INDUSTRIAL APPLICATIONS AND EDUCATION ON FUZZY SYSTEMS IN JAPAN

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ABSTRACT - The total number of industrial fuzzy applications in Japan is now more than 200. Two big fuzzy research projects started in 1989. Most Japanese people including non experts now recognize the word "fuzzy" as an aspect of human intelligence because of the result of fuzzy home electronics vogue in 1990. Such a historical story of research activities and technical trends in Japan are introduced.

1 BEGINNING OF FUZZY RESEARCH IN JAPAN

After the publication of Prof. Zadeh's paper "fuzzy set" in 1965, many Japanese people studied it. But only small number of people showed great interests on it. Among them Prof. T.Terano (Tokyo Institute of Technology) and Prof. H.Shibata (Tokyo University) established a working group on fuzzy systems in Tokyo. They organized regular research meetings almost once a month in Tokyo university and Tokyo Institute of Technology. Although the size of the working group was not so big, i.e., the number of registered members was less than 100, each member studied very hard not only fuzzy theory but also general ambiguous information processing methodology including probability theory, statistics, and so on. They published a series of annual English written reports named "summary of papers on general fuzzy problems" and distributed the reports to various places in foreign countries.

Also in Kansai area including Osaka and Kyoto prefectures, Prof.K.Tanaka (Osaka Univ.), who has already disappeared, and Prof.K.Asai (Osaka Pref. Univ.) established another working group on fuzzy science in the late 1970's.

Both of these working groups contributed so much in the Japanese fuzzy community in the early stages. They organized several fuzzy research projects based on the Japanese government research fund called "Monbusho Kakenhi." But the main body of these Japanese fuzzy community was not so big one and mainly consists of university researchers. Most of the company engineers and other university researchers did not pay any attention to this field or some of them are so called anti-fuzzy scientists. So the general atmosphere for the fuzzy research was not good in these early days.

2 ACTIVITIES OF IFSA JAPAN CHAPTER

In the summer of 1984 it was decided to establish the IFSA (International Fuzzy Systems Association) during FIP'84 (Fuzzy Information Processing) Conference in Hawaii. Then the Japanese two working groups mentioned above were merged into the IFSA Japan Chapter in January 1985.

But the total number of individual members in IFSA Japan Chapter was not many (about 50 in 1985) because of the following two reasons. One is that the annual membership fee of IFSA was too expensive compared with that of other major academic societies. Another reason was that the fuzzy theory itself was not popular. So the IFSA Japan Chapter made a new membership grade "chapter member." The annual fee of the IFSA Japan Chapter Member was very reasonable (2000 Japanese yen i.e. about $14).

Each chapter member, of course, could not receive the IFSA official Journal FSS (Journal of Fuzzy Sets and Systems), but instead of it they could receive a quarterly published IFSA Japan chapter news written in the Japanese language.

The IFSA Japan Chapter also started so many activities to make the fuzzy theory popular for the Japanese company

engineers. Several special interests' groups were organized such as "fuzzy control", "fuzzy OR", and "fuzzy inference and expert systems". These research groups especially pay attention to practical applications and the research meetings were opened even for non members. Usually in the evening just after finishing the lectures in the regular meetings, most of the participants went to the Japanese style public house, where they drank and discussed what is the essential point of the fuzziness in the presented lectures. In such a way the number of participants gradually increased.

The IFSA Japan Chapter also started the annual symposium called "fuzzy systems symposium". The first fuzzy systems symposium was held in Kyoto Univ. in the May 1985. The total number of papers submitted was 30 and that of the participants was 110. The second one was held in Gakushuin Univ. (Tokyo) in June 1986, and the numbers of papers submitted and participants were 60 and 200, respectively. It should be emphasized that about 50 % came from companies. In 1987 the 2nd IFSA World Congress was held in Gakushuin University and it was a great success to promote the fuzzy concepts (especially in the field of industrial fuzzy control applications) in Japan. Many scientific journalists in Japan wrote the reports on fuzzy control applications. The following table shows the increasing of the number of industrial fuzzy applications in Japan in these days.

Table 1 The Number of Industrial Fuzzy Applications in Japan

Date	Numbers
1986.8.27	20
1987.6. 1	50
1988.3. 3	86
1988.8.24	100
1989.3.15	124

3 INDUSTRIAL APPLICATIONS AND FIRST FUZZY VOGUE

It will be clear from the table 1 that the number of industrial fuzzy applications start to increase in the middle of 1980's in Japan. But of course several difficult efforts were made in a few Japanese companies before such successful results.

The vanguard companies of industrial fuzzy applications in Japan were Hitachi and Fuji Electric. Both of them started their fuzzy project in 1979/1980. Hitachi's project was on the Automatic Train Operation. They have already realized the PID control based ATO system in Sapporo Subway. But the total performance of the PID based ATO system compared with that of skilled human operator/driver was not sufficient. So the engineers tried to improve the performance by doing various methods including tuning up the PID parameters. However the result was unsuccessful. Here the performance means the following five factors: precision of the stopping position, electric energy consumption, average running time between railway stations, traceability of skilled characteristics in the velocity and the running distance curve, and riding comfortability for passengers (it depends on how many times the acceleration/deceleration notches are changed). Finally the engineers noticed that the essential difference between the PID ATO and the skilled operator was the prediction of the future trend, i.e. human operators decide the operation from a global view point based on their experience of the train operation. Such factors could be considered by introducing the rule based fuzzy inference. So they decided to introduce the fuzzy control method though their proposal was not necessarily welcomed by their managers. After their continuous efforts for more than three years in the severe research condition, they could obtain a successful result by the field test in Sapporo. Such a result was reported in the several occasions and it was a good advertisement for the promotion of fuzzy control method to other engineers in Japan. But it took another several years till their result was realized in the newly constructed Sendai subway system: the real operation started in July 1987. You can understand that the government officers must pay precise attentions to confirm the safety and reliability against the newly introduced "fuzzy" technique. So nearly 8 years were necessary to realize the real operation of the fuzzy ATO system.

Another example of the industrial fuzzy applications in the early stage was the water treatment system developed by Fuji Electric. It usually takes more than 5 years for a freshman to become an expert operator in the water purifying process operation. It is essentially a feed forward control based on the human expertise knowledge, because a few hours are necessary to get the result after the medicine injection. And there exists no reasonable mathematical model based on differential equations to fit the water treatment process. So it was difficult to realize an automatic control system based on the traditional control technique. It was also the same time as the Hitachi's case, i.e. in 1980, that the engineers in the water treatment section in Fuji Electric started their fuzzy control project in the anti-fuzzy atmosphere. After their noble efforts for more than 3 years they could announce a successful experimental result confirmed in Akita-city water treatment department, where only ten fuzzy production rules realized the expert human operation. But it took also other few years to realize their fuzzy control technique in the real industrial operation (in Sagamihara-city) because of several political reasons. Fuji Electric, however, could develop and send to the real market the Japanese first general fuzzy controller named FRUITAX in 1985. It was a process controller mainly consisted of 16-bit process computer and FORTRAN fuzzy inference software.

These two examples became a good motivation for other company engineers to take part in the fuzzy community. As already shown in Table 1, many successful applications were announced in the later part of 1980's. Most of them concerned with process control, where skilled human operators could operate well but the traditional control technique could not realize an automatic operation. Some of them are indicated randomly in the followings:

- The Group Control Operation in Elevators (Hitachi Ltd., others) During the rush hours in elevators, it scatters the operation to reduce the waiting and riding

time.

- Ventilation Systems in Expressway Tunnels (Toshiba Corp., oth ers) Judging by the amount of traffic, it lessens the number of times the jet fans inside the tunnels are turned off and on, saving electricity and prolonging the life of the fan.
- City Garbage Incinerators (Mitsubishi Heavy Industries Ltd.) By making the layers of garbage equal in thickness for incineration, it reduces the damage done to the incinerators.
- Powder Substances Measuring System (Fuji Photo Film Co.Ltd.) By processing the supply flow speed of powder substances through a closed loop, it attains high grade measurement.

These kinds of applications were announced in various places including IFSA Japan Chapter regular meetings. So we could observe research and development cooperation between company engineers and university researchers in the middle of 1980's. The 2'nd IFSA world congress held in 1987 (Tokyo) was a good opportunity to inform the usefulness of fuzzy technique to many engineers. More than 30 Japanese fuzzy scientists made various efforts for the organization of 2'nd IFSA world congress to push the fuzzy technology under the sunshine from the shadow. It was remarkable that all of them works by their own expense. Their activity covers calling for R&D cooperation with companies, publishing easily understandable textbooks written in the Japanese language, giving a series of special lectures and seminars on fuzzy technology, making arrangements to invite many talented fuzzy researchers from all over the world, making attractive exhibition examples and calling for scientific journalists to announce the applicability of fuzzy techniques. As a result the 2'nd IFSA world congress made the first fuzzy vogue for university researchers and company engineers in 1987.

4 TWO BIG NATIONAL FUZZY RESEARCH PROJECTS

The first Japanese fuzzy vogue in 1987 was brought by the cooperation between universities and companies. Then the Japanese government took part in such a research field.

The Science and Technology Agency (STA) of the Japanese Government asked the possibility of a national research project on this topic in the late of 1987. The STA has special coordination funds and has already promoted several high-tech issues.

Then in the spring of 1988 the Ministry of International Trade and Industry (MITI) also announced the concept of the Laboratory for International Fuzzy Engineering research (LIFE).

Both of them started the one year feasibility study in 1988 (precisely speaking from April 1988 to March 1989, note that the Japanese budget year starts April). Both of the groups reported the affirmative answer, and two national fuzzy research projects started from 1989.

The STA fuzzy project is a five-years project with funds of 1,200,000,000. The subject of the project is "Fuzzy Systems and Their Applications to Human and Natural Systems". It is divided into several sub themes and each theme is entrusted to a university or a national laboratory or a private company. The followings are the list of such themes and organizations in charge:

(Group 1) Foundation and Fundamental Techniques in Fuzzy Theory

- **1-1** Foundation of Fuzzy Logic (Meiji Univ.)
- **1-2** Fuzzy Inference Algorithms (Meiji Univ. and Osaka Univ.)
- **1-3** Fundamental Techniques for Developing Fuzzy Computers (Meiji Univ. and Nihon InfraLogic Co.Ltd.)

(Group 2) Human Features and Human Interface

- **2-1** Control Technique
  - **2-1-1** Intelligent Control for High-Speed and Unstable Systems (Tokyo Institute of technology)
  - **2-1-2** Intelligent Control for Unstructured Systems (The Institute of Physical and Chemical Research)
- **2-2** Recognition Technique
  - **2-2-1** Real Time Image Understanding (Hosei Univ.)
  - **2-2-2** Hand-written Character Recognition (OMRON Co.)
- **2-3** Modeling for Process of Sensory Information Processing and Its Implementation (National Aerospace Lab. and The Institute of Physical and Chemical Research)
- **2-4** Human Interface
  - **2-4-1** Human Interface for Everyday Life (Industrial Products Research Institute)
  - **2-4-2** Human Interface in High-Speed and Unstable Systems (Kawasaki Heavy Industries Ltd.)

(Group 3) Processes of Human's Intelligent Information Processing and Natural and Social Phenomena

- **3-1** Intelligent Information Processing Techniques
  - **3-1-1** Intelligent Evaluation Systems (Laboratory for International Fuzzy Engineering research)
  - **3-1-2** Fuzzy Information Retrieval Techniques (Matsushita Electric Industrial Co.Ltd.)
  - **3-1-3** Fuzzy Processing in an Association Mechanism (Communication Research Lab.)
- **3-2** Human Behavior and Social Phenomena
  - **3-2-1** Reliability Estimation of Large-Scale Systems (Kumamoto Univ.)
  - **3-2-2** Development of Fuzzy Techniques and Systems for Management and Social Problems (Osaka Institute of Technology)

3-3 Natural Phenomena

- **3-3-1** Fundamental Techniques for Earthquake Prediction (Meteorological Research Institute)
- **3-3-2** Development of Simulator for Prediction of Environmental Pollution (National Institute of Environmental Studies)
- **3-3-3** Modeling of Plant Growth (National Agriculture Research Center)

The research results are reported in the fuzzy systems symposium sponsored by STA. (Usually held in November, but reported in Japanese language).

Another national fuzzy research project LIFE (Laboratory for International Fuzzy research) was founded on March 28, 1989 by permission of the Minister for International Trade and Industry, according to the National Research and Development Program. It is a consocium and a 6-years project with funds of 5,000,000,000. There exist nearly 50 association company members, i.e. CANON INC., FUJITSU Ltd., Hitachi Ltd., IBM Japan Ltd., KAWASAKI STEEL Co., KONICA Co., MATSUSHITA ELECTRIC INDUSTRIAL Co.Ltd., Mazda Motor Co., Minolta Camera Co.Ltd.,Mitsubishi Electric Co., NEC Co., NIPPON STEEL Co., NISSAN MOTOR Co.LTD., NKK Co., NTT DATA COMMUNICATIONS SYSTEM Co., Oki Electric Industry Co.Ltd., Olympus Optical Co.Ltd., OMRON Co., Ricoh Co.Ltd., SHARP Co., SHIMIZU Co., SONY Co., TAKENAKA Co., TOSHIBA Co., TOYOTA MOTOR Co., YAMAICHI SECURITIES Co.LTD. and so on. Nearly 30 researchers are sent from these companies and studying various topics. The LIFE is in Yokohama city (Siber Hegner Building 3F/4F, 89-1 Yamashita-cho Nakaku, Yokohama-city 231, Japan). The LIFE consists of 3 laboratories and the research subjects are listed below:

1st Laboratory: Fuzzy Control

- **1-1** Study on fuzzy control theory
- **1-2** Development and experimental production of tools for supporting fuzzy control system structuring
- **1-3** Experimental production and evaluation of application systems

2nd Laboratory: Fuzzy intellectual information processing

- **2-1** Fuzzy decision support system
- **2-2** Image understanding
- **2-3** Fuzzy expert system shell
- **2-4** Fuzzy Diagnosis System for power station
- **2-5** Language understanding for robot
- **2-6** Intellectual evaluation and semantic understanding

3rd Laboratory: Fuzzy computer

- **3-1** Fuzzy computer architecture
- **3-2** Fuzzy software
- **3-3** Fuzzy hardware

The research results are reported in the International Fuzzy Engineering Symposium (IFES). The 1st IFES was held in Yokohama Nov. 1991. The number of participants was 424 (Japan 342, foreign 24 countries 82), and 167 papers were published. The 2nd IFES will be held in 1995 in cooperation with FUZZ-IEEE.

The organizations and the studying subjects in both STA Project and LIFE will be modified according to the research environment. But these two national fuzzy projects made an important role to promote the fuzzy technology in Japan.

5 JAPAN SOCIETY FOR FUZZY THEORY AND SYSTEMS (SOFT)

After the 2nd IFSA world Congress in Tokyo 1987, fuzzy technology was accepted for many Japanese researchers including company engineers. Finally the total number of IFSA Japan Chapter members exceeded 500. Many individual members requested to publish Japanese language written journals instead of IFSA Japan Chapter News and to establish a Japanese fuzzy society.

So a project team was organized and finally the Japanese fuzzy society named SOFT (Japan Society for Fuzzy Theory and systems) was established in June 3 1989 during the 5th fuzzy systems symposium in Kobe.

The secretariat office of SOFT was set in LIFE (Laboratory for International Fuzzy Engineering research). The total number of individual members right now (July 1992) is 2000 and that of company members is 115.

The SOFT has 8 region chapters; Hokkaido region, Tohoku region, Kanto region, Hokusinetsu region, Tokai region, Kansai region, Chugokusikoku region, Kyushu region (from the north to the south), and 5 special interest research groups; fuzzy control, fuzzy OR, fuzzy inference and expert systems, non-engineering fuzzy application, fuzzy civil engineering. Each region chapter and each research group are arranging symposiums, panel discussions, seminars and so on for 3 to 12 times a year.

In 1991 the SOFT organized a new research investigation group, which is set directly under the SOFT directors' board to study the future direction of fuzzy technology. The journal of SOFT is published bimonthly and written in Japanese language with average 130 pages. (Recently its English translation is available from Allerton Press, Inc. NY, USA.) A lot of technical papers, valuable information, excellent reports and so on could be seen in this journal.

Of course the SOFT has a close relation with the IFSA Japan Chapter. The IFSA Japan Chapter is now a not so big organization, because it consists of only IFSA headquarters members (less than 50 people).

The biggest event in SOFT is the fuzzy systems symposium. In this year 1992 the 8th fuzzy systems symposium was held in Hiroshima and about 170 technical papers were presented for 450 participants.

Three years have already passed since the SOFT was established. It is now working very well, but all members are of course investigating how to find the prosperous was of the SOFT toward the 21st century.

6 FUZZY HOME ELECTRONICS AND THE 2ND FUZZY VOGUE

As already mentioned, the 1st fuzzy vogue appeared in 1987 in response to the 2nd IFSA World Congress. But this vogue was only for technical specialists, i.e. mainly for control engineers, because the practical application fields are limited to process fuzzy control.

However many engineers were studying how to introduce this noble technology "fuzzy control" to more familiar things, i.e. consumer products. Several products introducing fuzzy control technique appeared in the last stage of 1980's such as the water mixing valve developed by Matsushita Housing Equipment Co., the home air-conditioner by Mitsubishi Heavy Industry Co., the fuzzy auto iris 8 mm VCR by Sanyo Co., the fuzzy autofocus still camera by Canon Co. and others. These fuzzy consumer goods were welcomed in the real market and the performances were really improved compared with nonfuzzy goods from various viewpoints. But most of the consumers did not aware of the difference nor recognize the principle of fuzzy control.

In the late January 1990 a drastic decision was made by Matsushita Electric Industrial Co.Ltd (Panasonic may be popular outside Japan). They named their newly developed, fuzzy controlled automatic washing machine "Aisaigo(beloved wife) Day Fuzzy", printed the word "fuzzy" on the front panel, and said "fuzzy, fuzzy, fuzzy" in TV commercials and newspaper advertisement from February 1990.

It was a very strong impression for most of the consumers. (Even we Japanese fuzzy scientists were amazed to find a famous actress advertising the Panasonic "Fuzzy" washing machine in TV and newspapers).

At that time the English word "fuzzy" was not popular in Japan. Most Japanese did not aware of the real meaning of "fuzzy". So the Panasonic people prepared the explanation "intellectual fuzzy", i.e. "fuzzy" means "intelligence", to avoid the misunderstanding such as "fuzzy washing machine is fool or stupid". Anyway the "fuzzy" washing machines were sold very well and other home electronics companies followed the Panasonic's "fuzzy business". Fuzzy vacuum cleaners, fuzzy rice cookers, fuzzy refrigerators, fuzzy hot lugs, and almost all fuzzy home electronics goods were produced and sent to the Japanese consumer market in 1990.

The results were perfect. Most of the home electronics companies got a great profit by "fuzzy" products in 1991. Consumers including housewives and even small children recognized the word "fuzzy", and "fuzzy" won the gold prize of the new word in 1990. It should be noted that there existed the following several important points to realize this fascinating result:

1. The consumers could recognize the crisp improvement in the fuzzy products, e.g. the fuzzy washing machine can establish the best washing conditions (time, cycle,etc.) by using fuzzy inference to determine the amount, quality, and how dirty the wash is.

2. The economical situation in 1990 was very good so there existed so many consumers to pay a big money for excellent goods.(In general, the fuzzy goods were very expensive compared with ordinary goods, because various sensors are equipped with and because of R&D expense).

In such a way the 2nd fuzzy vogue could be observed in 1990. This phenomenon was reported to all over the world and became a good stimulus for the promotion of fuzzy technology.

7 EDUCATION OF FUZZY SYSTEMS IN JAPAN

After 1985 the IFSA Japan Chapter started so many activities to make the fuzzy theory popular for the Japanese company engineers. Several special interests' groups were organized such as "fuzzy control", "fuzzy OR", and "fuzzy inference and expert systems". These research groups especially pay attention to practical applications and the research meetings were opened even for non members. Usually in the evening just after finishing the lectures in the regular meetings, most of the participants went to the Japanese style public house, where they drank and discussed what is the essential point of the fuzziness in the presented lectures. In such a way the number of participants gradually increased.

The core members of IFSA Japan chapter published a good textbook "Introduction to Fuzzy Systems" written in Japanese language in 1987. More than 10,000 copies have been sold out. It was translated in English, Korean and Chinese language later.

One example of the industrial fuzzy applications in the early stage was the water treatment system developed by Fuji Electric. On the basis of the result Fuji Electric developed and sent to the real market the Japanese first general fuzzy controller named FRUITAX in 1985. It was a process controller mainly consisted of 16-bit process computer and FORTRAN fuzzy inference software. Many company engineers showed great interests to this controller but it was not easy to use such a fuzzy control system in real line since they did not know the fundamentals of fuzzy control. So the inventor Fuji Electric and the author's group cooperated by NTT started to develop an engineer friendly fuzzy educational system. That was a CAI system called "Fuzzy Expert Systems" that worked on Japanese personal computer NEC PC. It took about 2 years to develop and finally released in 1989. More than 100 copies were sold.

Another educational tool that was a correspondence course on fuzzy systems has also been developed by the author's group in 1989. More than 2,000 company engineers graduated this course.

Recently the fuzzy technique is combined with other techniques such as neuro computing, genetic algorithms, chaos theory, and artificial life. Such a combined technique can also be studied by using CAI systems developed by the author's group, e.g. "An Introduction to Fuzzy, AI and Neuro" in 1991, "Practice in Fuzzy, AI and Neuro – Stability Control for Inverted Pendulum System–" in 1993 and "Chaos and Fractal" in 1994. More and more application examples will be generated after studying such educational systems.

8 RECENT FUZZY RESEARCH PROJECTS IN JAPAN

Recently a few other fuzzy research projects have started. Among them two research projects will be introduced in this section.

The first one is the project on "Fuzzy Technology and Applications for Space" sponsored by "The Japan Society for Aeronautical and Astronautical Sciences" and "NAtional Space Development Agency of Japan" (=NASDA or Japanese NASA). It started in April 1990 and technical reports (written in the Japanese language) were published in 1991 and 1992.

Subjects that are suitable for fuzzy applications in space are extracted. They are summarized as follows;

1. Orbital System
   - RCS(Reaction Control System) command generation,
   - RCS jet selection logic,
   - CMG angular momentum management,
   - management of redundant sensors and effects,
   - supervision of operational mode changes,
   - control law or parameter tuning for mass property variations,
   - kinematic alternative for space manipulator control,
   - positioning control of a large space manipulator,
   - motion planning for a manipulator,
   - active damping in a flexible structure,
   - modeling of a flexible structure,
   - image enhancement,
   - pattern recognition for stars,
   - pattern recognition for geometry or a characteristic mark,
   - satellite tracking and motion identification,
2. Transportation system
   - rendezvous guidance, proximity operations,
   - collision detection and avoidance,
   - recovery path generation,
   - GPS satellite selection,
   - supervision of guidance or control phase transitions,
   - entry profile design,
   - automatic landing,
3. Moon and planet exploration system
   - optical navigation,
   - approach and orbit insertion guidance,
   - descent guidance, landing site determination,
   - path planning for a rover,
   - rover-position identification using landmarks,
   - obstacle detection using a range finder,
4. Ground station
   - telemetry monitoring for status logging and health check,
   - fault detection isolation and reconfiguration,
   - system inspection,
   - spacecraft activity scheduling,
   - resource management.

In 1991, the following simulation experiments were studied;

i) reentry vehicle guidance,

ii) RCS thruster control,

iii) recovery path generation for rendezvous and docking,

iv) reduction of backlash effects on space manipulator joints,

v) kinematic alternative for space manipulation control,

vi) connector-pin extraction process.

These studies will be continued toward the realization of fuzzy applications in the real space.

The second one is a research project for the development of skill discriminating technology in the food industry that is sponsored by the Japan Research & Development association for intelligent control systems in the food industry. The outline of the development subjects in 1991 is summarized as follows;

i) Development of an intelligence control system for frozen food production processes: to develop a fuzzy control system for carrying out an image analysis comparable to skilled operator's discrimination and operation in the baking processes,

ii) Development of a skill discriminating technology for soy sauce production processes; to establish a technology capable of discriminating production processes of soy sauce on the basis of measured data,

iii) Development of an automatic control system in production processes of processed vegetable and fruit products: to develop an automatic control system for automatizing analysis in production processes and controlling viscosity,

iv) Development of a skill discriminating technology for cooking and forming processes of processed wheat products: to carry out research and analysis of the designing processes for a skill discriminating system, as well as development of software, manufacturing tests, and summation of evaluation and judgment,

v) Development of a skill discriminating technology for production processes of meat products:

   (a) to establish a skill discriminating technology in each production process of material meat, salted meat and other meat products, and

   (b) to establish an intelligent control technology for use in the process of salting,

vi) Research on control of production processes of confectioneries; to improve and stabilize the quality of confectioneries by controlling numerical values for factors that may influence the quality of confectioneries in production process,

vii) Development of an on-line ingredient analysis and discrimination system for production processes of wheat flour; to automatize control of mixing ratios of water, protein, ash, etc, in the production processes of wheat flour on the basis of an analysis,

viii) Development of an intelligence control system in the flour milling processes; to develop a FAS technology in the flour milling processes, responding to the diversification consumers needs and the shortage of skilled operators,

ix) Development of an intelligence control in flow granulation of powdery food materials; to carry out

   (a) an analysis of a flow granulation process and

   (b) development of an automatic operation system using an expert system,

x) Development of a skill discriminating system for Japanese Sake brewing processes; to develop a skill discriminating system based on data obtained by sensors in Japanese Sake brewing processes.

Some of these results are now introduced in the real production line.

9 FUZZY TECHNOLOGY IN FUTURE

In Japan we have already experienced fuzzy vogue twice. Right now many researchers are investigating various possibilities of developing new application fields of fuzzy technology such as expert systems, image recognition, economics, biomedical applications, psychology, law, and so on. Several good results have already obtained.

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