Human centric computing paradigms, computing with words, and intelligent decision support systems: a synergistic combination?

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How to speak about computer science, information technology (IT), „informatics”, …?

No single recipe!

Many possibilities and perspectives, for instance:

- mathematical or technological,
- hardware or software,
- visionary or technical,
- specialized or popular,
- either the (important) subject (of interest, research,…) or a tool for solving other important problems, …

The perspective adopted here is rather:

- More general than technical (but an implementation!),
- A relation to what is going on at best universities and „think tank" institutes,
- A „tool type" perspective,
- Searching for a synergy between tools, …

To be more specific: related to a great, maybe the greatest „meta-problems" in science (and in our life!) that is far for a full understanding and solution:

Decision making

We, control engineers and computer scientist, have witnessed that:

we move towards more and more complex systems

and, sooner or later we proceed:

from inanimate to animate systems

Finally, we encounter:

systems in which a human being (individual or a group) is a key element

This significantly changes the situation because:

even the most complex inanimate systems do not exhibit „nasty” deficiencies of humans, notably various inpredictabilities, inconsistencies, „irrationality”, etc.

Moreover, for the humans the only fully natural means of articulation and communications is natural language (strange to the „machine”!)

A gap between the human and the „machine”!

And….

With humans we would rather go for a decision support philosophy for solving (complex) problems, that is we assume that:

- Human decisionmakers are good at solving (complex) problems, and they know how to solve them,
- For human decisionmakers additional information (decision support) should be helpful while making decisions,
- The human decision makers are autonomous, i.e. they can make decisions by **taking into account or not** our advice (support).

Therefore:

A (ideal?) solution would be:

- To use new, human-consistent models of decision making,
- To use modern architectures and implementations of decision support systems,
- To involve some sort of „intelligence”,
- To follow some modern computing paradigms,
- To use proper computation tools to implement those paradigms.

This is our line of reasoning

Basic interest and motivation:

Decision making: omnipresent, a „meta-challenge” and bottleneck

Decision aid/support is needed

Decision support systems (DSSs) are the only solution

DSSs are not meant to replace the human being but to help him/her

The success of a DSS is when they are useful and implementable

Decision making and decision support systems

Point of departure: decision making - Omnipresent!

First **formal** attempts: a **structured** problem:

- Set of options X={x},
- A preference structure (utility function), e.g. f(x)
- A simple rationality, i.e. a best decision is chosen (optimization):

$$x^* = \arg\max_{x \in X} f(x)$$

Many extensions: multiple crieria, multiple decisionmakers, dynamics, etc.

Recent trends

Decision making process:

- Use of own and external knowledge,
- Involvement of various „actors”, aspects, etc.
- Individual habitual domains (P.L. Yu),
- Use of explicit and tacit knowledge,
- Use of intuition,
- Non-trivial rationality,
- Different paradigms when appropriate.

Virtually all elements are ’’human specific’’, best expressible in words!

Some non-standard elements:

Habitual domains: a set of ways of thinking, judging and responding, etc. acquired by a person

Knowledge:

- **Tacit knowledge** (Polanyi, 1966) is difficult to articulate, highly personal and hard to formalize, difficult to communicate or to share with others; includes subjective insights, intuitions, and hunches,
- **Explicit knowledge** is more easily transmitted as it may be codified, and is therefore more easily processed and shared.

In reality, both are often vaguely defined → natural language!

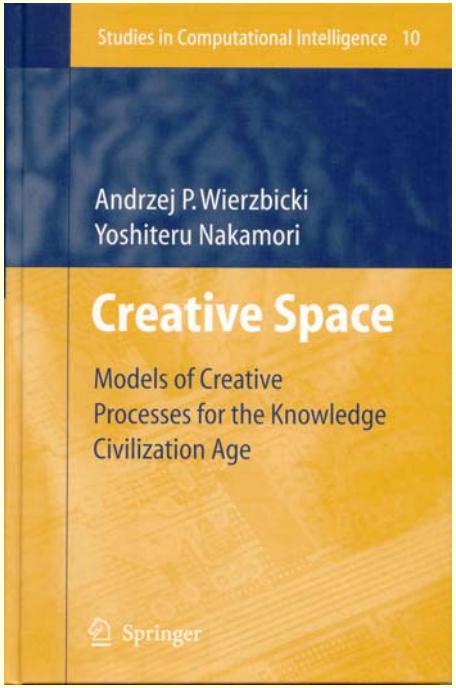
Intuition (1):

Intuition plays a particular role! Different views, schools, etc.

For instance:

- **Intuition** is an unconsious form of knowledge, not open to rational an/or analytical thinking and analyses.
- **Intuition** is thought as the sixth sense. Recent scientific research has found some evidence for the existence of this sixth sense and lots of unconscious processes,
- etc.

Wierzbicki AP and Nakamori Y. (2005) Creative Space. Models of Creative Processes for the Knowledge Civilization Age. Springer. Series: Studies in Computational Intelligence.



JAIST – Japan Advanced Institute of Science and Technology

Probably, a „different" type of mathematics

Computing with words and perceptions?

An interest in brain research, too

For instance:

Peter Checkland's (1975-99) deliberative (soft) decision making:

- To perceive the whole picture,
- To observe it from all angles (actors, criteria,...)
- To find a **good** decision using **knowledge** and **intuition**.

Modern decision making paradigms

- Heavily based on data, information and knowledge, but also on human specifics (intuition, attitude,...)
- Need number crunching, but also more ‘’delicate” and sophisticated analyses,
- Heavily relying on computer systems, and capable of a synergistic human-computer interaction.

So: Decision support systems!
Should be human centric/centered!
Should be human consistent!
Should be intelligent!

What are decision support systems (DSSs)?

Specific interactive computerized information systems

A basic philosophy:

The human decisionmaker knows how to make good (best?) decisions – probably has some ”decision making model” in his/her mind,

The human decisionmaker should benefit (most probably, we do not know for sure) from some additional information, hints, number crunching power, etc. provided by some formal and computational tools

But, he/she is autonomous!

DSSs: since the mid-1960s: development of IBM 360 and a wider use of distributed, time-sharing computing

Basic types of DSSs:

- Data driven,
- Communication driven and group DSSs,
- Document driven,
- Model driven,
- Knowledge driven,
- Web based and interorganizational.

Is a model of a (decision making) problem considered necessary?

No! But maybe helpful…

A famous citation:

”All models are wrong. Some models are useful”

Box, G.E.P., Robustness in the strategy of scientific model building, in Robustness in Statistics, R.L. Launer and G.N. Wilkinson, Editors. 1979, Academic Press: New York.

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Basically:

All non-models-based (driven) ones:

- emphasize access to and manipulation of internal and external data, numerical or textual, even multimedia,
- facilitate collaboration between decisionmakers,

Only the model-based (driven) one explicitly uses models to derive some **proposed** solutions

The best: a synergistic combination

What else: (some) „intelligence”!

What is intelligence?

Initially: psychology, cognitive science

Different views (an exact definition of intelligence is probably impossible), for instance:

- an ability to handle complexity and solve problems in some useful context as, e.g., reaching an agreement, finding a solution to the quadratic equation,
- an ability to protect the organism from bodily risks and to satisfy its wants with the least possible chance of failure,...

Nature of intelligence

But, from the perspective on an individual!

Two basic schools of thought on the nature of („individual”) intelligence:

- One general intelligence (Eysenck, Galton, Jensen, Spearman, ...)
- Multiple intelligences (Gardner, Sternberg, Thurstone,...)

One general intelligence

For instance, Eysenck (1982):

There is one general factor governing the level of intelligence of an individual

„Proof”:

- a high positive correlation (positive manifold) between tests of cognitive abilities (Spearman, 1904), e.g., good verbal abilities are usually linked to mathematical abilities,
- A high correlation of reaction time and IQ, ...

Multiple intelligence

How many types of intelligence?

Gardner (1983): 7 different forms of intelligence:

Linguistic, musical, spatial, bodily, interpersonal, intrapersonal, and logico-mathematical

Sternberg (1985): two different types of intelligence:

Analytic (academic) and practical

Etc.

A more pragmatic definition

Wiener's (1894-1964) pragmatic definition:

Intelligence is a process of acquisition and processing of information for attaining goals

Serves well our purpose!

A point of departure for „constructive", implementable intelligent systems!

However…

Normally, intelligence is viewed from the point of view of an individual

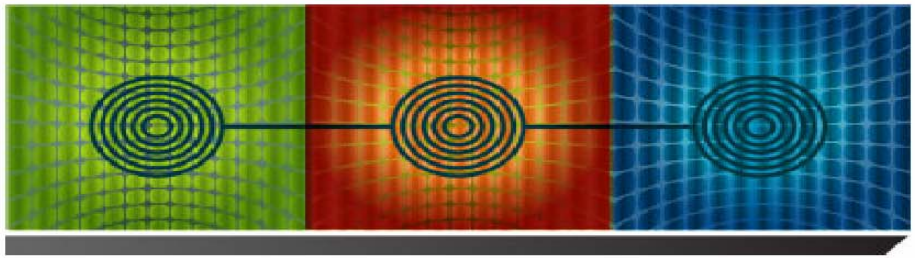
Recently, there is more and more evidence that collective intelligence is crucial

Massachussets Institute of Technology

Center for Collective Intelligence

e.g. Alex (Sandy) Pentland

Massachusetts Institute of Technology



How can people and computers be connected so that — collectively — they act more intelligently than any individuals, groups, or computers have ever done before?

While people have talked about *collective intelligence* for decades, new communication technologies—especially the Internet—now allow huge numbers of people all over the planet to work together in new ways. The recent successes of systems like Google and Wikipedia suggest that the time is now ripe for many more such systems, and the goal of the **MIT Center for Collective Intelligence** is to understand how to take advantage of these possibilities.

Our basic research question is: *How can people and computers be connected so that—collectively—they act more intelligently than any individuals, groups, or computers have ever done before?'*

The Center for Collective Intelligence brings together faculty from across MIT to conduct research on how new communications technologies are changing they way people work together.

NEWS AND EVENTS AT THE CCI

--> Spring 2007 Seminar Series Schedule Now Available

--> CCI in Technology Review

--> CCI in CSC World

--> CCI on NPR's "All Things Considered"

--> CCI in CIO Magazine

Collective intelligence

Collective intelligence is an intelligence that emerges from the collaboration and competition of many individuals, an intelligence that seemingly has a mind of its own.

Collective intelligence appears in a wide variety of forms of consensus decision making in bacteria, animals, humans, and computers. The study of collective intelligence may properly be considered a subfield of sociology, of computer science, and of mass behavior…

Collective intelligence

Collective intelligence is the capacity of human communities to evolve towards higher order complexity and harmony, through …differentiation and integration, competition and collaboration.

So:

- a „social view”, appropriate of human centric/centered decision making (support),
- emphasizes a (synergistic) collaboration of humans and computers.

What next?

We have some human consistent tools and techniques to grasp and deal with difficult (decision making type) problems, i.e.:

- Some non-conventional approaches and models,
- Some promising types and architectures of decision support (decision support systems), „intelligence”,

We would like to have something deeper: a proper computing paradigm

More than „human consistent”, rather human centric/centered

What is going on in this direction?

Very much!

- At top universities (MIT, University of California at Berkeley, Carnegie Mellon University, University of Illinois, Georgia Tech, Imperial College, etc.),
- An NSF Program: **Information and Intelligent Systems: Advancing Human-Centered Computing, Information Integration and Informatics, and Robust Intelligence,**
- Large industrial projects: IBM, Microsoft, HP, Nokia, Philips/LG…

Here: mostly MIT and UC Berkeley

First, why MIT:

One of the best (second best?) universities

A ‘’personal relation’’ to the Massachusets Institute of Technology (MIT) in Boston, USA:

- as the father of an MIT graduate,
- as the supervisor of a Ph.D. thesis of a researcher from the MIT Lincoln Lab,
- frequent visits and contacts with many people.

MIT is probably the first and most relevant in this context!

Second, why University of California at Berkeley:

One of the best (third best?) universities

A ‘’personal relation’’ to UC Berkeley, too:

- L.A. Zadeh, my mentor, is there,
- frequent visits and contacts with him and many people, from various departments,
- attendance at many inter-departmental seminars,
- An „interdepartmental culture” in the scientific life,
- **Tools (Zadeh!).**

Human centric computing at MIT

Prof. Michael Dertouzos (1936-2001)

MIT, Laboratory for Computer Science (distributed, time share computing, now Tim Berners-Lee, etc.)

A great scientist and visionary!

- M. Dertouzos (2001) ***The Unfinished Revolution: Human-Centered Computers and What They Can Do for Us***, Harper Collins.

  Foreword by Bill Gates!
- M. Dertouzos (1997) ***What Will Be: How the New World of Information Will Change Our Lives***, Harper Collins.
- M. Dertouzos, R.K. Lester, R.M. Solow (1986) ***Made in America***, MIT Press.

Human centric computing (Dertouzos, 2001):

„…I view human-centric computing as a total commitment to the human as the starting point... I start with the interface, and then I go down to all the applications. In the approach we have had for the last 40 years, there is a machine that has all this number crunching power, and then there is an interface that lets us talk to the machine… In the new approach, you're not talking to the interface, you're talking to the machine -- it doesn't need an interface…”

Human centered computing

cf. A. Jasmine, D. Gatica-Perez, N. Sebe, Th. Huang
Human-centered computing: toward a human revolution. Computer (IEEE), May, 2007

A systems view integrating:

- Computational tools,
- Cognitive aspects,
- Social aspects.

For instance:

HCC: Human-Centered Computing Consortium (University of California at Berkeley)

Georgia Tech, Carnegie Mellon, etc.

Some other related ideas:

Human (based) computation (and interactive evolutionary computation) – the computer asks a person (group) to solve a problem, then collects, interprets and integrates the solutions obtained

So: the humans help the computer to solve a difficult problem

For instance: University of Illinois at U.-Ch. (David Goldberg's group)

Related: Social computing, social software, symbiotic intelligence, collaborative intelligence. human computer, etc.

But…

Human, human centric/centered/… *computing* try to attain a synergy and amplification between human abilities (e.g. intelligence) and computational power of computers

The very basic philosophy of all of them is similar!

Just how to implement these ideas!

However:

This all is easier said than done because of

a lack of human centric/centered tools!

Zadeh's computing with words provides such tools!

It is totally commited to exploiting human characteristic features, mainly:

- By using natural language as much as possible, and right from the begining,
- By advocating computations using human-consistent words not ''artificial" numbers,

Computing with words and perceptions

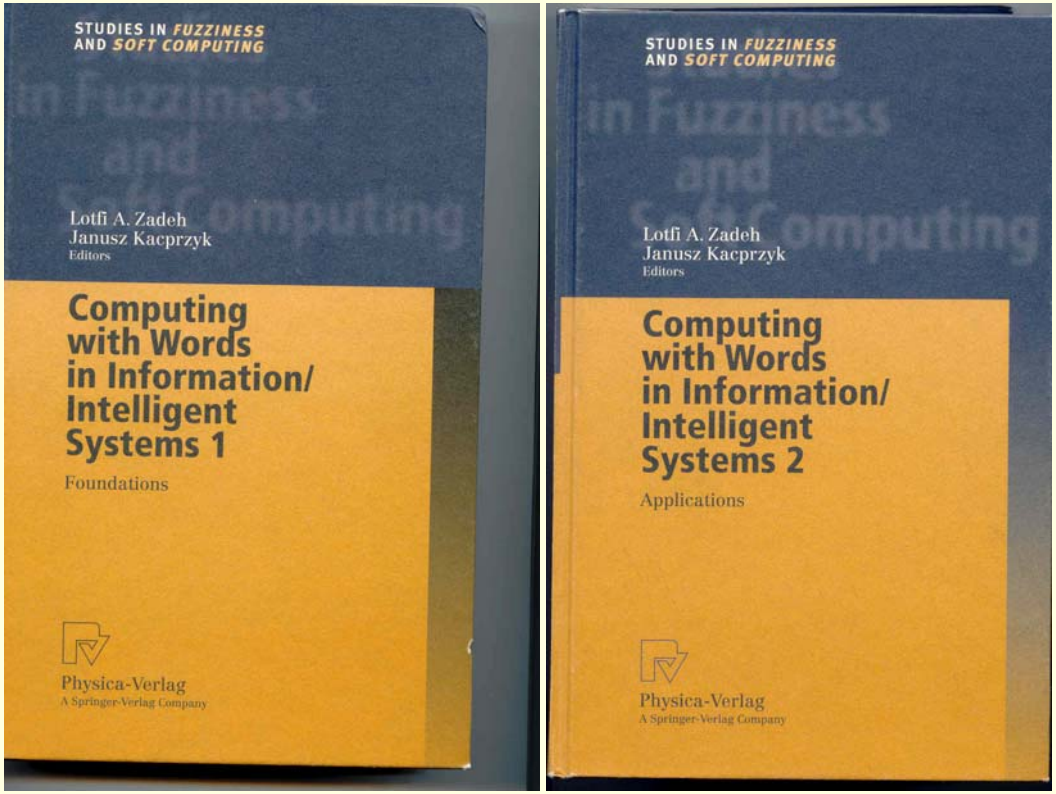
Zadeh has advocated since ca. 1995 his paradigm of

computing with words and perceptions (CWP)

Books by Zadeh and Kacprzyk (1999a, b)

Can be viewed from different perspectives

We: a pragmatic one



Computing with words and perceptions: A pragmatic perspective

For a human being, the only fully natural means of articulation and communication is **natural language**

Therefore, maybe, in many situations:

instead of traditional computing with **numbers** (from measurements) it would be better to compute with **words** (from perceptions)?

So, we may skip an ‘’artificial’’ interface (numbers) and try to operate on what is human specific: natural language!

Basic idea

A key idea in CWP is that the meaning of a proposition, p, in a natural language may be represented as a generalized constraint:

X isr R (e.g.: price is(r) *high*)

where:

- X is a constrained variable which, in general, is implicit in p;
- R is the constraining relation which is in general implicit in p;
- r is an indexing variable whose value identifies the way in which R constrains X

Here: r refers mainly to modality in linguistics

Modality in language

Modality refers to how to communicate fine shades of meaning and allows us to express degrees of (degree – even in traditional approaches!):

- **usuality** – how frequently something occurs or is true,
- probability, possibility or certainty – the likelihood of something happening or being the case,
- obligation or necessity – how necessary it is for things to be done or to be a certain way,
- ability – the ability of someone or something, to do something,
- inclination – the inclination or willingness of someone to do something.

Various forms of generalized constraints

The principal types of constraints are:

- Equality: X is= R (X=R)
- Possibilistic constraint: X is R (R is a possibilistic distribution)
- Probabilistic constraint: X isp R (R is a probabilistic distribution)
- Usuality constraints: X isu R [usually(X is R)]
- Veristic, rough set, etc.

All are powerful tools for the representation and manipulation of real world uncertain, imprecise, etc. Information

Not all are clearly related to modalities so that a linguistic interpretation may sometimes be difficult

Various forms of generalized constraints

Usuality constraint is very important

≡ in most, almost all, much more than 50%, ... cases

Because:

- In our analyses we seek some „regularities", „normal/typical" relations in data, i.e. those which **usually happen,**
- Most facts and relations in the real world are at most **usually valid**, etc.

Usually valid facts, relations, etc. cannot be or are difficult to be easily handled using traditional means**!**

Fuzzy linguistic quantifiers!

Potentials of computing with words

We can express:

- Values of variables,
- Relations,
- Solutions (feasible, good, optimal, etc.)

in an imprecise way, in a (quasi)natural language.

Provides means for a linguistic representations and analysis of systems, decision making, controls, data, etc.

All this in a constructive way, effectively and efficiently

Two points of view

Depending on our background, interest, etc. we can emphasize the power of computing with words from the perspective of:

- Reasoning schemes, logical type expressions, etc.
- Systems modeling.

Mostly in both case some IF-THEN rules augmented with some quantification or qualification

Therefore: we have tools for modelling and solving a multitude of problems expressed in natural language

Example of own works (implementation!):

A Data Driven DSS – linguistic summaries of a database, implemented at a small-to-medium computer retailer

Kacprzyk and Zadrożny (1999 – 2007)

An example of:

- A non-model-based approach to decision support,
- A human centric/centered computing paradigm,
- Computing with words.

A small computer retailer in South Poland:

Owner: must make sophisticated decisions concerning:

- number of employees on Saturday,
- type of advaertisement,
- Commisions

But: very busy

$\Rightarrow$ Simple summaries, in natural language!

$\Rightarrow$ Inexpensive technology, add-in without any „touching” his database!

Example:...

Relations between **commision** and **type of product:**

About 1/2 of sales of network elements is with a high ommission
Much sales of accessories is with a high commission
Much sales of elements is with a low commission
About 1/2 sales of software is with a low commission
About 1/2 sales of computers is with a low commision

So:

- No problem with accessories and network elements,
- Critical are: elements, software and computers!

Extensions (external data from WWW)

Own database only!

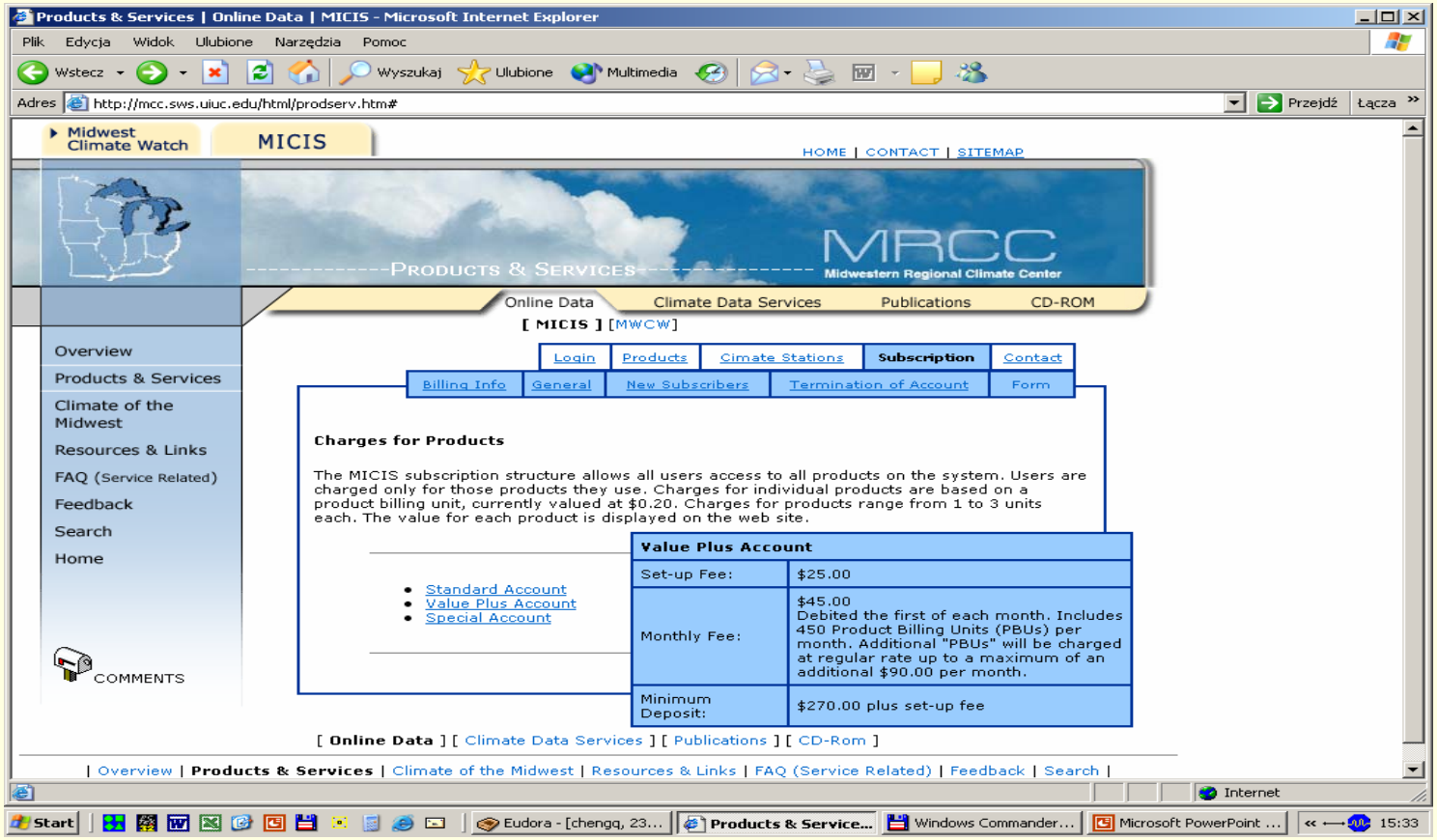
But: a company operates in an environment (e.g. weather)

So, e.g., Irelations between group of products, time of sale, **temperature, precipitacion**, and type of customers:

Very few sales of software in hot days to individual customers
About 1/2 of sales of accessories in rainy days on weekends by the end of the year
About 1/3 of sales of computers in rainy days to individual customers

Extensions (external data from WWW)

Can be done by using free/inexpensive weather data repositories at universities, agencies, etc.



Next step**: semi-structured** weather info (text forecasts from a local newspaper, SMS messages from a local provider) – **local info**!

How to get that information **in an inexpensive and easy way?**

From the Internet/WWW!

Very positive experience!

- Easy to use (after the initial setup stage, calibration, etc.),
- Intuitively appealing results,
- Inexpensive technology,

The use of (quasi)natural language gives a new human centric type quality

Conclusions

I wished to:

- Point out some „unorthodox”, not often presented views, perspectives and tools in broadly perceived „informatics”,
- To be more specific, decision making and decision support were considered,
- The use of intelligent decision support systems was advocated,
- New computing paradigms, of a human centric/centered type, and computing with words, that can help implement them, were shown.

A synergy between them is probably decisive!