Flirtation, a Very Fuzzy Prospect: a Flirtation Advisor

by

Matthew A. Martin
Sophomore, Merit Researcher

and

Jerry M. Mendel
Professor, Electrical Engineering

Signal and Image Processing Institute
Department of Electrical Engineering-Systems
University of Southern California
Los Angeles, CA 90089-2564

1995[1]

ABSTRACT

The purpose of this article is to educate high-schoolers of both sexes about fuzzy logic by giving them an example that they will be able to identify with. Our goal is to explain how fuzzy logic can be used by a person to determine whether or not someone is flirting with him/her.

To gather information about this process, college students (an equal number of whom were male and female) were interviewed. They were first asked to decide which actions are associated with flirtation and then to determine which combinations of these actions, in varying degrees, result in corresponding levels of flirtation. The results of these surveys showed that during a conversation, the top 4 actions associated with flirtation are: 1) Touching, 2) Acting witty or laughing at the other person's jokes, 3) Maintaining eye contact, and 4) Primping, adjusting one's outfit, and trying to look good.

A table was then formed, by filling in the blanks in sets of IF-THEN- rules, one example of which is: IF eye contact is *somewhat*, and touch is *a lot*, THEN there is a *pretty good amount* of flirtation. We show that some of the table's rules about levels of flirtation may conflict (i.e., give "mixed signals"), and how a decision can then be made about the overall flirtation level despite these mixed signals.

We conclude that fuzzy logic can be applied to emotion-based decision making processes, such as determining flirtation. Even when faced with mixed signals, the fuzzy logic system is effective in making a decision about the level of flirtation. The implication is that fuzzy logic may be a useful tool in psychology and sociology as well as in engineering. The value of the fuzzy logic system is its ability to make decisions in a way very much like a person, which is why fuzzy logic has a great advantage over other methods that deal with human problems.

I. INTRODUCTION

A. Overview

Flirtation is a very fuzzy thing. There are many different ways that people flirt. Some are rather obvious (they might come up and kiss you) and others might be very subtle (saying "hi" might be the most flirtatious thing they do). In-between these two extremes are thousands of other ways that people flirt. Sometimes people aren't flirting but are just being friendly, and other times they might be both flirting and being friendly. Figuring out if someone is flirting with you can be a difficult and very fuzzy thing to do.

For example, girls, if a cute guy looks you in the eyes and smiles, is he flirting, or just being friendly? And guys, if a good looking girl you know comes up and gives you a hug, is she flirting? What if she gives you a hug, but then goes on to hug your friends too? Is she flirting with you or not? These things can be hard to figure out, and many times you might be wrong. A person might be trying to flirt with you, but you think they are being friendly, or someone might only be trying to be your friend but you think that they are flirting. You know from experience that figuring out flirtation is not always an easy thing to do. Sometimes it is not obvious, and can be a very fuzzy thing to figure out.

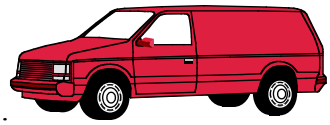
We do use some way of reasoning or some kind of logic to figure out whether someone is flirting with us or not. In this article we use a reasoning process called *fuzzy logic* to try to figure out flirtation. Right now you are probably wondering what in the world fuzzy logic is, what it could possibly have to do with flirting, and why you should have to read any kind of article with the word "fuzzy" in it. The entire and sole purpose of this article is to explain what fuzzy logic is to you in a fun way with examples that both guys and girls can relate to. Beyond that, it might teach you some things about the different ways guys and girls view flirting as well as how our minds might go about figuring out flirtation.

Flirting is something that can be very fuzzy and is something we all have some experience with. Believe it or not, it is a great example of how fuzzy logic works. By the end of this article you will understand: (1) some of the different things that guys and girls interpret to be flirtation; (2) what the difference is between fuzzy logic and normal (crisp) logic, and how fuzzy logic is used in flirtation; (3) how we describe things, like flirting, using items called fuzzy sets; (4) how a fuzzy logic system works to make decisions in a way similar to how people make decisions, even about whether or not someone is flirting with you; and, (5) how our brains work in fuzzy ways to understand things like flirtation and how you use fuzzy logic in everyday life.

Because fuzzy logic is new to you, the first part of this article explains the basics of what fuzzy logic is and how it works. It uses some simple examples to demonstrate the principles behind fuzzy logic. After you have read the introduction and understand the basics of fuzzy logic, you should move on to the next section, which shows how fuzzy logic can be used to help you figure out if you are being flirted with.

B. How Do People Describe Things?

Underneath the pictures of these cars, please write down whether or not the car is fast.

1. 

_____

2. 

_____

3. 

_____

While you might have written either "fast" or "not fast", you probably realized that none of the cars was as fast as an Indy car or a Lamborghini, and none of them were as slow as a bus or a go-cart. In fact, you probably thought to yourself more in terms of "that car looks very fast," or "that car looks like it's got about average speed," or "that one is really slow".

Depending on the topic, people usually do not group things such as cars, the weather, or someone's height into yes or no, true or false categories. Instead they use groups that vary in degrees between yes and no, fast or not fast, etc. For example, a weatherman rarely gives his report and says, "Today it is hot. Now back to Judy with the news." Instead he will use fuzzy terms such as, "Today is **very** hot. Tomorrow things should cool off **a bit** and the skies will be **partly** cloudy with a **light** breeze." Notice that these highlighted terms, while they are much more fuzzy than numbers, can convey just as much or more information than numerical data. We don't go outside and think to ourselves "There seems to be about 33.675% cloud cover today." Instead we think that it is **partly** cloudy. There are many more examples of how we use such terms as "a little, some, very, a pretty good amount, a lot", and a host of other words in conversation every day, but the point is that these fuzzy terms are used all the time and in many cases are more informative than actual numbers.

C. How Does a Computer Describe Things?

Computers operate on a very different level than people do. Rather than using any sort of fuzzy terms to describe things, a computer makes a clear separation between groups of objects. In the basic language of computers, every signal is either a zero or a one—there is nothing in-between. The computer would classify the cars as being either "fast" or "not fast", depending on whether or not the car could exceed a certain speed. If the computer's rule was "If a car can travel faster than 120 mph, then it is fast", and car 2 could only go 119 mph, the computer would label it as "not fast". We know that car 2 is actually pretty fast, but the computer can make no distinction, and puts the car that can go 119 mph into the same category as a car that can only go 10 mph. In this example the computer separates all cars into one of two groups (this is known as crisp logic, where everything is either true or false), but people put cars into several groups, and sometimes we put one car into more than one group at a time.

D. Fuzzy Sets

A *fuzzy set* is a collection (i.e., a group) of objects along with a description, called a *membership function*, of how much each member of the group belongs in the collection. Using the example of the cars from Subsection B, we decided that a car wasn't just fast or not fast, but that there were different levels in-between these two extremes of how fast a car is. These different levels make up fuzzy sets. For example, Fig. 1 shows membership functions for three different fuzzy sets, *slow, average,* and *fast*. These sets and their associated membership functions describe the degree of similarity of a car to one that is slow, average, or fast.

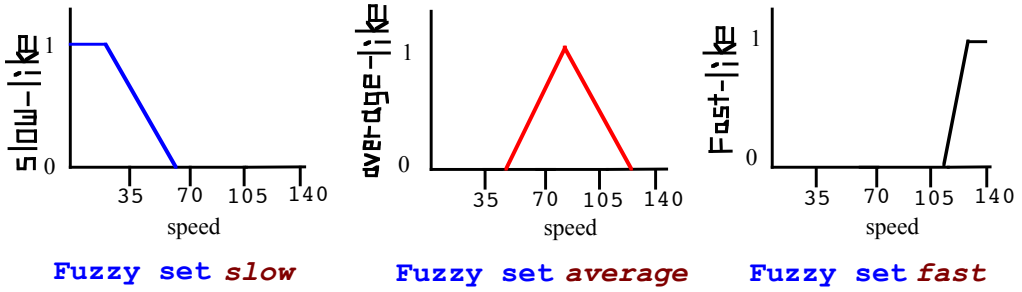


Figure 1. Different fuzzy sets for cars, based on the speed of the car. The horizontal axis displays different speeds in miles per hour, and the vertical axis displays membership values ranging from zero to one (unity). The membership function associates the speeds in each set with a membership value. The closer the membership value is to unity the more slow-like, average-like, or fast-like is your car; whereas, the closer the membership function is to zero the less slow-like, average-like, or fast-like is your car.

A membership value for a car describes how much the car belongs in that set and can vary from a membership value of zero (meaning it does not belong there at all) to a membership value of one, or unity (meaning that it completely belongs in that fuzzy set, and is described perfectly by that set). The value of membership a car has in any of these sets is determined by the car's speed. For example, (see Fig. 2) a car that has a top speed of 20 mph has a membership value of 1.0 in the set *slow.* A car with a top speed of 35 mph has a membership value of 0.7 in the set *slow,* and a car with a top speed of 119 mph has a membership value of 0.0 in the set *slow*, because it does not belong in this set at all.

An interesting thing about fuzzy sets is that an item, such as a car, can be in more than one fuzzy set at the same time. In traditional "crisp" sets, either an object is in the set (has a membership value of 1.0) or is out of the set (has a membership value of 0.0). With crisp sets no object can be kind of in one set and kind of in another. With fuzzy sets, this is no longer true. When the membership functions for the three different fuzzy sets *slow*, *average*, and *fast* are all put on the same axis (which is a measure of speed), as in Fig. 3, you can see that the sets overlap. If a car's top speed is between 48 and 60 mph, the car is described to some extent by both sets *slow* and *average.* Similarly, if a car's top speed is between 110 and 125 mph it is in the set *average* to some degree and in the set *fast* to some other degree.

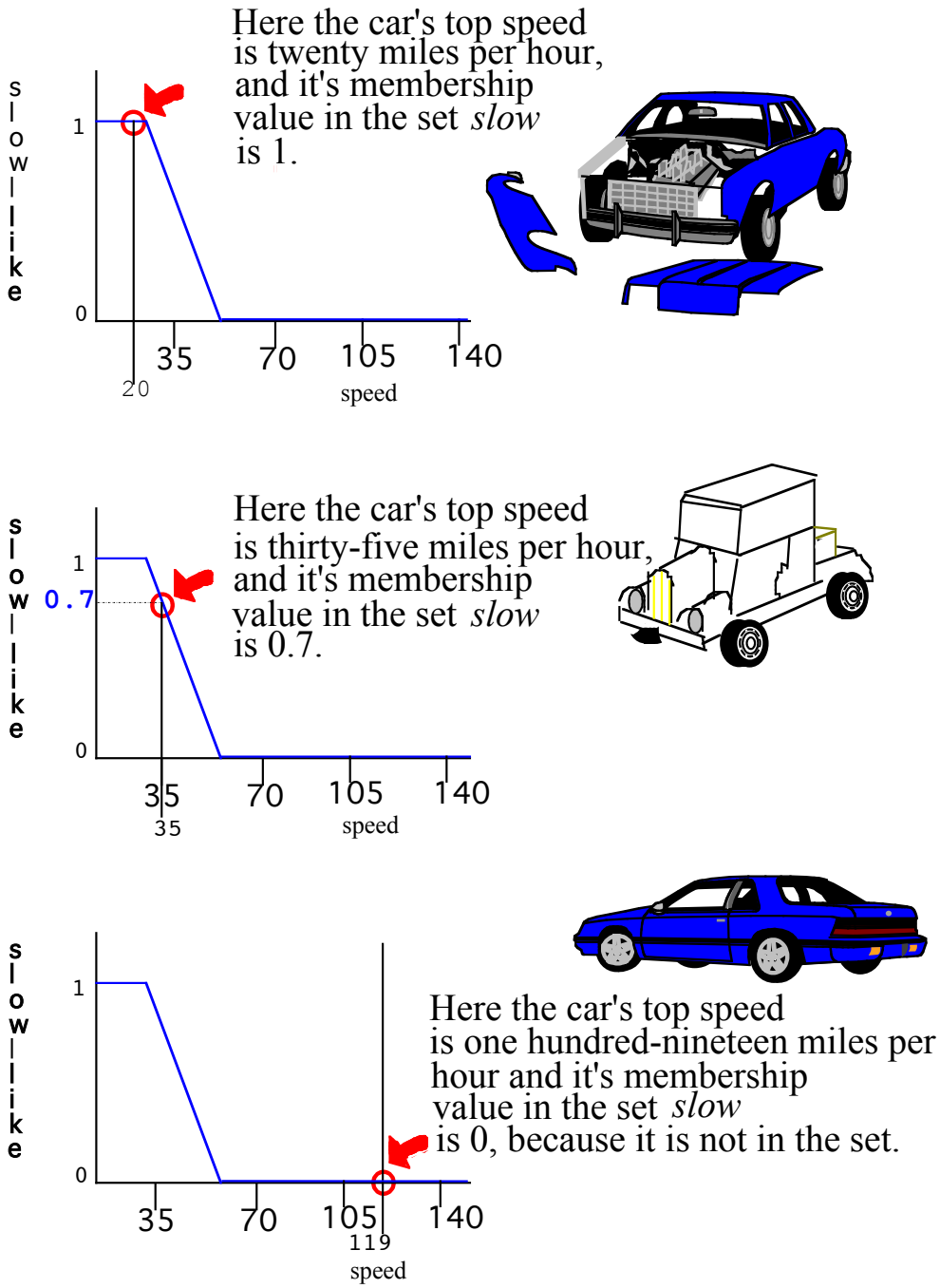


Figure 2. Membership values in the set *slow*.

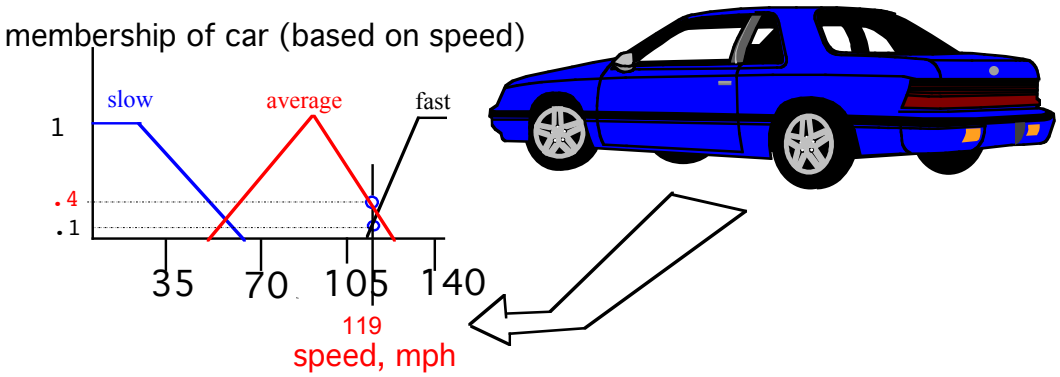


Figure 3. Fuzzy sets *slow, average,* and *fast*. Car 2 has membership values in the fuzzy sets *average* and *fast*.

Notice that car 2, whose top speed is 119 mph, is described simultaneously by the fuzzy sets *average* and *fast* (Fig. 3). As you can see, car 2 has a membership value of 0.4 in the set *average.* Because this value is less than 1, the car is not a perfect example of an average-speed car, but it still belongs in the set *average*. The car also has a membership of 0.1 in the set *fast*. This means the car also belongs to the group of fast cars, but not very strongly, because most fast cars have much higher top speeds than car 2 has. Car 2 has a membership value of 0.0 in the fuzzy set *slow*, because it does not belong in that set at all. (Note: The testing of the top speed of car 2 was done by a professional driver on a closed track. DO NOT try this at home.)

Because car 2 is in two sets, a choice has to be made about how to finally characterize it. In conversation, we usually don't refer to a car like car 2 as "40% average and 10% fast". Instead, we compare in our minds how much the car belongs in the *average* set and how much it belongs in the *fast* set. We don't use any numbers for this comparison; but, we do have some measure (i.e., gut feel) in our minds of how much the car belongs in each set. In this case, we decide car 2 belongs more in the *average* set than in the *fast* set. We realize that the car isn't only average or only fast, so we probably describe it as an "above-average-speed car" (Fig.4).

If we compare the two membership values given for the car in this example, the 0.4 membership value in the *average* set is bigger than the 0.1 membership value in the *fast* set. If we decide that the car is described more by the set with the bigger membership number, we arrive at the same conclusion just reached. Since car 2 is mostly average and slightly fast, car 2 is an "above average-speed car". Membership values can therefore be used to reach conclusions that are similar to the conclusions we make without ever considering numbers. This procedure can be implemented by computers because they deal with numbers.

The main things to remember about fuzzy sets are:

1. Their membership functions indicate how much an item (object, idea, feeling, etc.) belongs in the sets.
2. Membership values range from 0 to 1 and provide a degree of similarity of an item to the fuzzy set.
3. Items can belong in more than one fuzzy set at the same time.

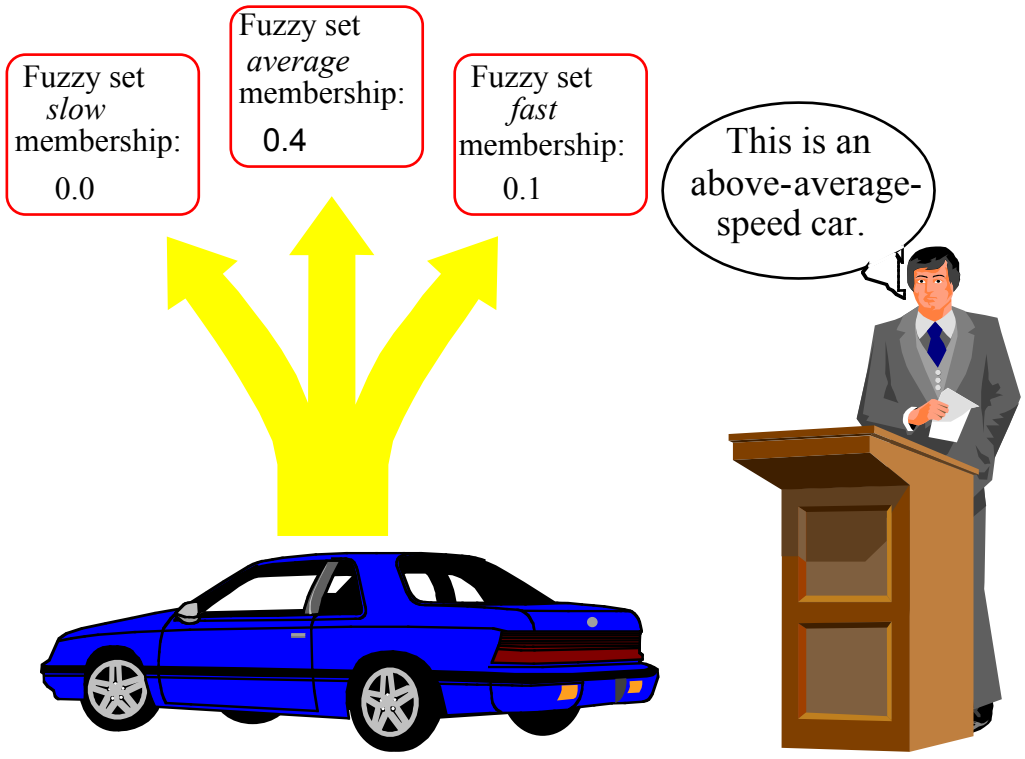


Figure 4. Different fuzzy membership values for car 2, and how we would describe that car.

E. Fuzzy Logic and a Fuzzy Logic System

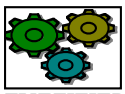
The reason that fuzzy sets are important is that people associate items with them all the time without even thinking about it. We use these sets to figure out what's going on around us, and then how to respond. Because of our ability to do this, we can do things that a computer could never do, like decide: what to wear to school that day, when it's safe to pass a car, or even whether or not we are being flirted with.

Fuzzy logic is a process that tries to simulate the "fuzzy" decision making of a person, by using fuzzy sets. When fuzzy logic is programmed into a computer and a fuzzy logic system is established, the computer can accept information and deal with it in a more human-like, "fuzzy" way.

Why would we want a computer to work in this way? There already are computer programs, which don't use fuzzy logic, that are designed to deal with fuzzy problems. These programs often use a huge number of rules and computations to model and then solve a problem, but don't always do a great job. Fuzzy logic often only requires a small number of fuzzy sets and a small collection of simple rules to solve the same problem. In fact, when dealing with a fuzzy problem, computers that operate using fuzzy logic often perform tasks more quickly, efficiently, and in many cases better than normal computers which use traditional crisp logic.

An example which illustrates the difference between fuzzy and crisp logic is the way in which a computer controls an air conditioner. The normal crisp-logic computer has a sensor that measures the temperature, after which this number is fed into a computer that has some built-in logical rules under which it operates. For example, if the temperature is between 70 and 78 degrees Fahrenheit, the computer turns the air conditioner on to 50% of its maximum setting; if the temperature is between 78^{o} and 84^{o} the computer turns the air conditioner on to 75% of its maximum setting; if the temperature is above 84^{o} it turns the air conditioner on full blast; or, if the temperature is below 70^{o}, the computer turns the air conditioner off. As a result, when the temperature gets right around 70^{o} you can hear the air conditioner clicking on and off as the temperature goes above and then below 70 degrees.

A computer with a fuzzy logic system works differently. A fuzzy logic system has three main components:



FUZZIFIER 1. A fuzzifier, that takes in numbers (in this case the temperature) and transforms them into fuzzy sets;

LOGIC CONTROL CENTER 2. A logic control center that uses rules, which are activated by fuzzy sets, and, produces fuzzy sets at its output; and,

DEFUZZIFIER 3. A defuzzifier, that takes the fuzzy output sets and transforms them back into numbers that indicate what action should take place, or decision should be made.

Our simple fuzzy air conditioner is governed by two basic rules (real air conditioners would probably be governed by more than two rules), which use the two fuzzy input sets *cold* and *hot.* These fuzzy sets describe the temperature, and are shown in Fig.5. The rules are associated with two fuzzy output sets, *high* and *off* which describe the settings for the air conditioner, and are shown in Fig. 6.

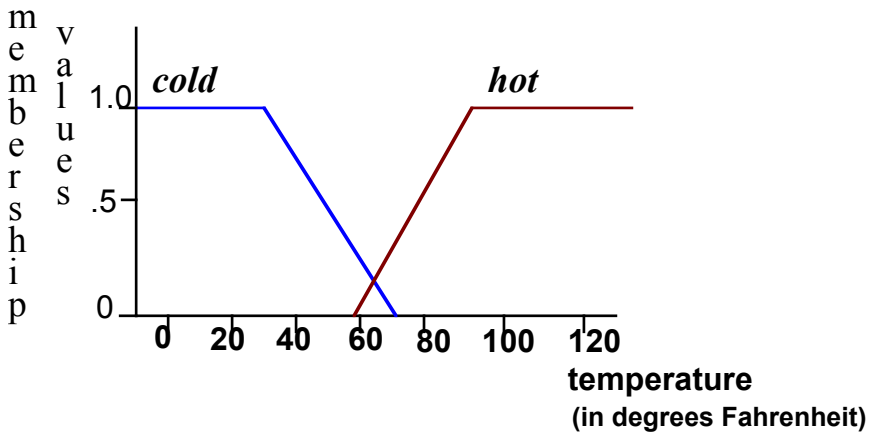


Figure 5. The fuzzy sets *cold* and *hot* that describe temperature.

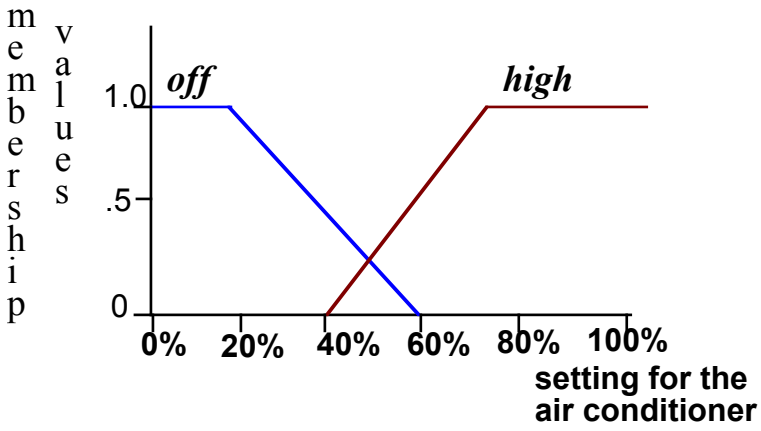


Figure 6. The fuzzy sets *off* and *high* that describe settings for the air conditioner.

Let's consider a specific example, when the fuzzy computer's temperature sensor indicates that the temperature is 82^{o}. In this case, the fuzzifier transforms 82^{o} into the fuzzy set *hot*, with a membership value of 0.8, and into the fuzzy set *cold*, with a membership value of 0.0 [Fig. 7 (a)]. At this point the logic control center uses it's rules, starting with Rule 1: "**IF** the temperature is *hot*, **THEN** the air conditioner should be turned on *high*". The membership value of 0.8 for *hot* multiplies, or "scales" the height of the membership function of the fuzzy output set *high*, so this rule produces the output fuzzy set *high*, with a maximum height of 0.8 [Fig. 7 (b)]. Next Rule 2 is used: "**IF** the temperature is *cold*, **THEN** the air conditioner should be turned *off*". This produces the fuzzy output set *off* [Fig. 7 (b)]. Because the membership value in *cold* is 0.0, the entire membership function for the fuzzy set *off* is 0 (multiply zero by the membership function for *off*). This means that Rule 2 is not activated; only Rule 1 is activated. At lower temperatures, both rules may be activated, or only Rule 2 may be activated.

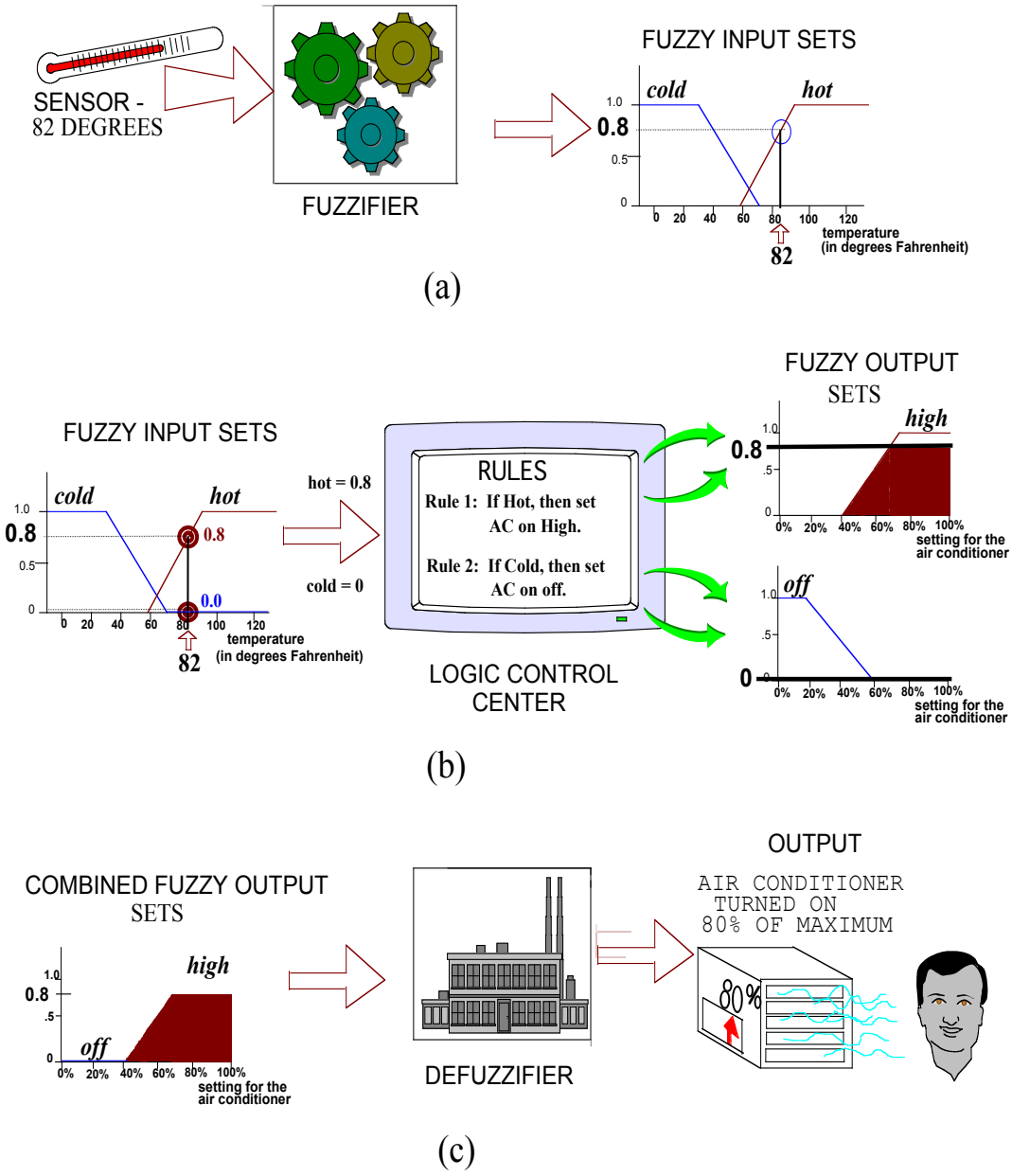


Figure 7. A fuzzy logic system controlled air conditioner. (a) The temperature 82^{o} is fuzzified into the fuzzy sets *cold* and *hot*; (b) rules are used to produce scaled output sets *high* and *off*; and, (c) the output sets are defuzzified to determine that the setting for the air conditioner should be 80% of the maximum setting.

The output fuzzy sets from the two rules are then combined. This is done by scanning along the axis labeled "setting for the air conditioner" and keeping the largest values of the output sets *off* and *high* that resulted from the two individual rules. In this case, when scanning from 0% to 40% on the graphs [Fig.7 (b)] of the fuzzy output sets *off* and *high*, the maximum height is zero. Then from 40% to 100%, the value for the output set *high* rises and then levels off at a maximum height of 0.8, while the entire fuzzy set *cold* has a maximum height of 0.0; therefore, the combined fuzzy sets [Fig.7 (c)] look like the fuzzy output set *high*. Finally, the defuzzifier uses a mathematical formula to transform the combined fuzzy output set back into a number—80%—

which commands the computer to turn the air conditioner on 80% of its maximum setting. As the temperature cools down, the logic part of the computer uses its rules and gradually turns the air conditioner down.

As you can see, the fuzzy logic controlled computer does a smoother job of controlling the air conditioner than the crisp logic controlled AC; it also maintains the desired temperature more effectively and can save money in electric bills. For the crisp logic computer to be able to do anywhere near as smooth a job as the fuzzy computer, it would require more than seventeen rules, because a rule would be needed to describe what setting to turn the air conditioner to for every single temperature between 70^{o} and 84^{o}, and rules would be needed to describe what to do when the temperature is below 70^{o} and above 84^{o}. Our simple fuzzy logic computer only had to use two rules (a more realistic fuzzy logic computer would need a few more rules), compared to at least 17 required for the crisp logic computer. It is clear that in this case fuzzy logic is a much better method to use.

Of course, the job of turning an air conditioner to the right setting is fairly simple. Usually, as a job gets more complex, fuzzy logic has more and more of an advantage over crisp logic. The more fuzzy and complex a job becomes, like controlling an airplane or deciding what car to buy, the more rules are required to deal with the problem. Fuzzy logic systems need far fewer rules than crisp logic systems, and in many cases do a better job of dealing with the problem. That is one of the main reasons why fuzzy logic is so useful.

Another one of the advantages of fuzzy logic is that we can use rules, obtained from people, just like you, who know about a subject and what the rules should be, to create a fuzzy logic system that can deal with problems in a way just like we would. As you will see later, the rules we use are not set in concrete, i.e., we can choose different rules, and can change them if they don't work or as we become smarter.

II. FLIRTATION—A VERY FUZZY PROCESS

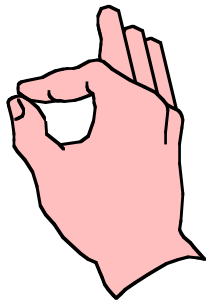
A. Overview

Depending on how someone acts, it can be very difficult to tell whether or not they are flirting with you (unless they say something like "Hey baby! Check you out, you are FANTASTIC!"). Some people are always very friendly and may not necessarily be flirting with you. Sometimes someone may be a little flirtatious and friendly at the same time. Usually when you talk to someone there is not always a clear distinction that they either are or are not flirting; instead, they might just be friendly, or kind of flirting, or both.

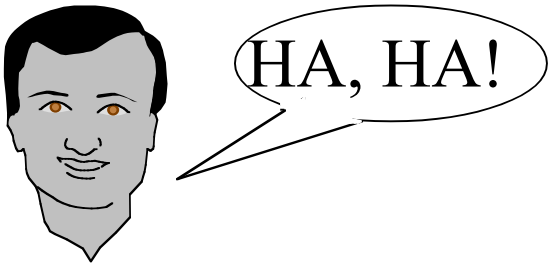
It would be pretty easy to tell how much someone was flirting with you if flirtation only depended on one thing. In the example of the cars, all we had to know was the top speed of the car and then we could decide what fuzzy set or sets the car belonged in. The car could either be *slow, average*, or *fast*, or, might even be a combination like car 2 (it was in both the *average* and *fast* sets). With flirting, there is no one indicator, like top speed, that absolutely determines the level of flirtation, but instead there are many things a person can do which we may interpret as being flirtatious.

To find out the main things people do in conversation that are flirtatious, six male and six female college students were interviewed and asked to name the top four things that they considered to be indications of flirtation (besides things such as pick-up lines). Based on their responses, the top four indicators of flirtation are:

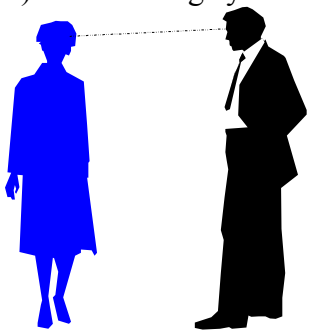
1) Touching



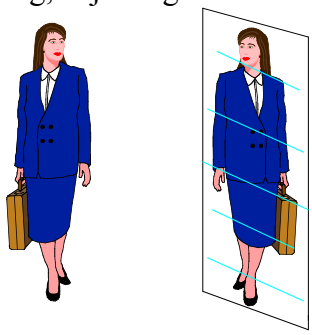
2) Acting witty or laughing at the other person's jokes



3) Maintaining eye contact



4) Primping, adjusting one's outfit, or trying to look good



For *guys*, the top four indicators of flirtation are: (1) touching, (2) acting witty, laughing at jokes, (3) maintaining eye contact, and (4) primping. For *girls* the top four indicators of flirtation are: (1) touching, (2) acting witty, laughing at jokes, (3) and (4) (tie between) primping, trying to look good, (and) maintaining eye contact.

The guys' and the girls' responses looked very similar. Based on these results it seems that they agree on **which** actions can indicate flirtation. Later on when students were asked to help determine IF-THEN rules, it became apparent that guys and girls did not necessarily agree on **how** these actions are interpreted to decide if someone was actually flirting with them. This will be discussed later in the article.

Now it is clear that these four indicators of flirtation are pretty fuzzy. Consider touching, for example. There are many different types (levels) of touching. If someone shakes your hand you might think of that as not being very much touch (as far as flirtation is concerned), but if they hug you and give you a kiss you would think of that as a lot of touch. So, there are many different levels of touch, and the levels aren't always clearly distinguished from one another. The hug you get from someone could range from being hardly any touch to a lot of touch, depending on what kind of hug you got. The other indicators of flirtation—eye contact, acting witty, and primping—are also pretty fuzzy, each with many different levels. To keep things manageable, we assigned five levels to each of the four indicators of flirtation.

When we interact with someone, we observe their actions, and then decide how "touchy-feely" they are, how much eye-contact we have with them, whether they are trying to make us laugh or are laughing at our jokes, and whether they are trying to look nice. All of these things are sort of fuzzy, but they are all things that we can sense and that we somehow use to determine whether or not we are being flirted with. Whether we think about it or not, our brain somehow uses these different fuzzy inputs and decides if we are or are not being flirted with, and how much.

As mentioned before, fuzzy logic begins with fuzzy inputs and uses IF-THEN rules to decide what the fuzzy output is. In this case the fuzzy inputs are the level of touch, eye contact, acting witty, and primping. The output is the level of flirtation.

Several college students were asked to help the authors establish the IF-THEN rules for flirtation. For example, these students were asked, **If** "When you meet somebody, there is *a bit* of touch, and *a lot* of eye contact, **then** the level of flirtation would be what?". The students could have been asked to decide the level of flirtation based on all four different actions (touching, eye contact, acting witty, and primping), but dealing with four indicators is difficult because it would require 5x5x5x5 = 625 rules. To keep things more manageable, the students were asked to determine the flirtation based on just two of these indicators at a time, for which we only need 5x5 = 25 rules.

Our first group of two indicators included *touching* and *maintaining eye contact*, and a second group included *acting witty* and *primping*. Every possible combination of touching and eye contact, as well as acting witty and primping, was explored until 25 IF- THEN rules were determined for each of the two groups. Then a summary table was created, from which we could determine, for example, that if touching was *a bit*, and eye-contact was *a lot*, then the result is a

pretty good amount of flirtation. In this article, we present results and illustrate examples for only the 25 rules associated with touching and maintaining eye contact.

Our table of rules provides enough information to program a computer, using the mathematics of fuzzy logic. The computer can: accept inputs about touch and eye contact (or acting witty and primping), fuzzify the information, use the IF-THEN rules, and defuzzify the output to indicate how much flirtation is occurring.

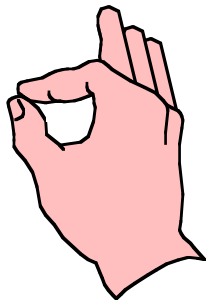
B. Using a Survey to Determine Indicators of Flirtation

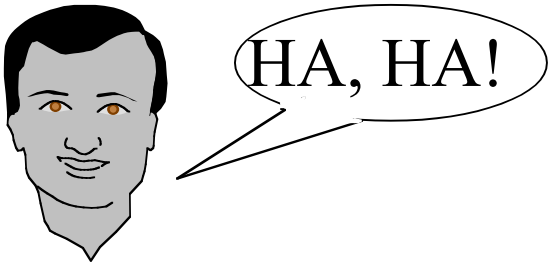
As mentioned above, it is very important to understand what actions imply flirtation if you are ever going to determine if you are being flirted with. To get an understanding of which actions people associate with flirting, six college guys and six college girls filled out a survey, in which they were asked to name the top four actions which imply flirtation. We would like you to take the survey too. Here it is:

> Which four of the following indicators, that a person could display during a conversation with you, do you most associate with flirting? Please rank them in order from most flirtatious (1) to least flirtatious (4).
>
> #_____ acting witty, laughing at your jokes
>
> #_____ complimenting
>
> #_____ maintaining eye contact
>
> #_____ primping, fixing hair or outfit, trying to look good
>
> #_____ smiling
>
> #_____ touching
>
> Based on your own experience, are there other things a person may do in conversation to indicate that they are flirting? If so, add them to our list, and indicate their ranking in relation to our 6 indicators.
>
> _____
>
> _____
>
> _____

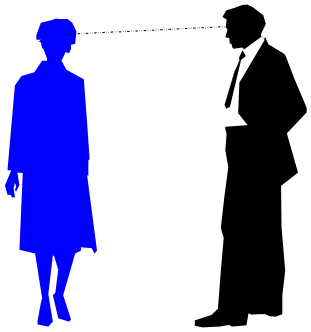
Now that you have taken the survey, compare your top four indicators of flirtation with some of your friends' top four indicators and see whether or not you all picked the same things. After that, compare your results to the overall results of our twelve college students. Recall that their top four indicators of flirtation are:

1) Touching 2) Acting witty or laughing at the other person's jokes

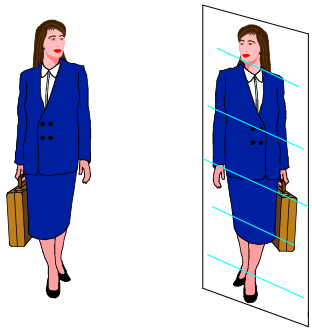




3) Maintaining eye contact



4) Primping, adjusting one's outfit, or trying to look good



You probably found out that your results are not the same as everybody else's. In fact, the results can vary significantly from person to person. The top four flirtation indicators mentioned above are the overall average top four. The actual individual responses varied a lot. For this article we are going to stick with the above top-four list.

C. Establishing Fuzzy Sets

When we interact with someone in everyday life we notice the amount of touching, eye contact, acting witty, and primping that goes on, and then we are able to decide how much we are being flirted with, or if we are being flirted with at all. The way we use our sense of these four indicators to decide whether or not we are being flirted with is very similar to the way the computer of the fuzzy-controlled air conditioner (Fig.7) used temperature as an indicator to decide how it should control the air conditioner.

The fuzzy air conditioner took the measured temperature (in the example it was 82^{o}) and established its degree of similarity to the fuzzy sets *cold* and *hot*. It then used it's rules to come up with scaled fuzzy output sets *high* and *off* (which described which setting to turn the air conditioner to). It combined these sets, after which it defuzzified the combined set to finally decide what setting to put the air conditioner on (in this case, it was 80% of the maximum setting).

With flirtation we use the amount of touching, for example, rather than temperature, as an indicator. When we meet someone and they give us a hug, we sense how much touching that hug

represents. We can take the action we observe (in this case a hug) and rank it on a scale of touching that ranges from zero to ten, where zero means absolutely no touch occurred and ten means a maximum amount of touching occurred (Fig. 8).

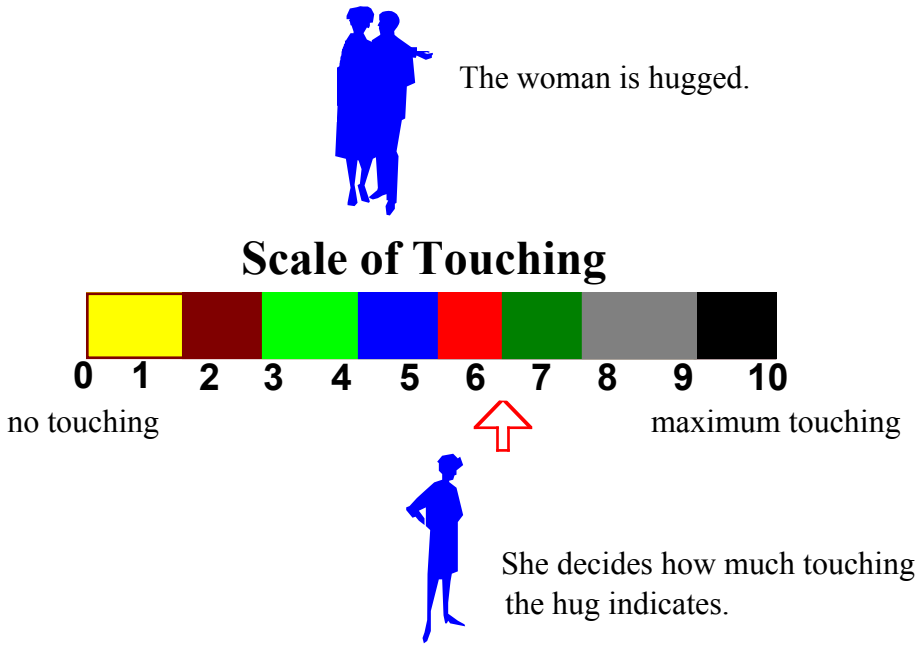


Figure 8. The scale of touching. A person can use this scale to indicate the amount of touching they sensed from whatever action they encountered (hug, squeeze, kiss, etc.). In this example, a woman is hugged and uses an arrow to indicate where the hug fit in between no touching and maximum touching on the scale. The location of the arrow can be translated into a number. Here the arrow indicates that the hug was a 6.4 out of 10 on the scale of relative touching.

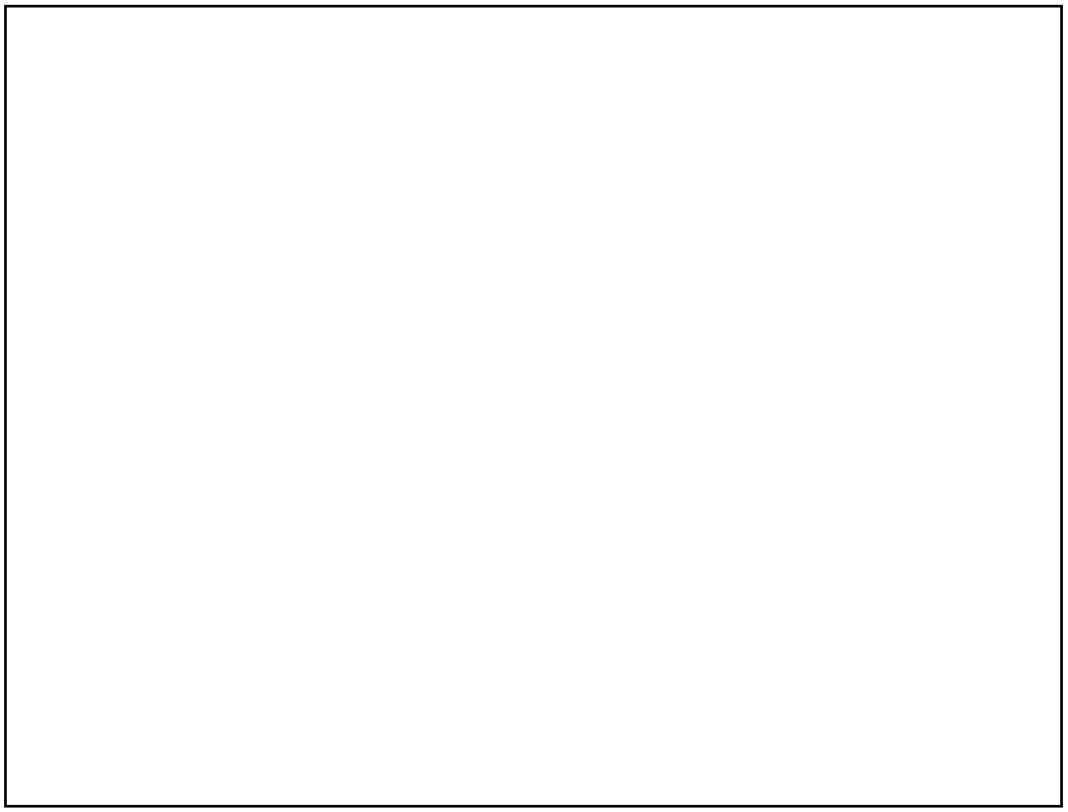
There are lots of different kinds of hugs. A really intense hug could rank close to a 10, and a very weak hug could rank close to a 2. The person who is hugged is the one who senses how much touching is going on, and uses the scale of touching to rank that particular hug. Every type of touch (e.g., hug, kiss, handshake, etc.) can range from 0 to 10 on the scale.

In the case of temperature, 82^{o} was fuzzified into *cold* and *hot.* Notice that, whereas temperature was described by the fuzzy sets *cold* and *hot*, it could have been described by many more fuzzy sets ranging from cold, cool, OK, lukewarm, and hot, to scalding hot. Touching is just as fuzzy, if not more fuzzy than temperature and can be described by many different fuzzy sets.

Think of all the different kinds of touching (handshakes, pats on the back, hugs, kisses, massages, etc.) and all the different rankings they could have on the scale of touching. What kind of fuzzy sets would you use to describe touching? *Light* and *Hard*? *Cold* and *Friendly*? Maybe you would need more sets to describe the wide range of touching, e.g., J*ust A Very Tiny Bit, A Little Bit, Light, Average, Some, A Large Amount,* and *Muchos Grande.* An example of fuzzy sets for touching is shown in Fig. 9. In the example, a hug that ranked a 6.4 on the scale of touching is described by the sets *casual* and *romantic.*

It makes sense to describe touching by using fuzzy sets. If someone of the opposite sex gives you a hug you might wonder if that example of touching was *friendly* or *romantic*, or a little bit of both. When using fuzzy logic there are no pre-existing fuzzy sets that you must use. Instead, *you* get to decide what the fuzzy sets should be. The better the sets you pick, the better your fuzzy logic system will work.

Take a minute to think about what kinds of fuzzy sets best describe touching to you, and draw your fuzzy sets (on a scale of touching from zero to ten) in the box below. Remember, with fuzzy sets, kinds of touching (like hugs, for example) usually fall into more than one set, so your sets should overlap, like the example in Fig. 9.



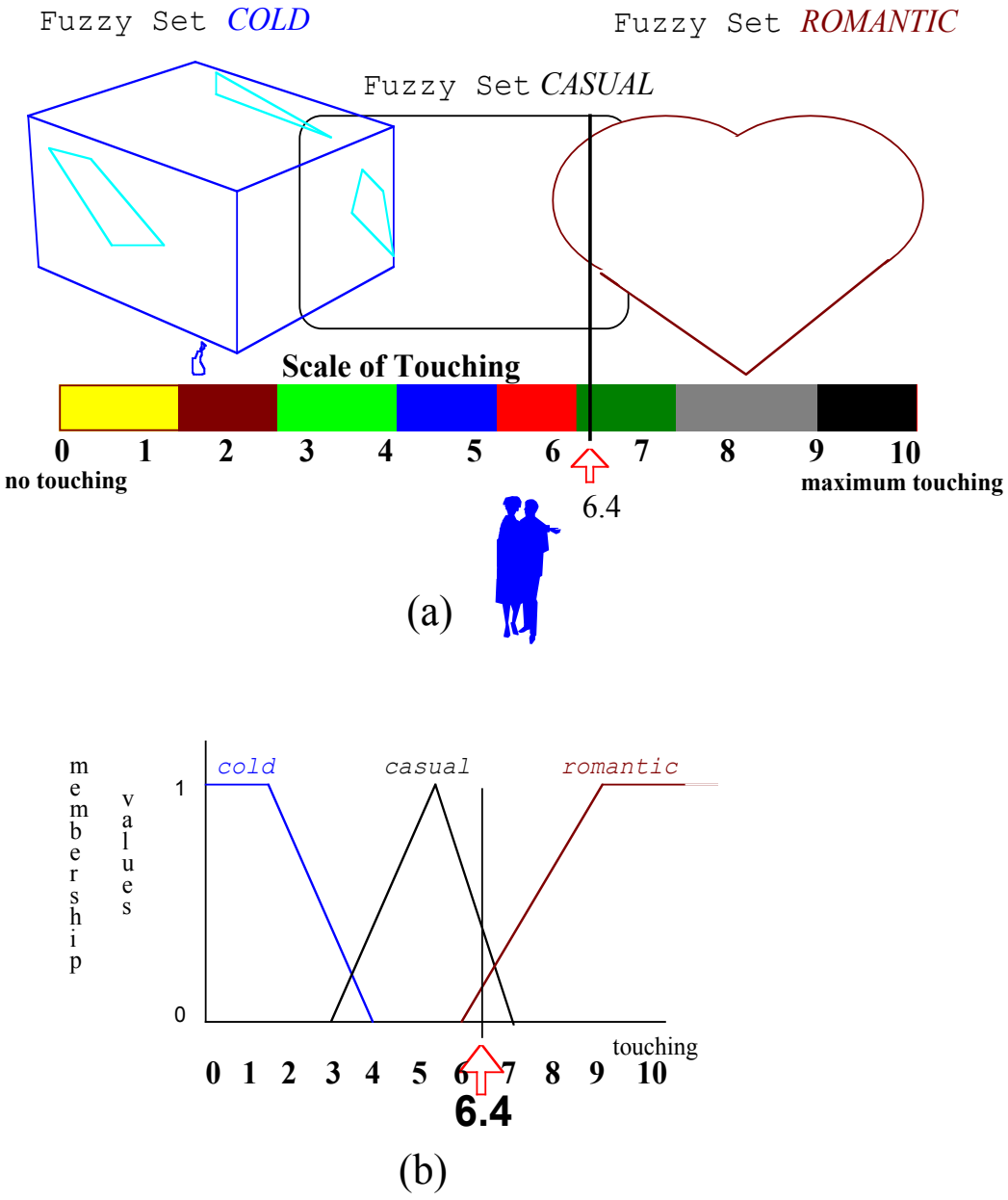


Figure 9. Examples of fuzzy sets that describe touching. In (a), some kinds of touching, like a hug that ranks a 6.4, can be in more than one fuzzy set at the same time. Another way to represent the sets is with a graph like the one in (b).

The five fuzzy sets we chose to describe touching are:

Not At All, Hardly, A Bit, Pretty Good Amount, and *A Lot*.

These terms are abbreviated as: *NAA, H, AB, PGA,* and *AL*.

To keep things uniform, these same fuzzy sets are also used by us to describe all of the flirtation indicators, including maintaining eye contact, acting witty, and primping or trying to look good. Although the names of the sets *NAA, H, AB, PGA,* and *AL* are the same for each indicator of flirtation, what is meant by *A LOT* of touching is different than what is meant by *A LOT* of maintaining eye contact. The meanings of the sets depends on which flirtation indicator we are referring to. To make this clear, graphs of the fuzzy sets for touching and for maintaining eye contact are shown in Figs. 10 and 11, respectively.

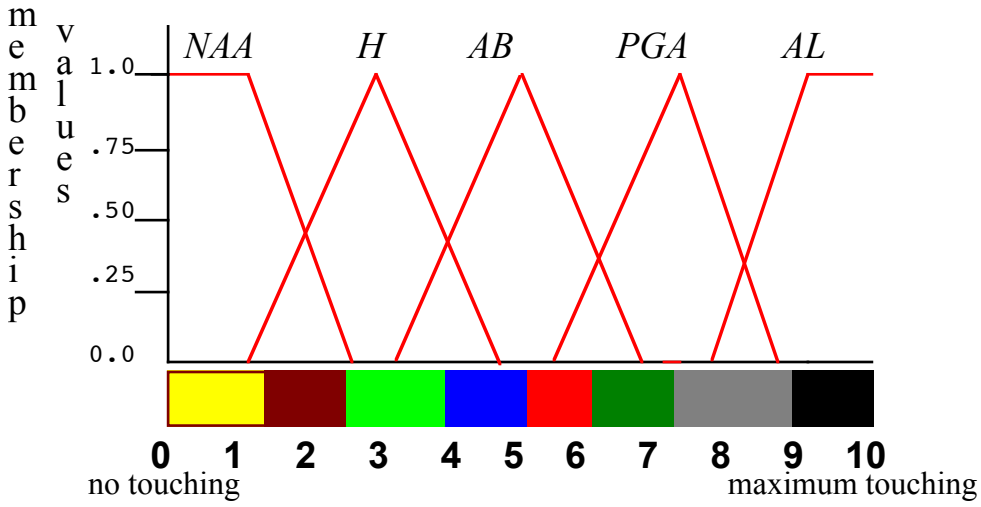


Figure 10. The fuzzy sets that describe touching. Some of the different kinds of actions that range between *No Touching At All* and *A Lot Of Touching* include: no touch, handshakes, high fives, hugs, tickling or teasing, kisses, massages, etc.

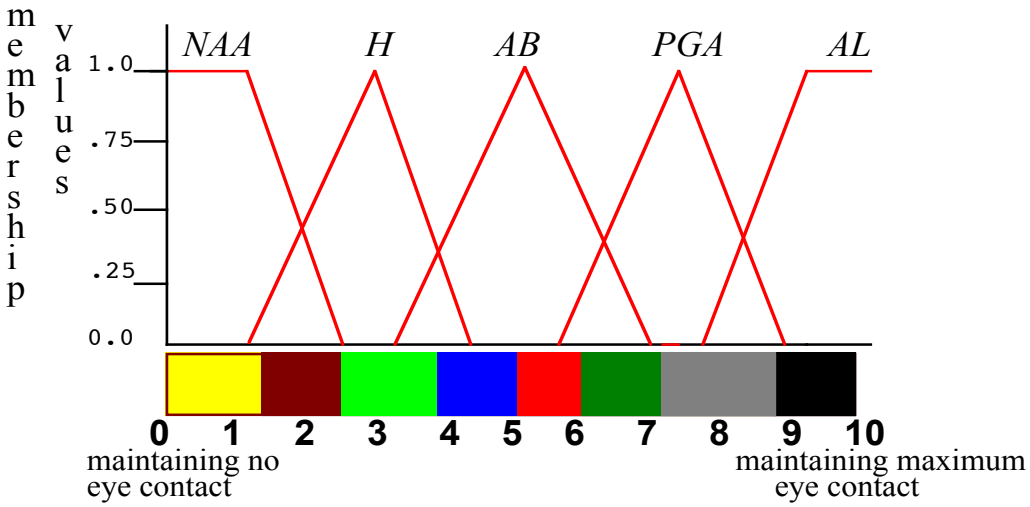


Figure 11. The fuzzy sets that describe maintaining eye contact. Some of the different kinds of actions that range between *Maintaining No Eye Contact* and *Maintaining A Lot Of Eye Contact* include: no eye contact, the person never or hardly ever looks you in the eyes, there is some eye contact occurring about half the time, there is quite a bit of eye contact occurring more than half of the time, the person never takes his/her eyes off of you, etc.

As you can see, the fuzzy sets overlap, and different kinds of touching or maintaining eye contact can often be in more than one set. Figures 10 and 11 show the membership functions for the sets, all on the same axis. Notice that the numbers on the horizontal axis of the sets are based on a 0 to 10 scale for touching and maintaining eye contact. Previously, the fuzzy sets you have seen were based on speed or temperature, which are things that can be *measured* numerically (with units of mph or degrees Fahrenheit). While actions like hugs or kisses aren't measured with numbers, they certainly can be *sensed* by you. When you talk with someone you can definitely sense how touchy-feely the person is or how much eye contact is maintained. You don't necessarily think in terms of numbers when you sense these things, but you have a good idea of where the touching you sensed fits in between no touching and maximum touching. Instead of numbers, you might use fuzzy descriptions to provide a sense of the action, e.g., "there was a lot of touching". This is why a scale of 0 to 10 touching is used on the horizontal axis of the graph. After you locate where the touching you sensed fits on the scale between no touch and maximum touch, that location can be converted to a number, like a six out of ten. This is important because computers deal with numbers and not sensations.

We have now established the fuzzy sets which describe Touching and Maintaining Eye Contact. They provide us with a fuzzy but accurate sense of these flirtation indicators. When you meet someone and sense how much they are touching, maintaining eye contact, etc., you then decide how much they are flirting with you, and this can be a very fuzzy process. Rather than deciding they are not flirting with you, or they are flirting with you, you might decide they were flirting a little bit, some, or a lot. Therefore, fuzzy sets are also needed to describe levels of flirtation.

In the case of the fuzzy air conditioner, the fuzzy sets *hot* and *cold* are its inputs and the fuzzy sets *high* and *off* are its outputs. In the case of flirting, our input sets are *NAA, H, AB, PGA*, and *AL,* which describe touching and maintaining eye contact, and we need to decide on output sets that describe how much flirtation is occurring. Once again, it's up to us to establish the fuzzy sets that describe flirtation. To keep things simple, the fuzzy sets used to describe flirtation in this article are the same ones used for the indicators of flirtation, namely *NAA, H, AB, PGA,* and *AL* (see Fig. 12).

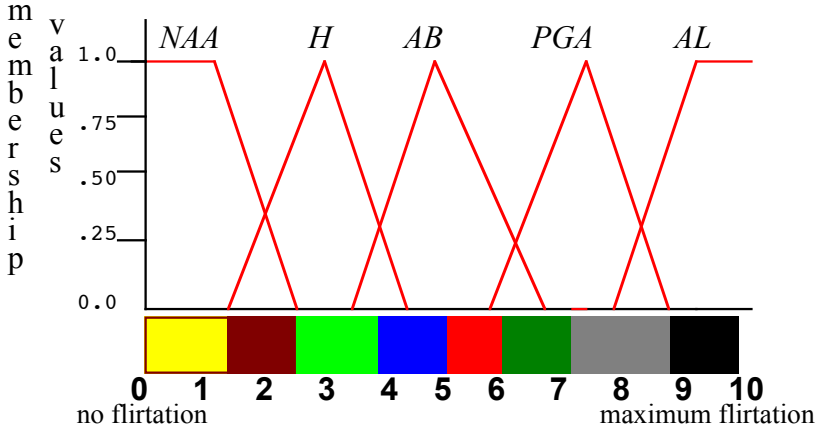


Figure 12. The fuzzy sets that describe flirtation.

D. Establishing Rules For The Fuzzy Logic System

Now that the top-four indicators of flirtation and the fuzzy sets describing them, have been determined, our next step is to figure out how to *interpret* these fuzzy measurements to decide how much flirtation is occurring. A fuzzy logic system (Fig. 7) uses *rules* to do this. Just like fuzzy sets, the rules of a fuzzy logic system are established by the person who designs the system, or are obtained from other experts. The most important part of the fuzzy logic system is its rules, and the better the rules, the better job the system does of deciding a level of flirtation.

Establishing rules for flirtation is a lot more complicated than establishing the rules for how to control an air conditioner. The fuzzy-controlled air conditioner computer had two basic rules: 1) **IF** the temperature is *hot*, **THEN** the air conditioner should be turned on *high*, and 2) **IF** the temperature is *cold*, **THEN** the air conditioner should be turned *off* (of course, a more realistic air conditioner would have more than two rules). When it comes to flirting, two simple rules don't seem to be able to do the job. For example, the two rules, 1) **IF** touching is *a bit*, and maintaining eye contact is *a bit*, **THEN** flirtation is *a bit*, and 2) **IF** maintaining eye contact is *a lot*, and touching is a *pretty good amount*, **THEN** flirtation is a *pretty good amount,* just don't cover all the different possibilities.

Our actual flirtation rules were determined in a very specific way. First, we created a table, with the fuzzy sets for touching shown along its top and the fuzzy sets for maintaining eye contact shown along its left-hand side (see Table 1). The 25 boxes of the table represent all the possible combinations of touching and eye contact. Students were asked to fill in each box with a level of flirtation (*NAA, H, AB, PGA, AL*) based on the particular combination of touching and eye contact. After filling out the table, it was easy to establish IF-THEN- rules. Note, for example, that Box 8 [Box 8 is where row 2 (which is *HARDLY* any eye contact) and column 3 (which is *A BIT* of touching) intersect] is filled in. In this case, the students decided that when they interact with someone, **IF** *hardly* any eye contact is maintained and there is *a bit* of touching, **THEN** there is *hardly* any flirtation going on. In this way, each box was filled in, and twenty-five IF-THEN- rules for determining flirtation were determined. The consensus rules are displayed in Table 2.

E. Differences And Similarities In Student's IF-THEN- Rules

Some students' rules for determining flirtation are quite different from other student's rules. Obviously, not every person is the same, and different rules should be expected. It is important to remember that the rules these students decided on are not going to be absolutely correct. The rules for deciding flirtation for college students at USC are very different than the rules for college students in South America or in Africa. In America people usually greet strangers with a handshake, but in some cultures it is common to greet people with a hug or a kiss. The rules and fuzzy sets for flirtation in those countries will obviously vary from the rules and fuzzy sets in America. Even in America, the rules can be different for each individual person depending on their geographic location, culture, race, gender, and personality.

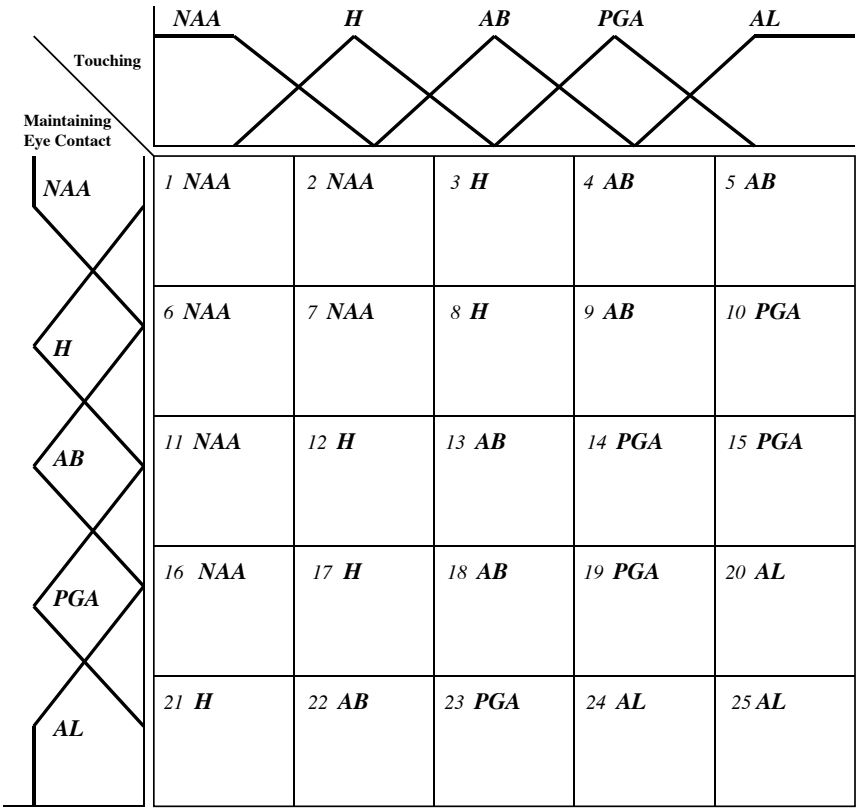
Table 1: A table which displays the rules for determining flirtation. The membership functions for touching and maintaining eye contact are shown at the top of and along the left-hand side of the table, respectively. Box 8 is associated with the rule: **IF** there is *A Bit* of touching and *Hardly* any eye contact, **THEN** there is *Hardly* any flirtation.

Maintaining Eye Contact \ Touching	***NAA***	***H***	***AB***	***PGA***	***AL***
NAA	*1*	*2*	*3*	*4*	*5*
H	*6*	*7*	*8* ***HARDLY*** any flirtation	*9*	*10*
AB	*11*	*12*	*13*	*14*	*15*
PGA	*16*	*17*	*18*	*19*	*20*
AL	*21*	*22*	*23*	*24*	*25*

Whereas guys and girls picked very similar indicators of flirtation, there are some clear differences in the way they established rules for determining levels of flirtation. The guys usually created rules where, regardless of eye contact, if touching was anywhere above *a bit,* then flirtation was a *pretty good amount* or *a lot*. However, the rules that girls established for the same conditions usually had lower levels of flirtation. For the most part, the guys said that they interpreted touching to be very flirtatious, whereas the girls usually said that some people are just very touchy and friendly, but that doesn't mean that they are being flirtatious. The difference in the way guys and girls interpret indicators of flirtation, especially touch, could potentially lead to confusion in an interaction between them (as is often the case).

If you want to have an idea of some of the rules that other people might have about flirtation, Tables 3 and 4 display some of the very different rules that guys and girls used for flirtation. Notice the differences between them, and try to use them to your advantage the next time you are talking to someone. It's possible you are just being friendly, but he or she might be getting messages that tell them you are flirting. Understanding how people read cues like touching and maintaining eye contact will help you to send the message you want to send and avoid confusion, as well as how to figure out when you are and when you aren't being flirted with.

Table 2. Consensus IF-THEN rules for determining flirtation.



1 ***NAA***	*2* ***NAA***	*3* ***H***	*4* ***AB***	*5* ***AB***
6 ***NAA***	*7* ***NAA***	*8* ***H***	*9* ***AB***	*10* ***PGA***
11 ***NAA***	*12* ***H***	*13* ***AB***	*14* ***PGA***	*15* ***PGA***
16 ***NAA***	*17* ***H***	*18* ***AB***	*19* ***PGA***	*20* ***AL***
21 ***H***	*22* ***AB***	*23* ***PGA***	*24* ***AL***	*25* ***AL***

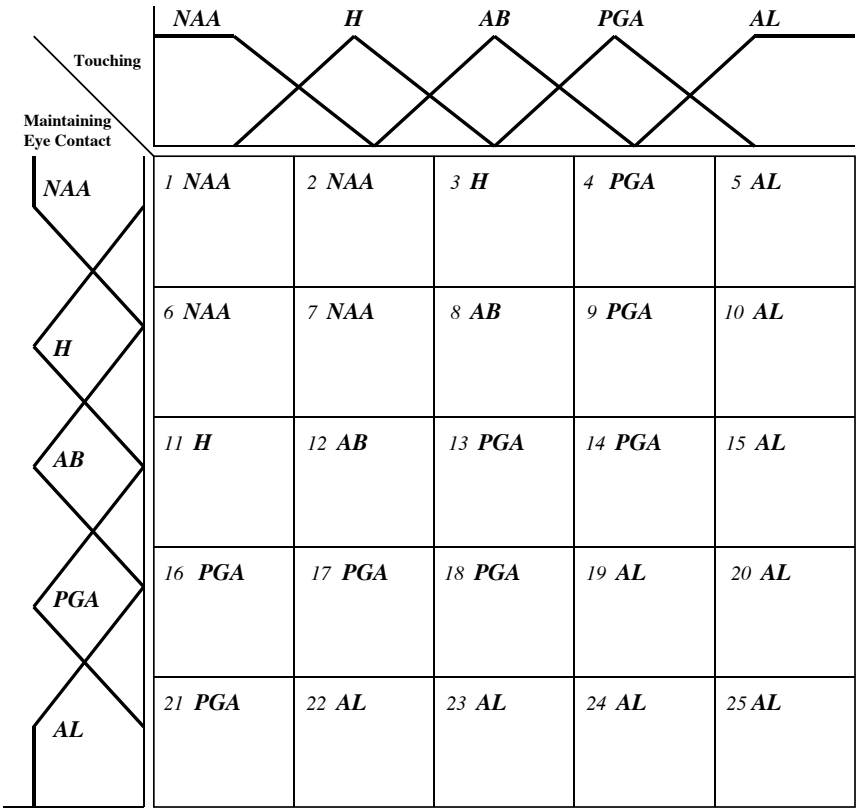
Of the students who were interviewed, one girl's rules (see Table 4) were at one extreme of the spectrum; she found almost nothing having to do with touching and maintaining eye contact to be very flirtatious. Table 3, on the other hand, shows the rules for flirtation at the other end of the spectrum; this guy found many combinations of touching and maintaining eye contact to be very flirtatious. As you can see, different people interpret flirtation very differently. Most people are somewhere in-between these two extremes, but people can vary a lot. With that in mind, try to figure out the rules that people around you use when they flirt.

F. Finalized IF-THEN- Rules For Determining Flirtation

Even amidst these gender, culture, and personality differences, after the students discussed things they were able to agree on a basic set of rules. This is how the *consensus* rules shown in Table 2 were obtained.

Remember, each box is an IF-THEN- rule for the fuzzy logic system. For example, Box 1, which gives Rule 1, reads as follows—Rule 1: **IF** there is *no* touching *at all*, and *no* maintaining eye contact *at all*, **THEN** there is *no* flirtation *at all*. These twenty-five rules were determined by people who know something about flirting (college students). Now, create your own rules in Table 5 and see if they agree with ours.

Table 3: One guy's (extreme) rules for flirtation



1 ***NAA***	*2* ***NAA***	*3* ***H***	*4* ***PGA***	*5* ***AL***
6 ***NAA***	*7* ***NAA***	*8* ***AB***	*9* ***PGA***	*10* ***AL***
11 ***H***	*12* ***AB***	*13* ***PGA***	*14* ***PGA***	*15* ***AL***
16 ***PGA***	*17* ***PGA***	*18* ***PGA***	*19* ***AL***	*20* ***AL***
21 ***PGA***	*22* ***AL***	*23* ***AL***	*24* ***AL***	*25* ***AL***

G. Mixed Signals

When you talk to people, some of their actions might indicate that they are flirting with you, whereas some of their other actions might indicate that they are not flirting with you. For example, let's say a guy talks to a girl, and she gives him a hug but seems distracted and doesn't look at him very much during their conversation (Fig.13). The guy senses these things and he might think of her hug as being more than friendly and pretty flirtatious, but the way she seemed distracted might also make him think she doesn't really want to be talking to him and is thinking of something or someone else. When he gets these "mixed signals" from her it makes it very hard for him to decide if she is flirting with him or not, but his brain somehow determines the amount of flirtation. In this case, he might reason that she is definitely flirting a bit, but not a whole lot.

The fuzzy logic system we created is also able to account for mixed signals. Here is an example of how this works. The guy uses the scale of touching to locate about how much touching he sensed from the girl's hug (Fig. 14). As mentioned before, there are numbers on the horizontal axis of the graph of fuzzy sets for touching, and in this case it turns out that the touching the guy sensed from her hug is a 6.8. Note that the guy might not always know that he sensed *exactly* 6.8 of touching. In some cases he might not be sure, and he could say he sensed *around* 6.8 of touching. Fuzzy logic systems can deal with uncertainty, but it makes things much more complicated. To keep things simple, in this article we will only use examples where the sense of touching is exactly a certain number, not *around* or *close to* a number.

Table 4: One girl's (extreme) rules for flirtation.

Maintaining Eye Contact \ Touching	*NAA*	*H*	*AB*	*PGA*	*AL*
NAA	1 ***NAA***	2 ***NAA***	3 ***NAA***	4 ***H***	5 ***H***
H	6 ***NAA***	7 ***NAA***	8 ***NAA***	9 ***AB***	10 ***AB***
AB	11 ***NAA***	12 ***NAA***	13 ***NAA***	14 ***PGA***	15 ***PGA***
PGA	16 ***NAA***	17 ***NAA***	18 ***NAA***	19 ***PGA***	20 ***PGA***
AL	21 ***NAA***	22 ***NAA***	23 ***NAA***	24 ***PGA***	25 ***PGA***

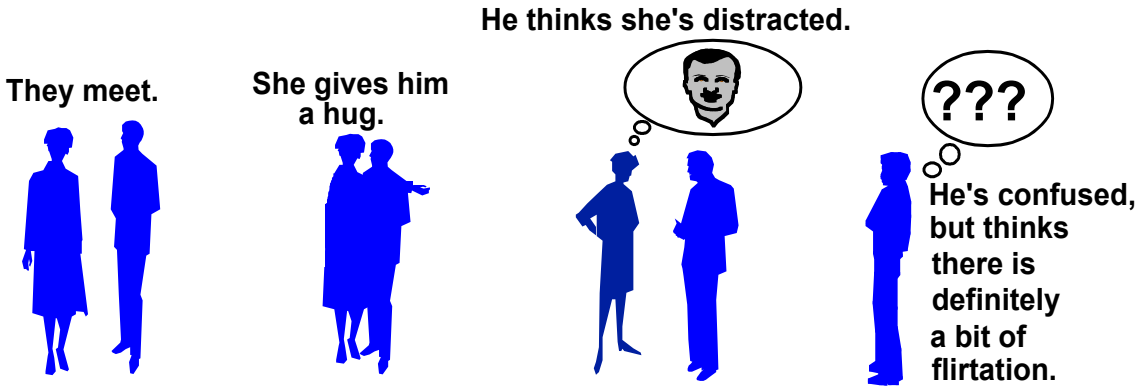
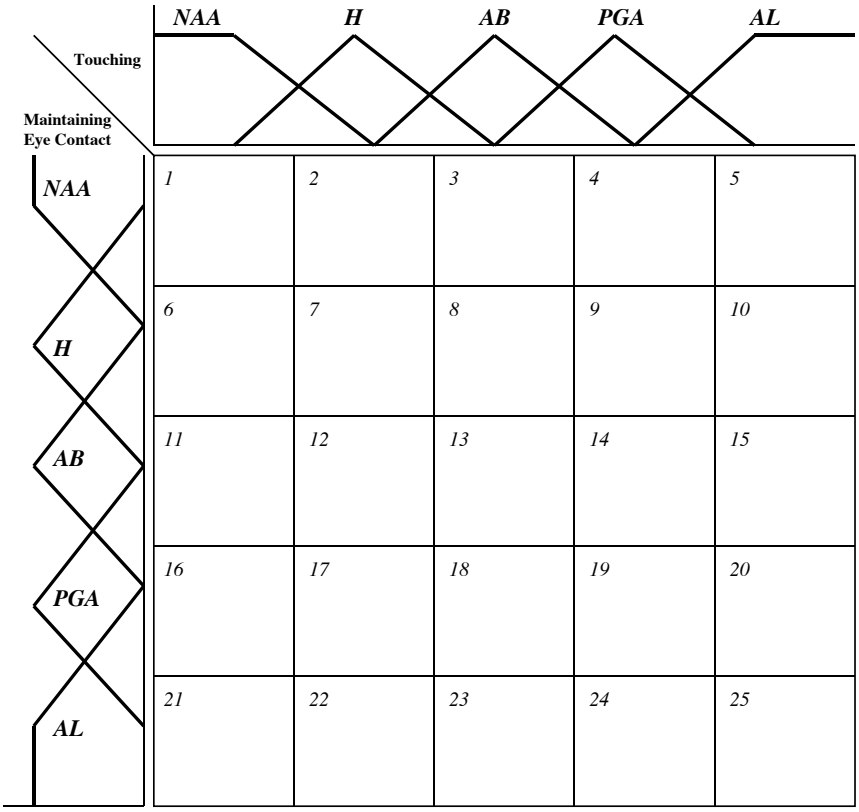


Figure 13. An example of mixed signals.

Now 6.8 can be located on the graph of fuzzy sets for touching, and fuzzified into fuzzy sets [this is shown Fig. 14 (c)]. From the arrow at 6.8, a line has been drawn straight up, and from this line it can be seen that the level of touching the guy sensed is described by the set *AB* with a membership value of 0.25 and the set *PGA* with a membership value of 0.75.

Table 5: Your own flirtation rules.



He also uses the scale of Maintaining Eye Contact to locate about how much eye contact he sensed when he talked to the girl (Fig. 15). In this case, he ranks the level of maintaining eye contact a 3.1. This level is described by two fuzzy sets, *H*, with a value of 0.8, and *AB*, with a value of 0.2. In summary, the girl's hug and eye contact have activated two of the guy's fuzzy sets for touching (*AB* and *PGA*) and two of his fuzzy sets for maintaining eye contact (*H* and *AB*). This in turn fires the four rules shown in Table 6. Just as in real life, when the guy got mixed signals from the girl, the four fired rules convey mixed signals.

The four fired rules are Rules 8, 9, 13, and 14. Here is what happens when the rules are activated (Fig.16):

> **Rule #8**: **IF** there is *a bit* of touching **and** *hardly* any maintaining eye contact, **THEN** there is *hardly* any flirtation.

The fuzzy input set for *a bit* of touching has the membership value 0.25 and the fuzzy input set for *hardly* maintaining eye contact has the membership value of 0.8. Rule #8 decides that these two fuzzy input sets result in the fuzzy output set of *hardly* any flirtation. Not only does it decide on the set *hardly*, it also decides what the membership value is for the set.

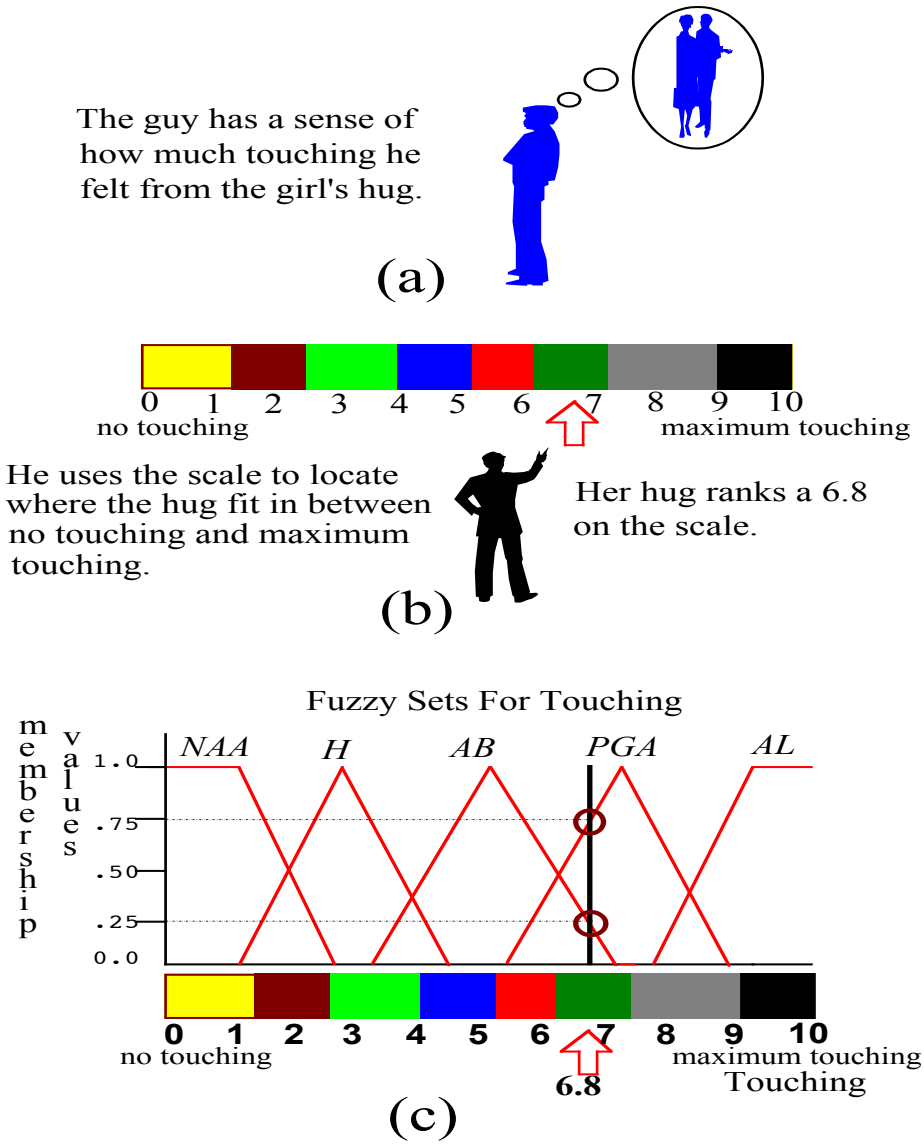


Figure 14. The girl's hug is described by two fuzzy sets at the same time: (a) the guy thinks about how much touching he sensed from her hug; (b) he ranks the touching, using the scale of touching, and it turns out to be a 6.8; and, (c) the 6.8 rank for touching is fuzzified into two different fuzzy sets, *A Bit*, with membership value 0.25, and *Pretty Good Amount*, with membership value 0.75.

In mathematics, the word **and** means multiplication, while the word **or** means addition (other interpretations for these two words are also possible). Because rule #8 says, "IF there is a bit of touching **and** hardly any maintaining eye contact...", this means that the membership values of the two input sets are multiplied and the result is the scaled membership function for the output set *hardly* any flirtation. In this example, the value for *a bit* of touching is 0.25 and the value for *hardly* maintaining eye contact is 0.8. The multiplication of the input values is 0.25 X 0.8 = 0.2, so that the membership function for the output set *hardly* any flirtation is scaled by 0.2. The result can be seen in Fig. 16 (b), and is the scaled triangle for *H*, where the maximum value is 0.2.

Rule #9: IF there is a *pretty good amount* of touching **and** *hardly* any maintaining eye contact, **THEN** there is *a bit* of flirtation.

Here the fuzzy input set *pretty good amount* of touching has the membership value 0.75 and the input set *hardly* any maintaining eye contact has the membership value 0.8. The multiplication of 0.75 X 0.8 = 0.6, so the fuzzy output set according to Rule #9 is *a bit* of flirtation, with a scaled triangular membership function, whose maximum value is 0.6 [Fig. 16 (b)].

Rule #13: IF there is *a bit* of touching **and** *a bit* of maintaining eye contact, **THEN** there is *a bit* of flirtation.

Table 6: Rules that are fired which give "mixed signals."

Maintaining Eye Contact \ Touching	***NAA***	***H***	***AB***	***PGA***	***AL***
NAA	*1*	*2*	*3*	*4*	*5*
H	*6*	*7*	*8* ***H***	*9* ***AB***	*10*
AB	*11*	*12*	*13* ***AB***	*14* ***PGA***	*15*
PGA	*16*	*17*	*18*	*19*	*20*
AL	*21*	*22*	*23*	*24*	*25*

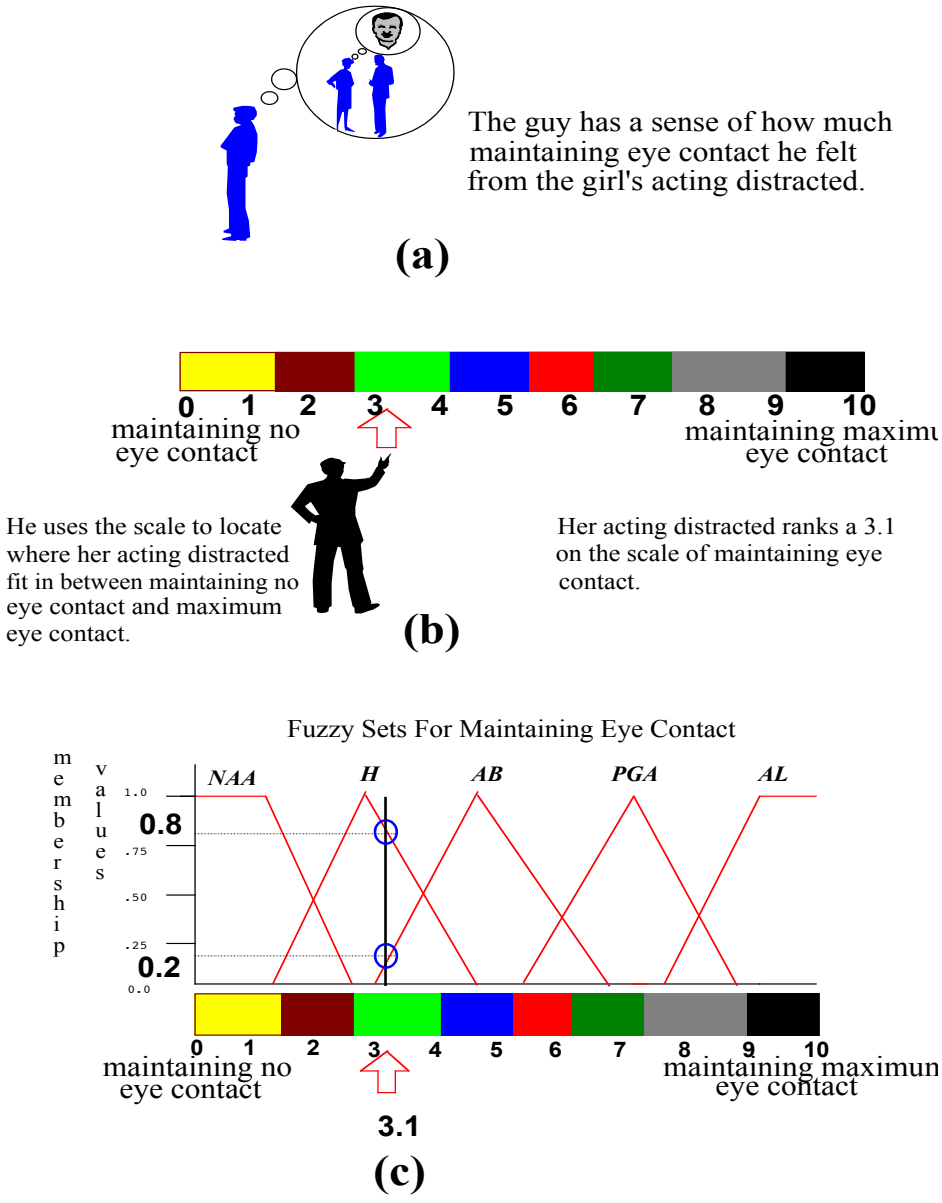


Figure 15. The girl's acting distracted is described by two fuzzy sets at the same time: (a) the guy thinks about how much maintaining eye contact he sensed; (b) he locates what he sensed on the scale, and it turns out to be a 3.1 of maintaining eye contact, and (c) the 3.1 of maintaining eye contact is fuzzified into two fuzzy sets, *Hardly*, with membership value 0.8, and *A Bit*, with membership value 0.2.

In this case the fuzzy input set *a bit* of touching has a membership value of 0.25 and the set *a bit* of maintaining eye contact has a membership value of 0.2. The multiplication of 0.25 X 0.2 = .05, so the fuzzy output set according to Rule #13 is *a bit* of flirtation, with a scaled triangular membership function, whose maximum value is 0.05 [Fig. 16 (b)].

> **Rule #14:** **IF** there is a *pretty good amount* of touching **and** *a bit* of maintaining eye contact, **THEN** there is a *pretty good amount* of flirtation.

The fuzzy input set a *pretty good amount* of touching has the membership value 0.75 and the input set *a bit* of maintaining eye contact has the membership value of 0.2 The multiplication of 0.75 X 0.2 = 0.15, so the fuzzy output set according to Rule #14 is a *pretty good amount* of flirtation with a scaled triangular membership function, whose maximum value is 0.15 [Fig. 16 (b)].

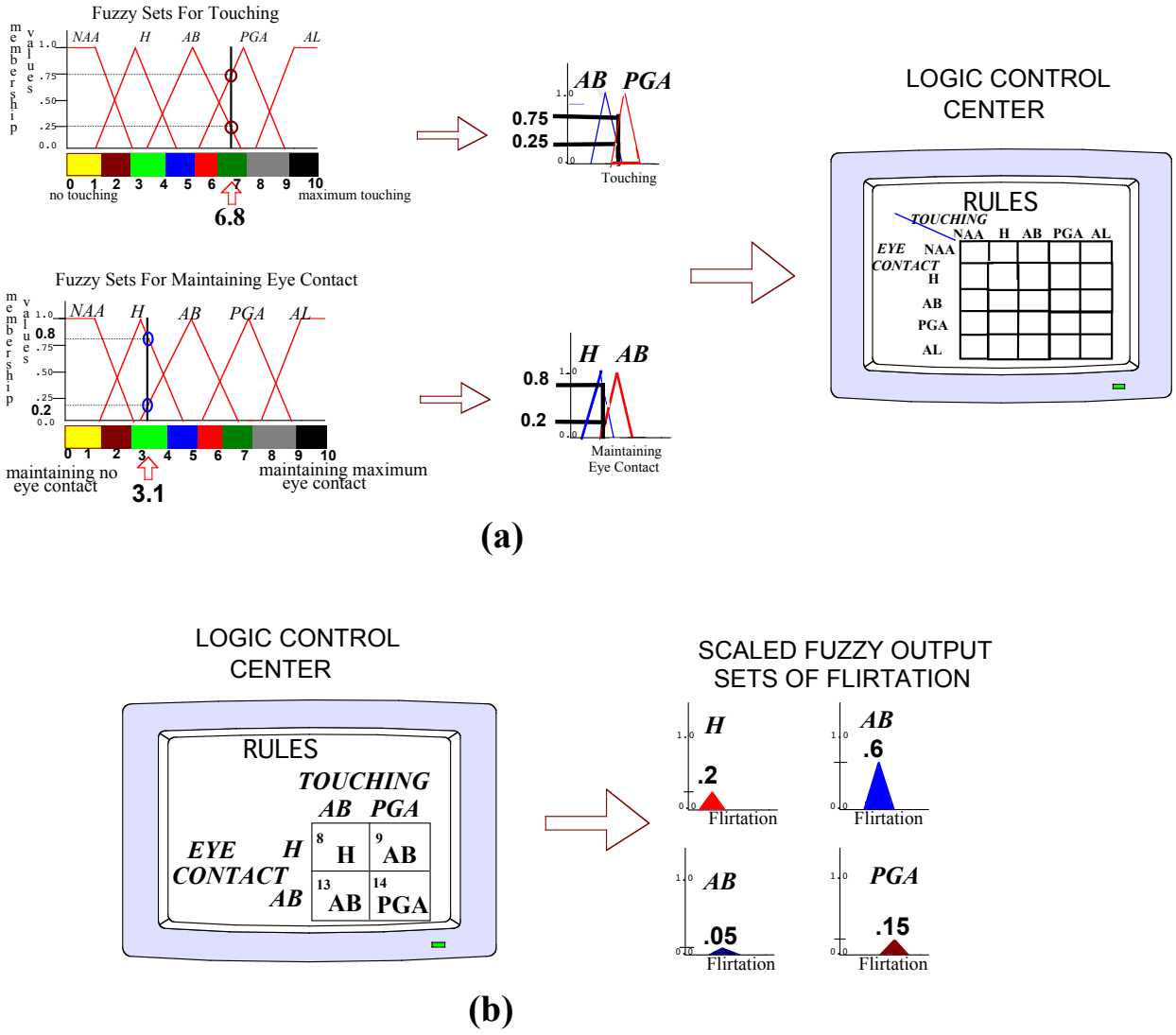


Figure 16. Fuzzy input sets fire rules in the Logic Control Center, which uses its rules to produce fuzzy output sets: (a) the fuzzy sets *A Bit* and *Pretty Good Amount* of touching, as well as *Hardly* and *A Bit* of maintaining eye contact are sent to the Logic Control Center; these input sets activate four of the Logic Control Center's rules; (b) the Logic Control Center uses these four rules to produce scaled fuzzy output sets of flirtation.

Rule 8 indicates that there is *hardly* any flirtation; Rules 9 and 13 indicate *a bit* of flirtation; and Rule 14 indicates a *pretty good amount* of flirtation. Hence, at one extreme Rule 8 indicates there is hardly any, or almost no flirtation, while at the other extreme Rule 14 indicates there is a pretty good amount of flirtation. What amount of flirtation is actually occurring? This is what the fuzzy logic system must next determine.

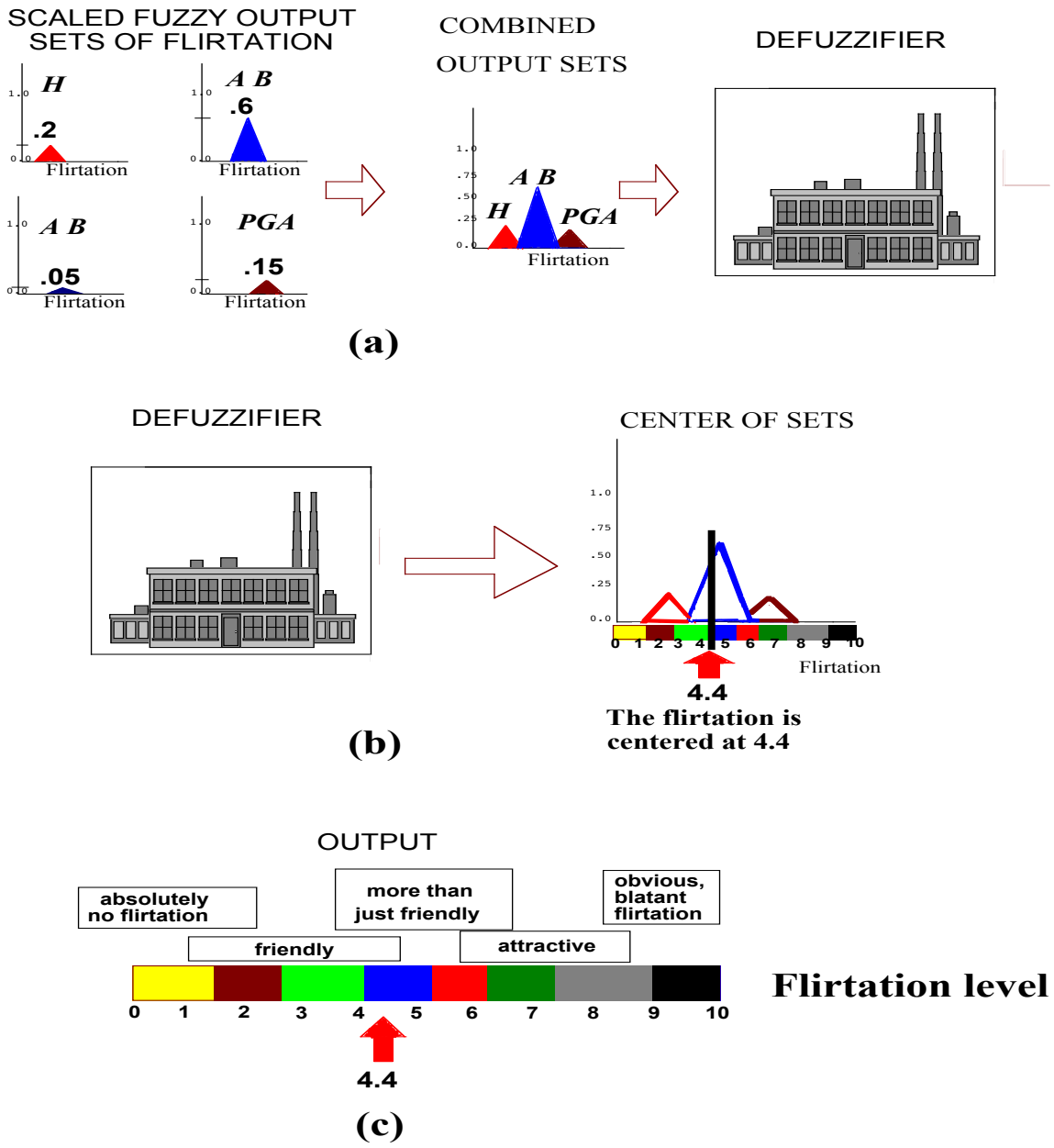


Figure 17. The fuzzy output sets of flirtation are grouped together in (a), defuzzified by finding the center of the fuzzy sets in (b), and the level of flirtation is indicated in (c). It appears that the girl is a little bit more than friendly, but not too much.

Now that a total of four different fuzzy output sets for flirting have been produced by the Logic Control Center, these four sets of flirtation are combined (by the same process described for the fuzzy air conditioner) and then sent to the defuzzifier [Fig.17 (a)]. The defuzzifier uses an equation to figure out the center of the combined fuzzy output sets. Before, in the example of the fuzzy air conditioner (Fig.7), the defuzzifier located the center of the combined fuzzy output sets *high* and *off* and converted that into a number, 80%, which commanded the air conditioner to be

turned on 80% of it's maximum setting. In the case of flirting, the defuzzifier can find the center of the fuzzy output sets, using an equation, and convert that into a number that ranges between 0 and 10 on a scale of flirtation (where 0 equals no flirtation and 10 indicates maximum flirtation). As you can see in Fig.17 (b), the defuzzifier found the girl's level of flirtation to be 4.4 out of ten.

Flirtation is not described by numbers; it is described by words. To say, for example, that "flirtation is 4.4," means nothing to us; but, to say "that person seems a little bit more than just friendly," can mean a lot. Unfortunately, the defuzzifier is not able to defuzzify the output sets directly into such a sentence; however, it can indicate on the graph of fuzzy sets for flirtation exactly where the person's level of flirtation lies, in this case at 4.4. By examining where 4.4 fits in with the phrases on the graph that describes flirtation (you have to create the phrases and place them where you think they belong on the 1-10 scale of flirtation), you can easily figure out the level of that person's flirtation. In Fig.17 (c) the location of this level of flirtation is shown by an arrow, which indicates that the girl is definitely a little bit more than friendly, but not too much.

Even though there were mixed signals, the fuzzy logic system was able to determine how much flirtation is going on. Interestingly enough, it came up with the same answer—the girl is a bit more than friendly, but not too much—that the guy did in Fig. 13. This entire process is summarized in Fig. 18. The implications of how fuzzy logic can model human decision making is discussed in the next section.

H. Your Brain And Fuzzy Logic

In the example of mixed signals, the fuzzy logic system we designed for flirting did a good job of figuring out flirtation, and came up with about the same level of flirtation that the guy did in Fig. 13. You might be thinking "It worked for that example, but not every guy is like that guy," or "that girl wasn't flirting at all," or "she was flirting a lot". You are right, the particular fuzzy logic system we used would not give the same result as the guy who thought she wasn't flirting at all, or the guy who thought she was flirting a lot; however, with a few adjustments to our fuzzy logic system we can get the same results that these guys did.

In Fig. 19, a different guy meets a girl and has exactly the same interaction as the guy from the example shown in Fig. 13, but this guy senses no flirtation at all. This guy's rules for flirtation are different than the previous guy's rules. For this new guy, it takes a lot more touching and eye contact to indicate flirtation than it did for the previous guy. He is basically more of a pessimist than the other guy, and it takes a lot for the guy to think a girl is flirting with him. If we wanted to model the way this new guy figures out flirtation, we could use the same fuzzy logic system we did before (Fig. 18), but just change a few of the rules in the Logic Control Center.

We can change rules 8, 9, 13, and 14 in the old Logic Control Center so that the same combinations of touching and eye contact indicate much less flirtation than before (see Fig. 20). Now we have a new Logic Control Center, with new rules. We can substitute this new Logic Control Center into the same fuzzy logic system we were using before, and this time it will decide that the girl is not flirting at all but is just being friendly (see Fig. 21).

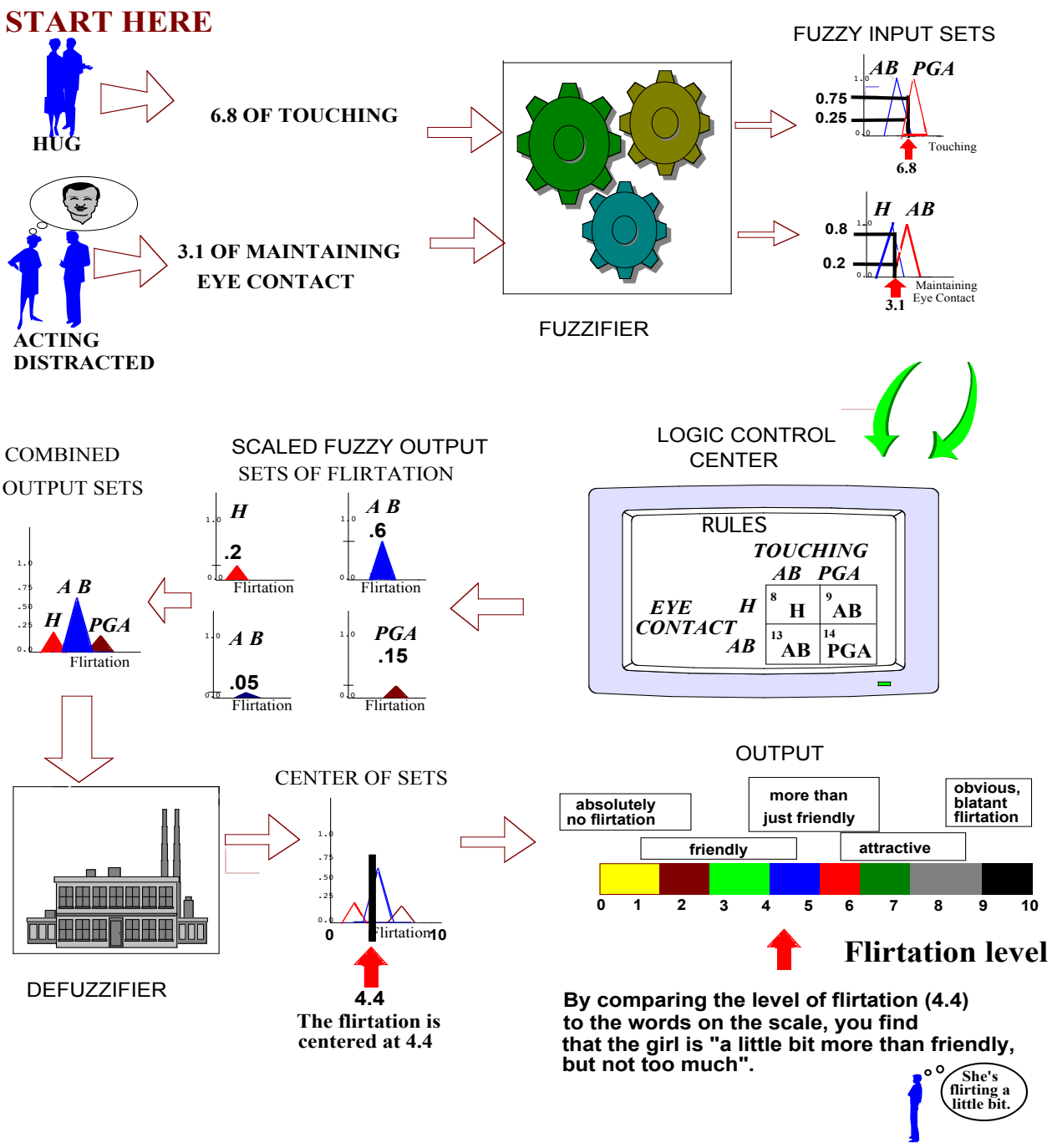


Figure 18. The entire process of our fuzzy logic system deciding on the level of flirtation when there are "mixed signals".

There are other ways that we could have changed the fuzzy logic system to make it decide the level of flirtation like the pessimistic guy did. We could have changed the way the fuzzifier works, or changed the way we defuzzified the fuzzy sets of flirtation. Also, if there is a guy who thinks he is a stud and every girl likes him, we could use similar methods to make the fuzzy logic system figure out flirtation like he does. The main point is that you can use fuzzy logic systems

to model the way almost any person decides on flirtation, depending on whether they have high or low self-esteem, are a pessimist or an optimist, or whatever.

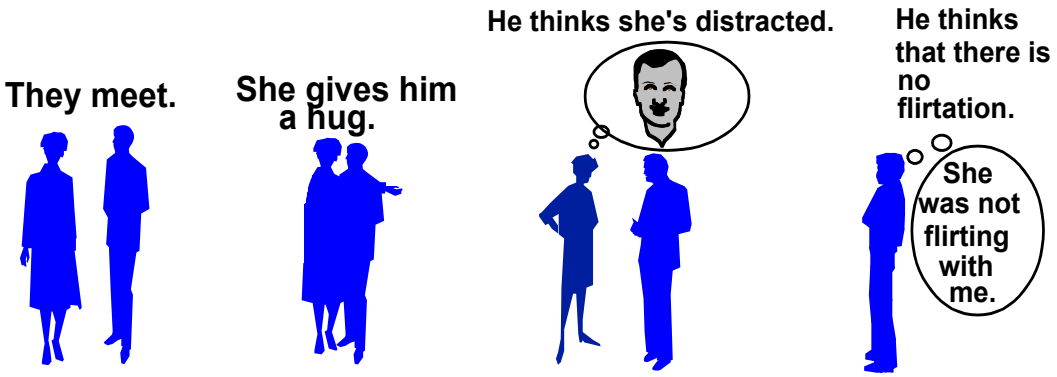


Figure 19. An example of a guy who has the same interaction as the guy in Fig.13, but he senses no flirtation.

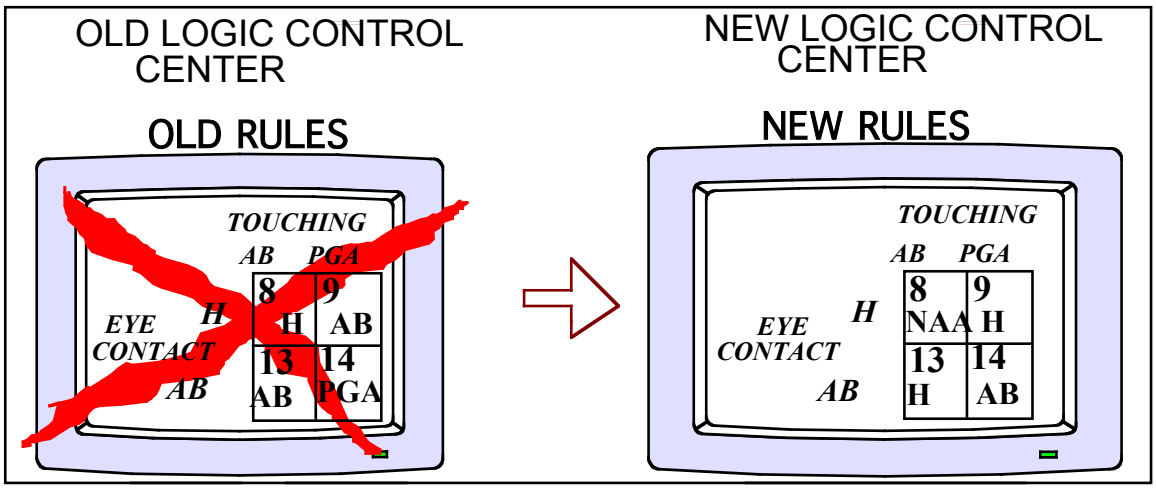


Figure 20. Changing the rules of the Logic Control Center.

Fuzzy logic systems are not restricted to just flirting. They can be used to decide just about anything you can think of. The fact that fuzzy logic systems make decisions that are very similar to the ones people make is very significant. We are not suggesting that your brain is actually a big group of fuzzy logic systems; however, it may be true that fuzzy logic systems work a lot like your brain does. This parallel between the way that fuzzy logic systems work and the way your brain works is what makes fuzzy logic systems so effective when dealing with real-life fuzzy problems.

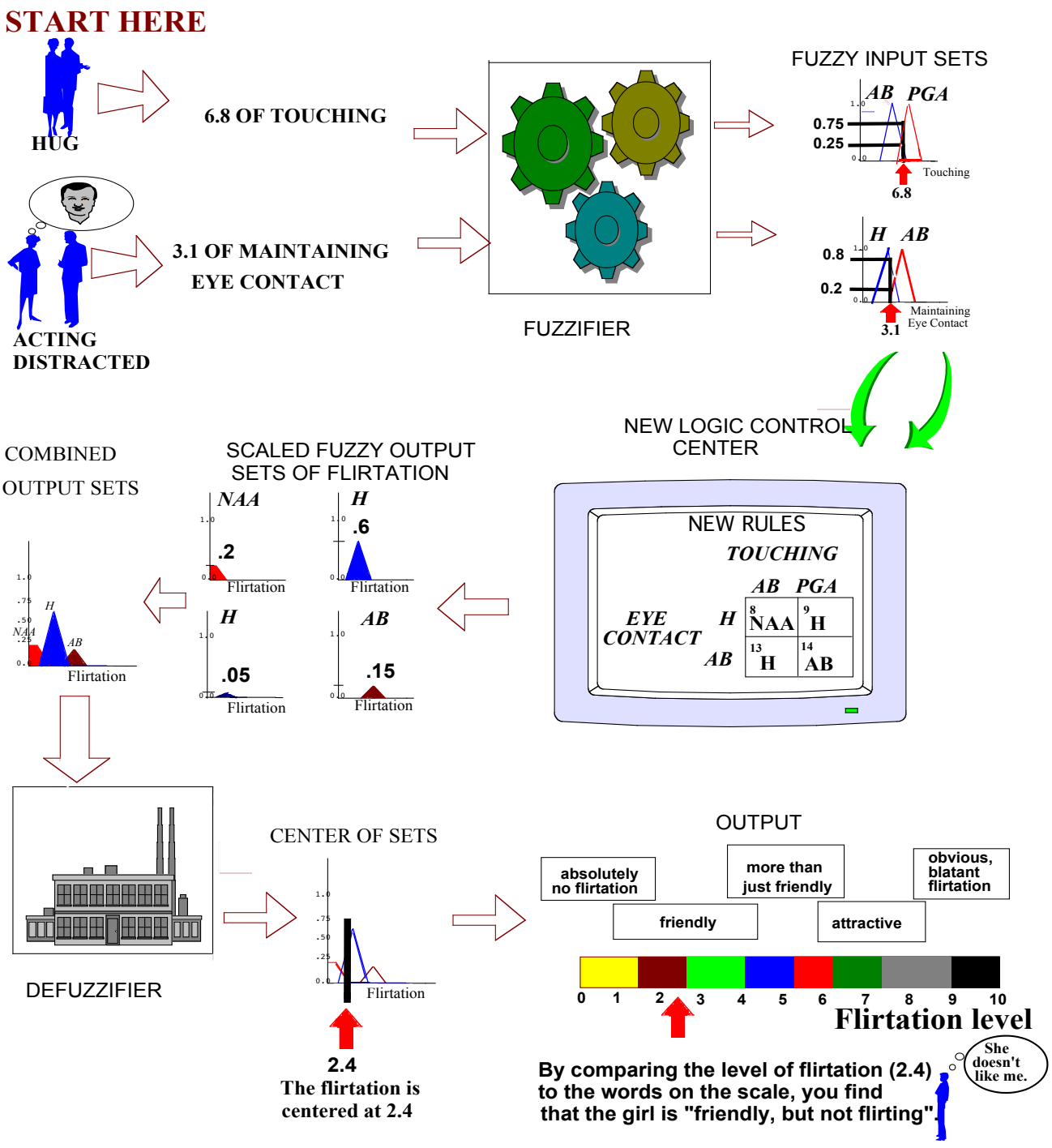


Figure 21. A fuzzy logic system with new rules for deciding on the level of flirtation.

III. CONCLUSIONS

Fuzzy logic is an important tool for two main reasons. First of all, it allows us to form a model of what's going on when decisions (like figuring out if you are being flirted with) are made. Having a model can help us to understand more about our decision making processes and learn how to make the best possible decisions. Second, we can use this model to design computers that can actually make fuzzy decisions.

If you follow some basic steps, you can make a fuzzy logic system to decide about anything you can think of, like figuring out flirtation. First, figure out what information you need to make your decisions. In this article, we had to know what things indicated flirtation. We found out that we had to have information about touching, maintaining eye contact, and some other things in order to decide how much we are being flirted with. Next, figure out what kinds of decisions can be made. In this article we had to decide on different levels of flirtation. Then, create fuzzy sets which describe the information needed for the decision, and also create fuzzy sets which describe the different kinds of decisions to be made. We used the sets *Not At All, Hardly, A Bit, Pretty Good Amount,* and *A Lot* to describe the input information (e.g., touching), and used the same sets to describe the output decisions (different levels of flirting). Finally, make up rules that will let you make decisions. For flirting, our rules were ones like, "**IF** touching is *A Lot*, and maintaining eye contact is *A Lot*, **THEN** flirtation is *A Lot*." The rules, of course, are most important.

You can apply fuzzy logic systems to just about any situation or decision because fuzzy logic systems seem to work in ways similar to our brains, which is what makes it so useful. Now that you know how fuzzy logic works, see if you can observe examples of how we use a fuzzy kind of logic in everyday life. As you have read through this article, you have made your own fuzzy sets as well as your own rules for flirtation. The next time you talk to someone, and you think you are being flirting with, try out the fuzzy rules that you created to see how much you actually are being flirted with.

Using fuzzy logic, it is possible to build a machine (e.g., computer) that could be your own flirtation advisor. The machine could receive information about how a person interacts with you, and then tell you how much that person is flirting with you. Beyond that, it is even possible to use fuzzy logic to program computers to flirt with each other, or with people (Fig. 22)! This could be used to help researchers understand the process of flirting, the way our minds work, and the way we interact with each other. Also, this type of research could lead to the development of much smarter, more "human-like" computers.

You already know how to flirt, and now, using fuzzy logic, you have a basic idea of how the process of determining flirtation works. Try out your own fuzzy logic the next time you think you are being flirted with.

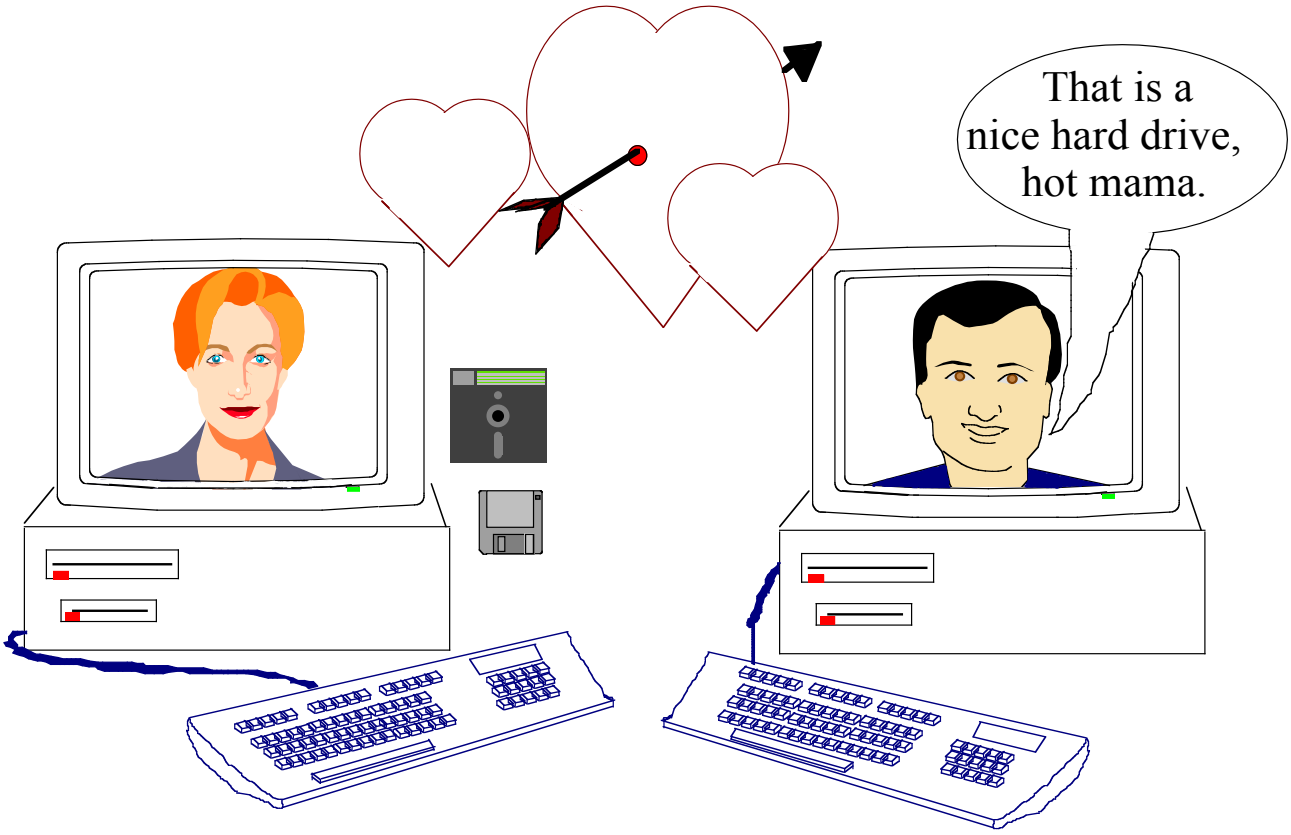


Figure 22. Two computers flirting with each other.

IV. TECHNICAL EPILOG

When we began this project, the goal was very clear, namely to write a short article (without any equations) about fuzzy logic that could be understood by highschool girls and guys. We chose flirtation as the example that would help us to accomplish our goal, because flirtation is something that every high-schooler has experienced, to some degree or another. We wanted to demonstrate that fuzzy logic could help a high-schooler determine to what degree he or she was being flirted with, in a flirtation situation. In retrospect, we wanted to provide the high-schooler with a 'flirtation advisor', but only to explain and to illustrate fuzzy logic.

As is often the case when we begin with one goal in mind other good things can occur. We believe that this is what happened during the preparation and writing of this article. Coming from an engineering background, all of our earlier applications of fuzzy logic had led to a device, called a fuzzy logic system (FLS), a device that accepts numbers at its input and provides numbers at its output. Fuzzy logic operates inside of the FLS. You could say we had a solution looking for a problem, namely the FLS. As long as we stayed within the confines of engineering applications, such as in fuzzy logic control, fuzzy logic signal processing, or fuzzy classification, the shoe fit, i.e., our FLS could be used to solve interesting control, signal processing and classification problems.

Flirtation did not fit into our 'shoe.' That was the first surprise! Why? Engineering applications for the FLS begin with quantities that can be *measured* and transform them through the FLS into other quantities that can be *measured*. In essence, then, a FLS can be interpreted mathematically by the equation $y_m = f(\mathbf{x}_m)$, where y_m is the measured

output of the FLS, $\mathbf{x}_m$ is a vector of measured inputs to the FLS, and $f(\bullet)$ is a nonlinear function whose exact structure is established by the tenets and precepts of fuzzy set theory and fuzzy logic.

Flirtation cannot be measured. It can be 'sensed' but not measured. This is exemplified by the adage 'You'll know it when you see it'. Conceptually, we can think of flirtation as an unknown function of some *indicators of flirtation*, i.e., we can think of flirtation as obeying an equation *like* $y = f(\mathbf{x})$*;* however, what are those indicators, and can they be measured? Determining flirtation indicators is akin to determining features in a pattern recognition problem; however, pattern recognition features can always be measured or mathematically constructed from other measured quantities, whereas *flirtation indicators cannot be measured; they can only be sensed*.

We determined through a survey and polling procedure that the top four indicators of flirtation are: touching, acting witty, eye contact, and primping. Clearly, none of these flirtation indicators can be measured, but they sure can be sensed by someone in a possible flirtation situation.

So, if we choose to think of flirtation as obeying an equation like $y_s = f(\mathbf{x}_s)$, this equation now represents an unknown transformation from a collection (vector) of sensed flirtation indicators, $\mathbf{x}_s$, into a sense of flirtation, y_s. As it stands, we can't use our FLS because it provides a transformation of a vector of measured flirtation indicators into a measured level of flirtation, i.e., $y_m = f(\mathbf{x}_m)$. So, what we had to do was add on a front-end device to the FLS that transformed $\mathbf{x}_s$ into $\mathbf{x}_m$, and a rear-end device to the FLS that transformed y_m into y_s.

Our front-end device was the same for each of the four indicators of flirtation. Believing that people can rank each of these indicators on a scale of zero to ten ('Wow! That touch was a 10!'), we mapped each sensed indicator of flirtation onto such a scale. Mathematically, this means that $\mathbf{x}_m = g_{sm}(\mathbf{x}_s)$, where $g_{sm}(\mathbf{x}_s)$ is a vector mapping, each of whose components works exclusively to map a particular component of $\mathbf{x}_s$ into its respective component in $\mathbf{x}_m$. Although we can conceptualize such a mapping, we do not know what it is. It is established by each person on an individual basis. One of the basic premises of this work is that we are in a *cooperative environment*; hence, $\mathbf{x}_m = g_{sm}(\mathbf{x}_s)$ will be provided to the FLS by you the user of the flirtation advisor. You don't think about this ranking process in terms of a mathematical formula; you just do it! But, whatever it is that you do can indeed be thought of by us mathematically as the creation of $\mathbf{x}_m = g_{sm}(\mathbf{x}_s)$.

Our rear-end device begins with the ranking of flirtation on a scale of zero to ten, because the output of the FLS will be a number, y_m, that resides on this scale. This device converts y_m into a linguistic statement that expresses your sense of flirtation for this number. Mathematically, this means that $y_s = h_{ms}(y_m)$. Again, although we can conceptualize such a mapping, we do not know what it is, and, again, it is established by each person on an individual basis. The user of the flirtation advisor must put labels (i.e., linguistic phrases) that indicate levels of flirtation on a scale from zero to ten (e.g., 0 $\Leftrightarrow$ "no flirtation", 10 $\Leftrightarrow$ "I'm in love"). Again, you don't think about this labeling process in terms of a mathematical formula; you just do it! But, whatever it is that you do can indeed be thought of by us mathematically as the creation of $y_s = h_{ms}(y_m)$.

We can now put all of these mathematical formulas together to give us a concise description of what the flirtation advisor is doing. Individually, we have: $\mathbf{x}_m = g_{sm}(\mathbf{x}_s)$, $y_m = f(\mathbf{x}_m)$, and $y_s = h_{ms}(y_m)$; hence,

$$y_s = h_{ms}(y_m) = h_{ms}(f(\mathbf{x}_m)) = h_{ms}(f(g_{sm}(\mathbf{x}_s)))$$

Beginning with the most nested quantity, we first sense the flirtation indicators $\mathbf{x}_s$, which are then converted into measured quantities, $g_{sm}(\mathbf{x}_s)$. These quantities are operated upon by the FLS to produce its numerical output, $f(g_{sm}(\mathbf{x}_s))$, which earlier we called y_m. Finally, $f(g_{sm}(\mathbf{x}_s))$ is converted back into a linguistic sensation of flirtation, $h_{ms}(f(g_{sm}(\mathbf{x}_s))) = y_s$.

For all of this to work, we need a *cooperative environment*. Your cooperation is needed to establish your very own mappings $g_{sm}(\mathbf{x}_s)$ and $h_{ms}(y_m)$. But, even more cooperation is needed in order to establish the FLS, $f(\mathbf{x}_m)$. The heart of this FLS is a collection of IF-THEN rules. The antecedents of these rules (i.e., the IF parts) can be all the indicators of flirtation or suitable subsets. The consequents of these rules (i.e., the THEN parts) are flirtation sets, which may or may not be the linguistic ones that you personally extablished in $h_{ms}(\bullet)$ unless you helped to create the rules. Most likely, you did not.

The rules are established cooperatively by individual groups of guys and girls. The rules can be quite different for guys and girls, or even for some guys and some girls. The key, though, is that we were able to meet with groups of guys and girls and get them to give us their flirtation rules. In order to make this manageable, we felt that rules with four-antecedents were too complicated, i.e., it was not feasible to ask guys and girls to create rules involving all four flirtation indicators. If each flirtation indicator is partitioned into 5 fuzzy sets (e.g., none at all, hardly, abit, pretty good amount, and alot) we'd need as many as $5^4 = 625$ rules, which we felt is way too many rules for guys and girls to create. Based on our own experience, we felt that two-antecedent rules were manageable, and so we asked the guys and girls to create $5^2 = 25$ rules for pairs of antecedents. This was quite manageable and it worked.

If determining whether or not we are being flirted with is easy, we would all be experts; but it is not, and we are not. We make lots of mistakes. In fact, many times we get 'mixed signals.' In this article we show how fuzzy logic leads to an explanation and resolution of 'mixed signals.' So our fuzzy logic flirtation advisor also provides us with *insight* into why determining whether or not we are being flirted with is often difficult.

A FLS is filled with many possible design choices. While these choices are important for a designer's implementation of $f(\mathbf{x}_m)$, they are not important for a high-schooler's understanding of the flirtation advisor; hence, these details are not discussed in this article. When certain design choices are made, they are for illustrative purposes. We must stress here that other choices are possible, but, again, this is technical detail, which is of no real interest to high-schoolers.

In two-level crisp decision making, we would decide between 'flirtation is present' or 'flirtation is not present.' In fuzzy decision making we provide a degree of similarity to 'flirtation is present,' ranging from zero to ten, and we then give the result a linguistic label. Standing back from what we have done, we now realize that we have developed a general approach to fuzzy decision making in a cooperative environment when: only sensed indicators are available, the quantity of interest can, itself, only be sensed, and, the existing FLS is used.

It seems to us that many other applications exist for what we have done for flirtation, including: a sexual harrassment advisor (and many other interesting social and psychological phenomena) , risk assessment (civilian and military), financial advisement, etc.

We hope that this article achieves its intended purpose, to explain how fuzzy logic can help you understand whether you perceive flirtation, and, if so, to what degree. We had a lot of fun working on it.

SOME ADDITIONAL READINGS AND RESOURCES

Fuzzy logic toolbox user's guide, 1995, The Mathworks, Inc. (Note: this manual comes with the Fuzzy Logic Toolbox, software that works within the MATLAB™ environment. This is excellent software to use to design fuzzy logic systems.)

Kosko, B.,1993, *Fuzzy thinking: the new science of fuzzy logic*: Hyperion.

McNeill, D., and Freiberger, P., 1993, *Fuzzy logic-the discovery of a revolutionary computer technology - and how it is changing our world*: Simon and Schuster.

For lots of additional references and some other tutorial articles about fuzzy logic and fuzzy logic systems, see: http://sipi.usc.edu/~mendel