Fuzzy Logic and Fuzzy Systems – Introduction

Khurshid Ahmad,
Professor of Computer Science,
Department of Computer Science
Trinity College,
Dublin-2, IRELAND
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https://www.cs.tcd.ie/Khurshid.Ahmad/Teaching.html

FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Computers systems can

- **Receive and send data across the Universe,**
- **help us in Internet banking,**
- **launch, fly and land flying machines ranging from a simple glider to the Space Shuttle.**

FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

- **Computer systems cannot satisfactorily manage information flowing across a hospital.**
- **The introduction of computer systems for public administration has invariably generated chaos.**
- **Computer systems have been found responsible for disasters like flood damage, fire control and so on.**

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

So why can't the computers do what we want the computers to do?

1. **Problems in engineering software – specification, design, and testing;**
2. **Algorithms, the basis of computer programs, cannot deal with partial information, with uncertainty;**
3. **Much of human information processing relies significantly on approximate reasoning;**

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Year	Definition & Elaboration of the *adjective* fuzzy
1616	1. Not firm or sound in substance; spongy.
1713	2. Frayed into loose fibres; covered with fuzz; fluffy, downy.
1778	3a. Blurred, indistinct.
1937	3b. Of thought, etc.: imprecisely defined; confused, vague. Also of persons: inexact in thought or expression.

From the Oxford English Dictionary. http://www.oed.com.elib.tcd.ie/view/Entry/75880

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Year	Definition & Elaboration of the *adjective* fuzzy
1964	3c.i *Computing* and *Logic*. [Fuzzy Set] (Of a set) defined so as to allow for imprecise membership criteria and for gradations of membership; pertaining or belonging to such a set;
	3c.ii fuzzy logic, the logic of fuzzy sets and fuzzy concepts; fuzzy matching, (the facility for) matching items which are similar but not identical.

From the Oxford English Dictionary. http://www.oed.com.elib.tcd.ie/view/Entry/75880

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Soft computing is used as an umbrella term for sub-disciplines of computing, including fuzzy logic and fuzzy control, neural networks based computing and machine learning, and genetic algorithms, together with chaos theory in mathematics.

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Soft computing is for the near future – next 5-10 years, and knowledge of the inclusive branches will help to work in almost every enterprise where computers are expected in helping with design, control and execution of complex processes.

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

This course will focus on fuzzy logic and fuzzy control systems; there is a brief introduction to neural networks.

A knowledge of soft computing techniques will help you to work with folks involved with patient care, public administration for instance.

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

You have probably only encountered standard systems of logic – Boolean Logic, First-order logic. However, there are non-standard logics – future-conditional logic, logics used by von Neumann in the development of quantum mechanics (Boolean logic with quantum uncertainty). Fuzzy logic may be regarded as an alternative or *deviant* logic.

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

You have probably only encountered classical control theory – the control and stabilization of a dynamical system by corrective action from an external control. However, such systems rely on the existence of mathematical and statistical formalisms (differential equations, Markov models), that are usually available for idealised situations.

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Your perception is imprecise as well: Consider the two images:

Is there a systematic difference between what you consider a tall/short woman and a tall short man?

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FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Course Content

1. **Terminology: Uncertainty, Approximations and Vagueness**
2. **Fuzzy Sets**
3. **Fuzzy Logic and Fuzzy Systems**
4. **Fuzzy Control**
5. **Neuro-fuzzy systems**

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Fuzzy logic is being developed as a discipline to meet two objectives:

1. **As a professional subject dedicated to the building of systems of high utility – for example fuzzy control**
2. **As a theoretical subject – fuzzy logic is "symbolic logic with a comparative notion of truth developed fully in the spirit of classical logic [..] It is a branch of many-valued logic based on the paradigm of inference under vagueness.**

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

The key point is this

We can be sure of the truth of the statement:
Jones/Jill is tall

But unsure of the truth of the statement:
Jones/Jill is 1.8297 metres tall

Hhack, Susan. (1974). Deviant Logic: Some philosophical Issues. Cambridge: Cambridge University Press.

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

The key point is this

The laws of physics can acquire this minuteness of detail only by sacrificing some of the fixed and absolute certainty of common-sense laws. There is a sort of balance between precision and certainty: one cannot be increased except to the detriment of the other. (Haack citing the philosopher Pierre Duhem, 1974:123).

Hhack, Susan. (1974). Deviant Logic: Some philosophical Issues. Cambridge: Cambridge University Press.

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Engineering & Technology

When confronted with a control problem for a complicated physical process, a control engineer generally follows a relatively systematic design procedure. A simple example of a control problem is an automobile "cruise control" that provides the automobile with the capability of regulating its own speed at a driver-specified set-point (e.g., 55 mph).

Kevin M. Passino and Stephen Yurkovich. (1998). *Fuzzy control*. California: Addison Wesley Longman, Inc

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Engineering & Technology

One solution to the automotive cruise control problem involves adding an electronic controller that can sense the speed of the vehicle via the speedometer and actuate the throttle position so as to regulate the vehicle speed as close as possible to the driver-specified value (the design objective). Such speed regulation must be accurate even if there are road grade changes, head winds, or variations in the number of passengers or amount of cargo in the automobile.

Kevin M. Passino and Stephen Yurkovich. (1998). *Fuzzy control*. California: Addison Wesley Longman, Inc

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Medicine

The diagnosis of disease involves several levels of uncertainty and imprecision, and it is inherent to medicine. A single disease may manifest itself quite differently, depending on the patient, and with different intensities. A single symptom may correspond to different diseases. On the other hand, several diseases present in a patient may interact and interfere with the usual description of any of the diseases.

Angela Torres and Juan J. Nieto (2006). Fuzzy Logic in Medicine and Bioinformatics. Journal of Biomedicine and Biotechnology. Volume 2006, Article ID 91908, Pages 1–7. (DOI 10.1155/JBB/2006/91908)

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Medicine

The best and most precise description of disease entities uses linguistic terms that are also imprecise and vague. Moreover, the classical concepts of *health* and *disease* are mutually exclusive and opposite. However, some recent approaches consider both concepts as complementary processes in the same continuum.

Angela Torres and Juan J. Nieto (2006). Fuzzy Logic in Medicine and Bioinformatics. Journal of Biomedicine and Biotechnology. Volume 2006, Article ID 91908, Pages 1–7. (DOI 10.1155/JBB/2006/91908)

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Medicine: Patient History

	Precise	Imprecise
Objective	Vital Signs, Lab Results, Diagnostic Tests	Patient behaving improperly during signs taking, diagnostic tests
Subjective	Mental disorder classification; Contraindications to drugs/therapy	Medical history supplied by patient/family

Angela Torres and Juan J. Nieto (2006). Fuzzy Logic in Medicine and Bioinformatics. Journal of Biomedicine and Biotechnology. Volume 2006, Article ID 91908, Pages 1–7. (DOI 10.1155/JBB/2006/91908)

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Economics, Finance & Politics

Many decisions are based on beliefs concerning the likelihood of uncertain events such as the outcome of an election, the guilt of a defendant, or the future value of the dollar. These beliefs are usually expressed in statements such as "I think that . . . ," "chances are . . . ," "it is unlikely that . . . ," and so forth.

Amos Tversky; Daniel Kahneman. Judgment under Uncertainty: Heuristics and Biases. *Science*, New Series, Vol. 185, No. 4157. (Sep. 27, 1974), pp. 1124-1131.

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Economics, Finance & Politics

Occasionally, beliefs concerning uncertain events are expressed in numerical form as odds or subjective probabilities. What determines such beliefs? How do people assess the probability of an uncertain event or the value of an uncertain quantity?

Amos Tversky; Daniel Kahneman. Judgment under Uncertainty: Heuristics and Biases. *Science*, New Series, Vol. 185, No. 4157. (Sep. 27, 1974), pp. 1124-1131.

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Economics, Finance & Politics

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FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

How rice is cooked: Cooking white rice is a four-phase process.

- **First, soak rice in water for a while;**
- **Second, bring the water to boil and keep the temperature to boiling point of water;**
- **Third, temperature increases now, tone down the heat;**
- **Fourth, few minutes afterwards, the rice s ready.**

http://www.fuzzylogicricecooker.org/

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FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

How rice is cooked: Cooking white rice is a four-phase process. First, water is added to a pot that has ample capacity so the white rice sits in water. Then using a source of heat like a gas stove or electric plate, the mixture is heated until it is boiling and the white rice is absorbing water. The temperature remains at 212 degrees Fahrenheit, which is the boiling point of water. Part of the water turns into steam and escapes into the air. When all of the water is gone from the rice on the stove, the temperature increases. Now it is resting and there is a need to tone down the heat and to cut it off later. A few minutes afterwards, the rice is ready for serving. As we can see, there is a lot of important timing, especially at the latter phases.

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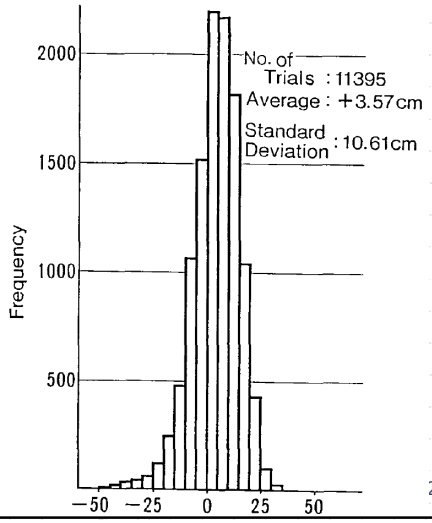
FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Applying brakes to stop a passenger train:

Oshirra, Hircryasu., Seiji Yasunobu and Shin-ichi Sekino. (1988). Automatic train operation system on predictive fuzzy control. In *Proc. International Workshop on Artificial Intelligence for Industrial Applications*. pp 485-489. http://ieeexplore.ieee.org.elib.tcd.ie/xpl/mostRecentIssue.jsp?punumber=714



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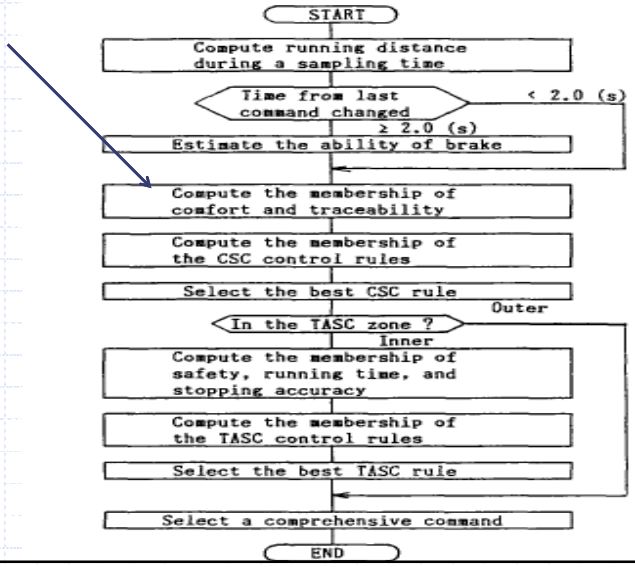
FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Oshirra, et al(1988)..

(1) CONSTANT SPEED CONTROL (CSC)

(2) TRAIN AUTOMATIC STOPPING CONTROL (TASC)



FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Oshirra, et al (1988)..

Fuzzy Control gives a smoother ride!

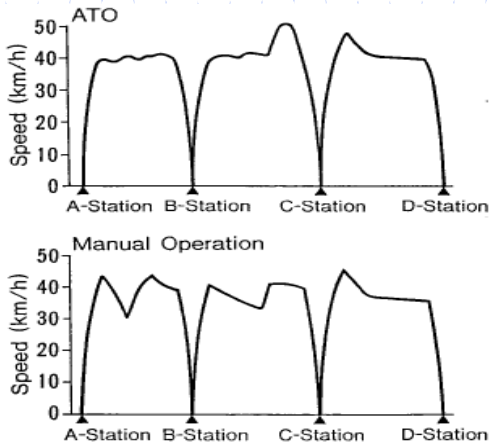


Fig. 8 Comparison between ATO Operation and Manual Operation

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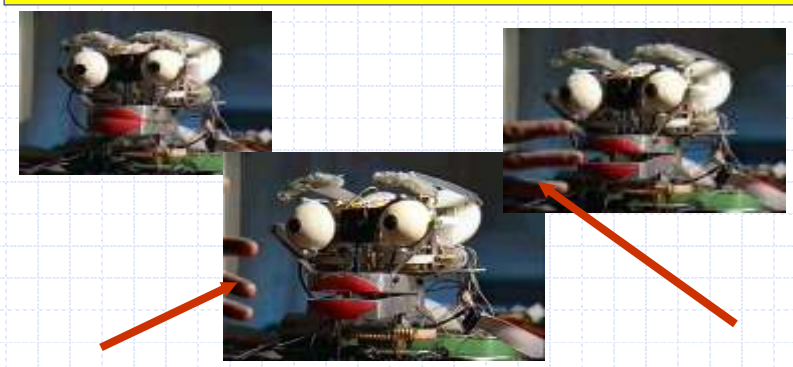
FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Reacting to *unexpected* and *expected* situations: A robot showing 'human emotions'. Somebody intruding in your space ! Relating PERCEPTION to EMOTION



Hossein Mobahi and Shahin Ansari. (2003)Fuzzy Perception, Emotion and Expression for Interactive Robots. IEEE International Conference on Systems, Man and Cybernetics, 5-8 Oct. 2003., Vol 4. pp 3918-3923
http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=1244500

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FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Reacting to *unexpected* and *expected* situations: A robot showing 'human emotions'. Somebody intruding in your space !

Heuristics for *fear, anger* and *surprise* when somebody approaches you slowly of fast, (or you encounter a stationary object). The reaction to an intruder also depends on whether you are close to the intruder or some distance away.

Hossein Mobahi and Shahin Ansari. (2003)Fuzzy Perception, Emotion and Expression for Interactive Robots. IEEE International Conference on Systems, Man and Cybernetics, 5-8 Oct. 2003., Vol 4. pp 3918-3923
http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=1244500

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FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Reacting to *unexpected* and *expected* situations: A robot showing 'human emotions'. Somebody intruding in your space ! A single variable mapping – *SPEED* or *DISTANCE* + *{Emotion}*

	PERCEPTION		EMOTION
DISTANCE			
IF	the intruder is Far away	*THEN*	we have No Fear
IF	the intruder is Very Near	*THEN*	we are Not Surprised
SPEED			
IF	the intruder is Stationary	*THEN*	we have No Fear
IF	the intruder is moving Fast	*THEN*	we are Not Angry

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FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

A Contingency table

Reacting to *unexpected* and *expected* situations: A robot showing 'human emotions'. Somebody intruding in your space ! A two variable mapping – *SPEED* and *DISTANCE* + *{Emotion}*

Distance	Speed	
	Stationary	Fast
Very Near	Very Angry, Not surprised, No Fear	Not Angry, Not surprised, Very Fearful
Far	Very Angry, Not surprised, No Fear	Not Angry, Very Surprised, No Fear

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FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Reacting to *unexpected* and *expected* situations: A robot showing 'human emotions'. Somebody intruding in your space ! A two variable mapping – *SPEED* and *DISTANCE* + *{Emotion}*

Distance	Speed		
	Stationary	**Slow**	**Fast**
Very Near	**VA, NS, NF**	**A, NS, F**	**NA, NS, VF**
Near	**A, NS, NF**	**NA, NS, NF**	**NA, S, F**
Far	**VA, NS, NF**	**A, S, NF**	**NA, VS, NF**

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FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Reacting to *unexpected* and *expected* situations: A robot showing 'human emotions'. Somebody intruding in your space ! A two variable mapping – *SPEED* and *DISTANCE* + *{Emotion}*

Emotional Linguistic Variable	Term Set
ANGER:	{VA → Very Angry; A → Angry; NA → Not Angry}
SURPRISE:	{VS → Very Surprised; S →Surprised; NS→ Not Surprised}
FEAR:	{VF → Very Fearful; F → Fearful; NF → No Fear}

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FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Reacting to *unexpected* and *expected* situations: A robot showing 'human emotions'. Somebody intruding in your space ! A two variable mapping – *SPEED* and *DISTANCE* + *{Emotion}*

Perception Linguistic Variable	Term Set
SPEED:	{F → Fast; SL → Slow; ST →Stationary
DISTANCE:	{VN → Very Near; N → Near; F→ Far Away}

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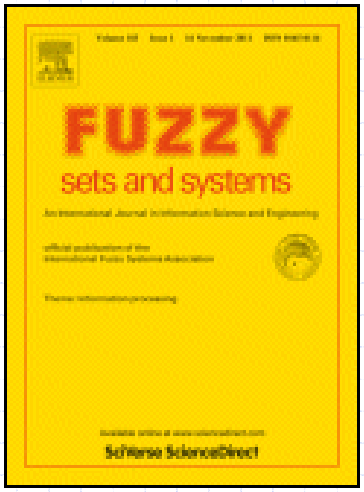
FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

What are fuzzy sets and systems

The theory of fuzzy sets now encompasses a corpus of basic notions including [..] aggregation operations, a generalized theory of relations, specific measures of information content, a calculus of fuzzy numbers.



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FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

What are fuzzy sets and systems

Fuzzy sets have led to
(1) a non-additive uncertainty theory [..possibility theory,]
(2) [a] tool for both linguistic and numerical modeling: fuzzy rule-based systems.

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FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Perception and Gender

When we look at men and women, our perception of the heights is approximate and motivated by pre-conceptions of what it takes to be a tall man or short woman.

It appears that the very quantitative concept of height has an in-built uncertainty.

P. J. MACVICAR-WHELAN (1978). Fuzzy Sets, the Concept of Height, and the Hedge VERY. *IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS*, VOL. SMC-8, NO. 6, JUNE 1978, pp 507-511

FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Perception and Gender

MacVicar-Whelan (1978) conducted 'an experimental and theoretical study of the categorization of human height is reported. Subjects of both sexes whose ages ranged from 6 to 72 were asked to class the height of both men and women using the labels VERY VERY SHORT, VERY SHORT, SHORT, TALL, VERY TALL, and VERY VERY TALL. The experimental results confirm Zadeh's contention about the existence of fuzzy classification (the lack of sharp borders for the classes)

P. J. MACVICAR-WHELAN (1978). Fuzzy Sets, the Concept of Height, and the Hedge VERY. *IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS*, VOL. SMC-8, NO. 6, JUNE 1978, pp 507-511

FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Perception and Gender: Term sets of heights were assigned different values by human observers in a controlled psychological experiment

Gender	Height in Centimetres					
	Very Very Short	Very Short	SHORT	TALL	Very Tall	Very Very Tall
Men	138.7	143.1	156.8	179.4	189.5	197.7
Women	134.8	143.0	149.2	172.9	181.4	190.9

FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Perception of Men's Height – figures in inches here

	Short			Tall		
OBSERVER	Very Very	Very	Just	Very Very	Very	Just
F1	59.2 (±1)	61.8 (±1)	67.0 (±2)	80.5 (2.5)	77(±2)	71.5(±1)
F8	44.4 (±1)	46.5(±3)	57.2 (±4.2)	75.2(±6)	68.2 (±10.8)	66.3 (± 12)
M11	53.0 (± 10)	54.0 (±11.7)	55. (±11.5)	80.4 (±7.5)	78.0 (±4)	75.2 (±6.5)
AVERAGE (8 obs; 2-3 methods)	54.6 (4.5)	56.34 (±5.58)	61.73 (5.75)	77.85 (±6.27)	74.60 ±5.32)	70.64 (±5)

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Perception of Women's Height – figures in inches here

	Short			Tall		
OBSERVER	Very Very	Very	Just	Very Very	Very	Just
F1	55 (±2)	57.5 (±2)	60 (±2)	78 (±2)	74.5 (±2)	70.4 (±1)
F8	52.4 (±5)	57.2 (±4)	52.4 (±9)	76.5 (±9.5)	73.2 (±10)	69.0 (±6)
M11	49.5 (± 11)	51.5 (±7)	54.8 (±11.5)	79.0 (±14.5)	76.4 (±8.8)	75 (±6.3)
AVERAGE (8 obs; 2-3 methods)	53.08 (7.4)	56.28 (±4.62)	58.75 (5.75)	75.16 (±6.75)	71.41 (±5.32)	68.06(±4.9)

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FUZZY LOGIC & FUZZY SYSTEMS

UNCERTA

Perception and Gender: Term sets of heights were assigned different values by human observers in a controlled psychological experiment

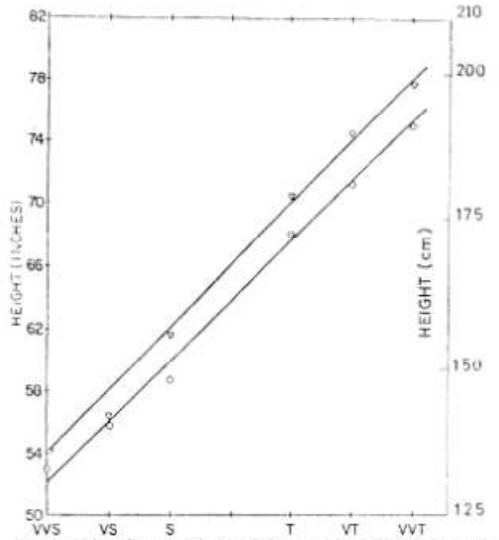

Fig. 4. Average values for neutral points of terms descriptive of height of men and women: VVS = VERY VERY SHORT; VS = VERY SHORT; S = SHORT; T = TALL; VT = VERY TALL; VVT = VERY VERY TALL; ○ = women; △ = men.

FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

So why can't the computers do what we want the computers to do?

The solution for some is *soft computing* – where methods and techniques developed in branches of computing that deal with partial information, uncertainty and imprecision

FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

"Soft computing differs from conventional (hard) computing in that, unlike hard computing, it is tolerant of imprecision, uncertainty, partial truth, and approximation. In effect, the role model for soft computing is the human mind. The guiding principle of soft computing is: Exploit the tolerance for imprecision, uncertainty, partial truth, and approximation to achieve tractability, robustness and low solution cost."

The above quotation is from http://www.soft-computing.de/def.html

FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Fuzzy sets are sets whose elements have degrees of membership.

Fuzzy sets are an extension of the classical notion of set.

Taken from (Wikipedia) http://en.wikipedia.org/wiki/Fuzzy_set on 7th October 2008

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

In classical set theory, the membership of elements in a set is assessed in binary terms according to a bivalent condition — an element either belongs or does not belong to the set.

Fuzzy set theory permits the gradual assessment of the membership of elements in a set; this is described with the aid of a membership function valued in the real unit interval [0, 1].

Taken from (Wikipedia) http://en.wikipedia.org/wiki/Fuzzy_set on 7th October 2008

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Fuzzy set theory permits the gradual assessment of the membership of elements in a set; this is described with the aid of a membership function valued in the real unit interval [0, 1].

Fuzzy sets generalize classical sets, since the indicator functions of classical sets are special cases of the membership functions of fuzzy sets, if the latter only take values 0 or 1

Taken from (Wikipedia) http://en.wikipedia.org/wiki/Fuzzy_set on 7th October 2008

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than precise.

Taken from (Wikipedia) http://en.wikipedia.org/wiki/Fuzzy_logic on 7th October 2008

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

As in fuzzy set theory the set membership values can range (inclusively) between 0 and 1, in fuzzy logic the degree of truth of a statement can range between 0 and 1 and is not constrained to the two truth values {true, false} as in classic predicate logic.

Taken from (Wikipedia) http://en.wikipedia.org/wiki/Fuzzy_logicon 7th October 2008

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

The Originators:
Jan Lukasiewicz
Born: 21 Dec 1878 in Lvov, Austrian Galicia (now Ukraine); Died: 13 Feb 1956 in Dublin, Ireland

Taken from http://www-groups.dcs.st-and.ac.uk/~history/Biographies/Lukasiewicz.html on 7th October 2008

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

The Originators:
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Born: 21 Dec 1878 in Lvov, Austrian Galicia (now Ukraine); Died: 13 Feb 1956 in Dublin, Ireland.

Multi-valued logics are logical calculi in which there are more than two truth values.

Taken from http://en.wikipedia.org/wiki/Multi-valued_logic on 7th October 2008

FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

The Originators:
Thomas Bayes
1702 – 1761

Bayesian probability is the name given to several related interpretations of probability, which have in common the notion of probability as something like a partial belief, rather than a frequency.

Rev. T. Bayes

Taken from http://en.wikipedia.org/wiki/Thomas_Bayes on 7th October 2008

FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

The Originators:
Lotfali Askar Zadeh born February 4, 1921; an Iranian-American mathematician and computer scientist, and a professor of computer science at the University of California, Berkeley.

Taken from http://en.wikipedia.org/wiki/Thomas_Bayes on 7th October 2008

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FUZZY LOGIC & FUZZY SYSTEMS

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The Originators:
Lotfali Askar Zadeh born February 4, 1921; an Iranian-American mathematician and computer scientist, and a professor of computer science at the University of California, Berkeley.

Taken from http://en.wikipedia.org/wiki/Lotfi_Asker_Zadeh on 7th October 2008

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

How is one to represent notions like:

large **profit**

high **pressure**

tall **man**

wealthy **woman**

moderate **temperature.**

Ordinary set-theoretic representations will require the maintenance of a crisp differentiation in a very artificial manner:

high, high to some extent, not quite high, very high

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FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

What is 'fuzzy logic'?

Are there computers that are inherently fuzzy and do not apply the usual binary logic?

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FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

And more recently FUZZY Machines have been developed

The Extraklasse machine has a number of features which will make life easier for you.

EXTRA KLASSE from Siemens

Fuzzy Logic detects the type and amount of laundry in the drum and allows only as much water to enter the machine as is really needed for the loaded amount. And **less water** will **heat up quicker** - which means **less energy consumption**.

① Fuzzy Logic

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FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

And more recently FUZZY Machines have been developed

The Extraklasse machine has a number of features which will make life easier for you.

EXTRA KLASSE from Siemens

•**Foam detection**

Too much foam is compensated by an additional rinse cycle:

•**Imbalance compensation**

In the event of imbalance calculate the **maximum possible speed**, sets this speed and starts spinning.

•**Automatic water level adjustment**

Fuzzy automatic water level adjustment adapts water and energy consumption to the individual requirements of each wash programme, depending on the amount of laundry and type of fabric.

① Fuzzy Logic

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FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Fuzzy logic is not a vague logic system, but a system of logic for dealing with vague concepts.

FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Finally, been driven away by an autonomous car that successfully avoids obstacles on its own!

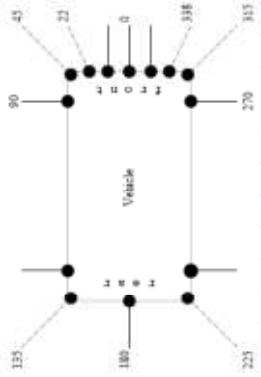
Obstacle avoidance requires a model of the actual environment of the vehicle. This model can be built from a priori information (maps of the stationary obstacles. etc.), or sensory data obtained on-line (information about the moving obstacles). This model is updated at each time step.

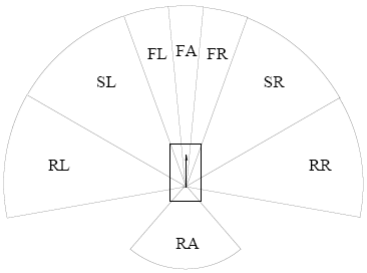
Fraichard Th., & Garnier, Ph. (2001). "Fuzzy control to drive car-like vehicles," *Robotics and Autonomous Systems*, Vol. 34 (1) pp. 1-22, 2001. (available at http://citeseer.ist.psu.edu/fraichard97fuzzy.html)

FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Finally, been driven away by an autonomous car that successfully avoids obstacles on its own!





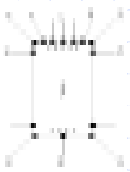
Forward Axle; Rear Axle; F. Left
F. Left; Side Left; Side Right; Rear Left; Rear Right

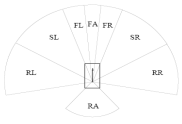
FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Finally, been driven away by an autonomous car that successfully avoids obstacles on its own!

– if (velocity is positive-high)
and (obstacle in FA is near)
and (obstacle in FL is near)
and (obstacle in FR is near)
then (acceleration is negative-high)





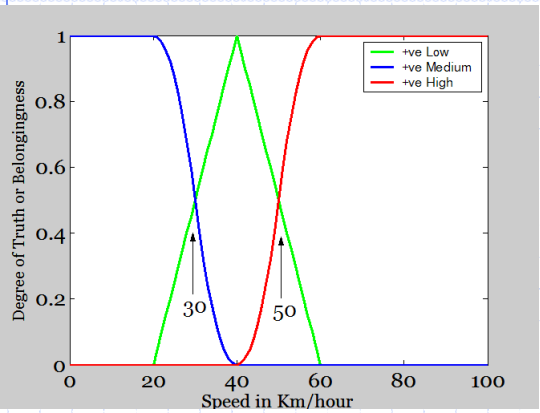
Forward Axle; Rear Axle; F. Left
F. Left; Side Left; Side Right; Rear Left; Rear Right

A 'linguistic' rule

FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Examples of velocity fuzzy membership functions (+ve Low, +ve Medium and +ve High, that may have been used by Ligier – the autonomous car



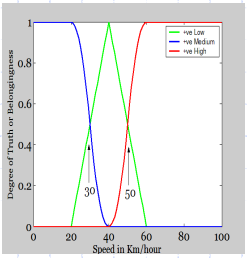
– if (velocity is positive-high)
and (obstacle in FA is near)
and (obstacle in FL is near)
and (obstacle in FR is near)
then (acceleration is negative-high)

A 'linguistic' rule

FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Examples of velocity fuzzy membership function +ve Medium that may have been used by Ligier – the autonomous car

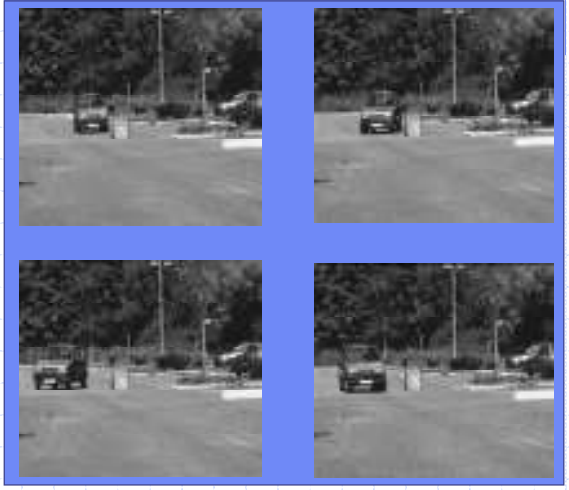


Velocity		Belongingness?
Speed	Degree of Truth →+ve Medium	
0	0	Definitely Not
5	0	Definitely Not
10	0	Definitely Not
15	0	Definitely Not
20	0	Definitely Not
25	0.25	Chances are less then even
30	0.50	Chances are about even
35	0.75	Chances are better than even
40	1	Definitely
45	0.75	Chances are better than even
50	0.50	Chances are about even
55	0.25	Chances are less then even
60	0	Definitely Not
65	0	Definitely Not
70	0	Definitely Not

FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Twenty linguistic rules drive a *Ligier*



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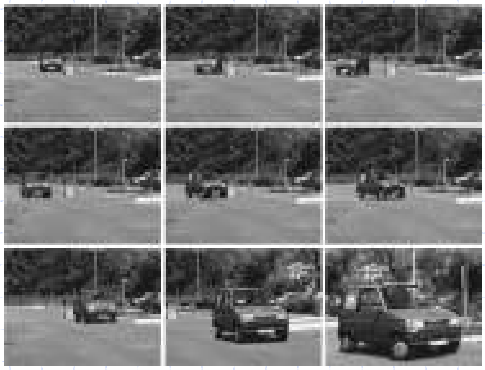
FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Finally, been driven away by an autonomous car that successfully avoids obstacles on its own!

Twenty linguistic rules drive a *Ligier*



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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Lotfi Zadeh introduced the *theory of fuzzy sets*: A fuzzy set is a collection of objects that might belong to the set to a degree, varying from 1 for full belongingness to 0 for full non-belongingness, through all intermediate values

Zadeh employed the concept of a membership function assigning to each element a number from the unit interval to indicate the intensity of belongingness. Zadeh further defined basic operations on fuzzy sets as essentially extensions of their conventional ('ordinary') counterparts.

Lotdfi Zadeh, Professor in the Graduate School, Computer Science Division
Department of Elec. Eng. and Comp Sciences, University of California Berkeley, CA 94720 -1776
Director, Berkeley Initiative in Soft Computing (BISC)
http://www.cs.berkeley.edu/People/Faculty/Homepages/zadeh.html
In 1995, Dr. Zadeh was awarded the IEEE Medal of Honor "For pioneering development of fuzzy logic and its many diverse applications." In 2001, he received the American Computer Machinery's 2000 Allen Newell Award for seminal contributions to AI through his development of fuzzy logic.

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Fuzzy control provides a formal methodology for representing, manipulating, and implementing a human's heuristic knowledge about how to control a system.

The heuristic information – information based on 'rules of thumb' come from two sources: Operators running complex control systems and design engineers of such systems who have carried out mathematical analysis.

Passino, Kevin M. & Yurkovich, Stephen (1998). Fuzzy Control. Menlo Park (California): Addison Wesley (http://www.ece.osu.edu/~passino/FCbook.pdf#search=%22fuzzy%20control%22)

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FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Washing machines, blood pressure monitors, and obstacle avoiding cars, that claim to have built-in *fuzzy logic* demonstrate how fuzzy set theory, fuzzy logic and fuzzy control are used conjunctively to build the intelligent washing machine, the 'wise' monitors and the clever car.

FUZZY LOGIC & FUZZY SYSTEMS

BACKGROUND & DEFINITIONS

Zadeh also devised the so-called fuzzy logic: This logic was devised model 'human' reasoning processes comprising:

vague predicates:	**e.g. *large, beautiful, small***
partial truths:	**e.g. *not very* true, *more* or *less* false**
linguistic quantifiers:	**e.g. *most, almost all, a few***
linguistic hedges:	**e.g. *very, more* or *less.***

FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

Scientific American: Ask the Experts: Computers

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FUZZY LOGIC & FUZZY SYSTEMS

UNCERTAINITY AND ITS TREATMENT

In this course you will learn:

1. how **imprecision** in concepts can be discussed using the basics of fuzzy sets;
2. the basic principles of **organizing** a fuzzy logic system
3. what is inside the **rule-base** of a fuzzy **control** system
4. about methods of **building** a fuzzy control system

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FUZZY LOGIC & FUZZY SYSTEMS
UNCERTAINITY AND ITS TREATMENT

Course Content

1. **Terminology: Uncertainty, Approximations and Vagueness**
2. **Fuzzy Sets**
3. **Fuzzy Logic and Fuzzy Systems**
4. **Fuzzy Control**
5. **Neuro-fuzzy systems**

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FUZZY LOGIC & FUZZY SYSTEMS
UNCERTAINITY AND ITS TREATMENT

Assessment

1. **Assessment is by examination and by project work. Project work attracts a mark of up to 20% of the year end mark, and the examination makes up the remaining 80%.**
2. **Project is conducted by each student individually. It encourages the design, writing and testing of programs as a means of appraising the theory and techniques discussed in the course.**

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FUZZY LOGIC & FUZZY SYSTEMS
UNCERTAINITY AND ITS TREATMENT

Assessment

The examination is three hours long, and students are required to answer three questions from a selection of five. Most questions will contain a short discursive component and a related question requiring the student to demonstrate problem-solving abilities related to that discursive component.

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FUZZY LOGIC & FUZZY SYSTEMS
UNCERTAINITY AND ITS TREATMENT

Books, Websites, Software

Recommended Texts

Kosko, Bart (1993). *Fuzzy Thinking: The New Science of Fuzzy Logic.* London: Harper Collins. (Available through Trinity Library → but have to wait for it to be called from Santry Collection);

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FUZZY LOGIC & FUZZY SYSTEMS
UNCERTAINITY AND ITS TREATMENT

Books, Websites, Software

Companion Texts

Negnevitsky, Michael (2002). *Artificial Intelligence: A Guide to Intelligent Systems (1st Edition).* Harlow:Pearson Education Ltd. (Chapter 4, pp 87-128). (Available at Hamilton Library Open-access Collection)

Kruse, Rudolf., Gebhardt, J., and Klawonn, F. (1994). *Foundations of Fuzzy Systems.* New York: John Wiley and Sons. (Chapter 2 for *fuzzy sets* and Chapter 4 for *fuzzy control*) (Available through Trinity Library → but have to wait for it to be called from Santry Collection)

Yager, Ronald R., and Filev, Dimitar P. (1994). *Essentials of Fuzzy Modeling and Control.* New York: John Wiley and Sons. (Chapter 4 for *fuzzy control*).

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FUZZY LOGIC & FUZZY SYSTEMS
UNCERTAINITY AND ITS TREATMENT

Books, Websites, Software

Online Book

Passino, Kevin M. & Yurkovich, Stephen (1998). Fuzzy Control. Menlo Park (California): Addison Wesley (http://www.ece.osu.edu/~passino/FCbook.pdf#search=%22fuzzy%20control%22)

Milestone Papers:

Zadeh, L. (1965), "Fuzzy sets", Information and Control, Vol. 8, pp. 338-353.

Takagi, H., and Sugeno, M. (1985). 'Fuzzy Identification of Systems and its Applications to Modeling and Control'. IEEE Transactions on Systems, Man, and Cybernetics. Volume 115, pages 116-132.

Introductory Papers

Scientific American.com (2006). "'What is 'fuzzy logic'? Are there computers that are inherently fuzzy and do not apply the usual binary logic."
http://www.sciam.com/askexpert_question.cfm?articleID=000E9C72-536D-1C72-9EB7809EC588F2D7&catID=3 (Site visited 9 October 2006)

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FUZZY LOGIC & FUZZY SYSTEMS
UNCERTAINITY AND ITS TREATMENT

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Zadeh, L. (1965), "Fuzzy sets", Information and Control, Vol. 8, pp. 338-353.

Takagi, H., and Sugeno, M. (1985). 'Fuzzy Identification of Systems and its Applications to Modeling and Control'. IEEE Transactions on Systems, Man, and Cybernetics. Volume 115, pages 116-132.

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http://www.sciam.com/askexpert_question.cfm?articleID=000E9C72-536D-1C72-9EB7809EC588F2D7&catID=3 (Site visited 9 October 2006)

Stanford Encyclopedia of Philosophy (2006). Fuzzy Logic. (http://plato.stanford.edu/entries/logic-fuzzy/, site visited 10 October 2006).

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FUZZY LOGIC & FUZZY SYSTEMS
UNCERTAINITY AND ITS TREATMENT

Books, Websites, Software

Fishing for Software:

Carnegie-Mellon University. (1995) http://www-cgi.cs.cmu.edu/afs/cs.cmu.edu/project/ai-repository/ai/areas/fuzzy/0.html (Site visited 9 October 2006)

Fuzzy Tech (2006). A software vendor offering demo programs (http://www.fuzzytech.com/) (Site visited 9 October 2006)

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