEN Hot

IF Very_Long_Time AND Small_Rice THEN Medium_Temperature
IF Very_Long_Time AND Medium_Rice THEN Medium_Temperature
IF Very_Long_Time AND Large_Rice THEN Medium_Temperature

Links :

https://en.wikipedia.org/wiki/Grain_quality → size of the grain
http://www.homecentricc.net/fuzzy-logic-rice-cookers/ → learn about 4 stages of cooking rice
http://riceofindia.com/non-basmati → example of Swastik rice

Distribution of work:

- Investigation.

- Creation of variables and linguistics terms.
- Rules evaluation.
- Membership functions of variables.
- Simulation on Matlab.
- Analysis of fuzzification, inference, composition and defuzzification thanks to an example.
- Writing the report.

It’s difficult to clearly define an owner for each part, because we have worked together in order to be sure that each proposed idea was correct.