PNL Applied to Economics

Barbara Diaz, Tomohiro Takagi, *Member, IEEE*, and Sema E. Alptekin
Berkeley Initiative in Soft Computing, UC Berkeley, CA 94720, USA

Abstract—**This work is a continuation of Zadeh's research on Precisiated Natural language. Precisiated Natural Language (PNL) provides a system for computation and deduction of propositions expressed in a natural language. The importance of PNL for economics is discussed. The improved process of PNL is presented using a real world example from economics.**

***Index Terms*— Fuzzy Logic, Computational Theory of Perceptions, Computing with words, Elasticity of demand, Precisiated Natural language.**

I. Introduction

A constant in Zadeh's papers has been the idea of emulating human reasoning and its ability to summarize, that is, to extract only the relevant information as well as its tolerance for imprecision. In almost all of his papers there is a mention of what he calls "humanistic systems" and the problems in dealing with them realistically.

In [1] he outlines an approach that has been widely used in scientific papers as well as applied to control systems: the characterization of simple relations between fuzzy variables by conditional statements, called fuzzy if then rules, and also the fuzzy algorithmic characterization of functions and relations. But this constituted only a first step in a very specific direction: "we need approaches which do not make a fetish of precision, rigor, and mathematical formalism, and which employ instead a methodological framework which is tolerant of imprecision and partial truths".

Zadeh has since outlined a much more complete framework. His "Precisiated Natural Language" [2] is a continuation of his work described in previous papers. In [3] he introduces the Computational Theory of Perceptions, CTP and Computing with Words. As he mentions in [3], the foundations for his research on computing with words were laid before in his previous work as he introduced concepts such as linguistic variables, fuzzy information granulation, and fuzzy constraint propagation.

This subject of our work is a continuation of Zadeh's research on Precisiated Natural language [2]-[4].

In his articles, Zadeh asks the following question regarding Precisiated Natural Language (PNL): "How can a natural language be precisiated – precisiated in the sense of making it possible to treat propositions drawn from a natural language as objects of computation?" He introduces the concept of Precisiated Natural Language, and provides a detailed description of the conceptual structure of PNL. Furthermore, he outlines the role of PNL in knowledge representation, deduction, and concept definition.

PNL is in its initial stages. There is a need for other researchers to build on what Zadeh initiated. Although Zadeh provides many examples in his articles, there is a need for examples in different problem domains to encourage implementation of PNL in areas such as economics. We, as researchers at Berkeley Initiative in Soft Computing (BISC), felt the responsibility of working on PNL first to improve our understanding of the concept. We also wanted to test the process of PNL to see how it could be implemented to produce answers to real world problems. As we worked on different examples using our multidisciplinary backgrounds ranging from economics to information retrieval (IR), we realized that not only had we developed material to share, we had also discovered improvements to the PNL process.

In the next section, we provide a brief introduction to PNL. The importance of PNL for economics is discussed in the third section followed by a real world example. Observations, conclusions and future work are reported in the final sections of the paper.

II. Precisiated Natural language

Precisiated Natural Language (PNL) provides a system for computation and deduction of propositions expressed in a natural language. PNL provides the ability to compute and deduct, similar to any math language. Why use PNL when we have any number of available tools? What makes PNL an excellent choice in disciplines such as economics is its ability to handle propositions with meanings that lay between 0 and 1 – something human beings are very good at handling and what the current tools are missing. Consider this sentence taken directly from a recent news article "Employers announced plans to cut more than 100,000 jobs again in October." As educated human beings, we can deduce a conclusion for the future of the economy using our perceptions. Can a machine compute the same? This is the goal of PNL – to precisiate these propositions so that they can be treated as objects of computation.

The conceptual structure of PNL, as described in [2], consists of the following principal components:

1) A dictionary to translate Natural Language (NL) to Generalized Constraint Language (GCL). "Information is conveyed by constraining, in one way or another, the values which one variable can take", "a proposition represents an

Manuscript received December 20, 2004. This work was supported in part by the Spanish State Secretary of Education and Universities and the European Social Fund under grant EX2003-0563, and by Grant-in-aid for scientific research from Japan Society for the Promotion of Science.

implicit constraint on a variable" [2]. The generalized constraint is expressed as "X isr R", where X is constrained variable, R is the constraining relation, and r is the modality of the constraint, that is, it defines the way in which R constrains X.

The principal modalities are given below:
Possibilistic (r is left blank), probabilistic (r=p), veristic (r=v), usuality (r=u), random (r=rs), fuzzy (r=fg), bimodal (r=bm), and Pawlaw (r=ps). More information can be found in [2].
2) A dictionary to translate from Generalized Constraint Language **(**GCL) to Protoform Language (PFL). Protoform is short for prototypical form and is another step in abstraction. The importance of the protoforms is that they reveal the deep semantic structure of the object to which they apply. There are propositions that can differ but have the same deep semantic structure.
3) A multiagent, modular deduction database (DDB). This database contains the rules of deduction. In many cases the constraints are of the basic, possibilistic type. The rules governing constrain propagation are, as stated in [3], the compositional rule of inference, the extension principle, the generalized modus ponens, the generalized extension principle, the syllogistic rule, the constraint modification rules…. . The list is not complete and should be extended to general constraints that are different from the possibilistic ones.
4) A world knowledge database (WKDB) that has "perception" based propositions that describe world knowledge that will be used in the process of constraint propagation (deduction).

In this paper, we demonstrate the process of PNL by using examples from economics. The utility of using PNL in economics is described in the next section, followed by an example demonstrating how the PNL process is applied to real world situations.

III. IMPORTANCE OF PNL FOR ECONOMICS

It is well known that the direct measurement of economic concepts can be quite difficult. Often "proxies" for real concepts are used in the analysis. This problem affects many of the variables used in economic studies, but it is even more obvious when we talk about intrinsically vague concepts such as poverty, well being, sustainability, or economic convergence. As an example, let us consider the concept of well being. It is even difficult to define it. What are the aspects that have to be taken into account? How can we compare well being in different countries and cultures? Even those approaches that are intended to be closer to reality such as Sen's capability approach or HDI (human development index)[1] have been criticized. Criticisms arise not only because of the aspects they cover but also because of the vagueness of the variables included in the computation of the index[2].

Other concepts that have been devised to reduce vagueness, encounter measurement difficulties. Usually, there is a gap between what is really measured and the concept that we are trying to represent. See, about productivity measure [6].

> "*Economists and practitioners have always been interested in how to generate more output with the same inputs, that is, how to increase productivity. The impacts of education, scientific research, and government policy on productivity have been researched extensively. As old as this research, however, is the debate on how to measure productivity"…."Measures of the ratio of output to inputs -- productivity -- can be constructed. Output measures are all revenue-based, which implicitly assumes that the relative value of different types of outputs can be measured by their relative price…".*

Measurement in economics is not comparable to measurement in physics in which the given conditions can remain the same between measurements. In economics, we must face the fact that exogenous conditions from one measure to another will change. There are no "immutable laws of behavior" that can explain the relationship among variables. That is why some economic theory that has been practical for a period of time is not reliable at other times.

Even with all these differences from other sciences, we have tried to imitate their models and there has been some resistance to adopt more suitable techniques to deal with vagueness[3], although recently progress has been made in this area. The vagueness that is inherent in most economic variables is addressed by fuzzy logic. *"Fuzzy sets offer researchers an interpretive algebra, a language that is half-verbal-conceptual and half-mathematical-analytical. Thus, the greatest value of fuzzy sets for social scientists is their potential for enlivening, intensifying and extending the "dialogue" between ideas and evidence in social research."* [8].

Some applications of fuzzy logic to economics can be found in [9]-[16]. But, even if vagueness is the reason claimed by most authors to use fuzzy logic, it should be noted that the theory of fuzzy sets and its application is numeric by nature. *"The prevailing neuro-fuzzy systems are problematic because they do not fully utilize the linguistic nature of this systems and they yield outcomes which are difficult to interpret in the context of the human sciences."* Vesa A. Niskanen, in his web page, and, in different terms, in Niskanen [17]. The use of fuzzy logic, often in combination with neural networks or

[1] It is an index that uses a measure of income and measures of longevity and education/literacy (a proxy for knowledge). In general, the criticism focused on the composition of the index, the statistical construction and data quality. Among other suggestions, one is the proposal of using a "expectancy of healthy life".

[2] In this sense, See [5] where a fuzzy approach to Sen's capability approach has been made.

[3] See, Zadeh, [7]. "*At present, most of the techniques employed for the analysis of humanistic, i.e., human centered, systems are adaptations of the methods that have been developed over a long period of time for dealing with mechanistic systems, i.e., physical systems governed by the law of mechanics, electromagnetism and thermodynamics. .....Given the deeply entrenched tradition of scientific thinking which equates the understanding of a phenomenon with the ability to analyze it in quantitative terms, one is certain to strike a dissonant note by questioning the growing tendency to analyze the behavior of humanistic systems as if they were mechanistic systems governed by difference, differential or integral equations*"

genetic algorithms, allows the interpretation in the form of if then rules that describe in a linguistic way the behavior of the system.

The non-linear relationships among variables also make this field very appealing for the use of fuzzy logic. Fuzzy inference systems have one important advantage: there is no need to make a-priori assumptions about the functional form of the relationships.

This is a first step to using less rigid models. But, in our opinion, there is still something not applied and potentially very useful: Zadeh's theory on computing with words and perceptions. This could potentially provide a qualitative jump in giving economics and human sciences in general, a tool to add perceptions to models. As professor Zadeh says, this technique would be added to existing techniques, it would be complementary rather than competitive. It would add functionality closer to the way humans reason: able to summarize and compute without details.

There is often some non-numerical knowledge that could be introduced to better understand some situations in the economy, and our perceptions about the reality. Here is where professor Zadeh's computational theory of perceptions, based on PNL could help us incorporate useful information for which we have no precise or completely quantified measurements. In Zadeh's framework, perceptions and words are units of computation.

Perceptions are generally expressed in natural language. Sentences, translated from natural language to precisiated natural language are objects of computation, using a rule database within a fuzzy logic architecture.

IV. EXAMPLE

In order to explain how the PNL process works, we will simulate it by using a very simple example. The following paragraph is a selection of key sentences from the President's report [18]:

> "U.S. demand for manufacturing products has been relatively *price inelastic*. That is, demand has not been very responsive to price declines.
> …The boost to real income from the relative price decline of manufactured goods…
> …Productivity gains have tempered price increases, and demand has not responded strongly enough to keep nominal revenues constant as a share of nominal GDP"

The question that we want to be able to answer is "What is the change in relative revenue for manufacturing products?".

Elasticity is described as responsiveness of demand to change in price with all the other factors affecting demand remaining unchanged. Elasticity is usually estimated empirically. A good example is provided by Gilden et al. [19]. In this study, 254 demand elasticity estimates for air travel demand were extracted from 21 Canadian and international studies. Those that are determined to be more representative of the data were selected as the elasticity values. This decision was made based on the judgment of the authors and tells us something about the precision with which elasticity is calculated[4].

We changed the extracted key sentences into GC forms (see Table 1). An information extraction module needs to be developed and implemented that would execute this step in order to fully automate the PNL system for actual applications.

TABLE 1: PRICE ELASTICITY AND REVENUE

Natural Language	U.S. demand for manufacturing products has been relatively *price inelastic*.
	…relative price decline of manufactured goods…
Question	What is the change in relative revenue for manufacturing products?
World knowledge	Elasticity is responsiveness of demand to change in price. Low elasticity means that demand is not very responsive to change in price and high elasticity means that the demand is very responsive to change in price.

The PNL process is shown in Fig. 1. The first step in the process is to translate NL to generalized constraints of the form "X isr R", where r specifies the modality of the constraint. This step takes the propositions given in the form of NL, and leads to the generalized constraint forms shown in Table 2 for: 1) the propositions, 2) the question and 3) the information in the WKDB:

TABLE 2: GENERALIZED CONSTRAINS

p_1^*: elasticity is low
p_2^*: change (relative price of manufactured goods) is negative medium
q*: change (relative revenue) is? D
w^*: elasticity isfg $(\sum_i R_i)$

where fg is the representation of a fuzzy graph constraint that can be expressed as a collection of fuzzy if-then rules, and such a rule-set may be interpreted as a description of a perception of the function that relates both variables. The rules are shown in Table 3, and should be read as follows:
Rule 1: If Elasticity is High and Price is Negative then Revenue is Negative.

For an alternative expression of the fuzzy graph constraint see [2]. This relationship will be denoted by (X,Y) from here on, to make it easier for readers familiar with fuzzy logic and the computational rule of inference. Fuzzy relationships are a classic topic in the introductory texts of fuzzy logic. The reader is referred to [20]-[24] for an overview of fuzzy relationships.

The second step in the PNL process is to translate from the Generalized Constraint Language (GCL) to a Protoform

[4] In this study a scoring system based on theoretical and measurement issues, takes into account; if the study is controlling the income impact, if the price of substitutes are included or not in the model, if it is a time series, panel or cross section data type based model, the similarity of the country to Canada, like appropriate segmentation of the market or if they differentiate among different routes or not, age of the study and adjusted R squared coefficient value, and others. They affirm that: *"The median value for a particular market is not necessarily representative of the corresponding market in Canada. It is argued in the report that analysts should instead consider a broader range of values around the median value when examining the impact of price changes on the demand for air travel in Canada"*.

Language (PFL): "A concept which plays a key role in PNL is that of a protoform – an abbreviation of prototypical form. Informally, a protoform is an abstracted summary of an object which may be a proposition, command, question, scenario, concept, decision problem or, more generally a system of such objects [2]."

TABLE 3: RULES FOR CHANGE IN PRICE AND CHANGE IN REVENUE WITH DIFFERENT ELASTICIES

	Elasticity	Change in Price	Change in Revenue
Rule 1	High	Positive	Negative
Rule 2	High	Zero	Zero
Rule 3	High	Negative	Positive
Rule 4	About 1	Positive	Zero
Rule 5	About 1	Zero	Zero
Rule 6	About 1	Negative	Zero
Rule 7	Inelastic	Positive	Positive
Rule 8	Inelastic	Zero	Zero
Rule 9	Inelastic	Negative	Negative

To translate the first proposition (p_1: U.S. demand for manufacturing products has been relatively *price inelastic*) from a generalized constraint to a protoform, we make use of the knowledge in the WKDB that allows us to interpret elasticity as a relationship between change in price and change in revenue. In other words, the translation of the first sentence into a protoform would give us: E is (X,Y).

Since this proposition implies specific information about the strength of the relationship, that is, "has been relatively *price inelastic*", we also make use of the WKDB to choose one of the possible values for the relationship. Only rules 7-9 will hence be used in the computing that follows.

With this example, we see specifically the way the world knowledge is letting us interpret the sentence as a relationship. World knowledge is given also in natural language and needs itself to be translated into GCL to be added to the system. We think this is an improvement to Zadeh's PNL theory. In his paper he mentions the importance of world knowledge, but it is not shown how it can be connected to the rules of deduction and to the protoforms.

Fig. 1. Basic Structure of PNL

X: change (relative price of manufactured goods)
Y: change (relative revenue of manufactured goods)

As mentioned before, proposition (p_1) selects the type of elasticity from the knowledge base (WKDB). For simplicity, (X,Y) is used to represent the elasticity relationship between the change in relative price and change in relative revenue. The protoforms in Table 4 are derived:

TABLE 4: PROTOFORMS

p_1^{**}: (X,Y) is E_i
p_2^{**}: X is F

q**: Y is ?D

The third step in the PNL process is to come up with a rule that leads from (p_1^{**}, p_2^{**}) to q** in order to answer the question successfully. This is accomplished by referring to the deduction database (DDB) which contains rules of deduction for a particular domain. In our case this database has rules of fuzzy logic one of which is the computational rule of inference (see Table 5).

TABLE 5: COMPUTATIONAL RULE OF INFERENCE

	p1: (X,Y) is E_i
(X,Y) is B	p2: X is negative
X is A	low
Y is A∘B	
	Y is X ∘ (X,Y)

Instead of using a crisp value for elasticity, "linguistic variables" for granulation of elasticity, i.e. low, medium, high, could be used to take advantage of PNL's ability to handle propositions with quantifiers. Using fuzzy arithmetic such as the computational rule of inference, we then will be able to handle NL propositions such as "U.S. demand for manufacturing products has been relatively *price inelastic*" as shown in the following discussion.

p_1^*: elasticity is low
p_2^*: change (relative price of manufactured goods) is neg. medium
q*: change (relative revenue) is ? D

The fuzzy relationship between these two linguistic variables is given in Fig. 2. In Fig.3 the values of the "change in revenue" for a given "change in price" are shown.

Fig. 2. Fuzzy relationship between change in price and change in revenue

Fig. 3. Change in revenue for negative change in price and inelastic demand

Its calculus leads to the max-min composition:

$$\mu_B(y) = max_x\, min\,(\mu_A(x), \mu_R(x, y)) = \vee_x(\mu_A(x) \wedge \mu_R(x, y))$$

Intuitively, one can see in Fig.3. that under inelastic demand a decrease in price will cause a decrease in revenue. As we see, our answer is not precise. But, with the information we had there is no other tool that could give us an answer to this question.

V. OBSERVATIONS

We examined how PNL works using economic information from an economic report. Our objectives in this work were to find out if PNL has enough functionality to deal with real world situations and to clarify the procedure used to add world knowledge in the computation. We saw that PNL

successfully simulated human reasoning to compute with the inputs (sentences) given and we explained how sentences in the world knowledge database need to be translated also into generalized constrains to be added to the system. This is not explicitly explained in Zadeh's paper [2].

The modalities used here for the constraints in the Generalized Constraint Language are of two kinds: possibilistic and fuzzy graph. As rules for deduction in the Deduction Database we used the compositional rule of inference from fuzzy logic.

We want to emphasize the fact that by solving this example we are giving an answer not only to this case but also to any other situation in which we find the same deep semantic structure, that is, the protoforms used here.

VI. Conclusion and Future Work

This paper is a first attempt to demonstrate PNL in a practical application. The automation of PNL, even if we are currently still far from it, would be a very powerful tool. A system would interpret sentences by means of fuzzy logic relationships, as shown in this paper and would reason with them.

From a real economic report we extracted key sentences describing a situation and changed them into GC forms. An information extraction module needs to be developed and implemented that would execute this step in order to fully automate the PNL system for actual applications.

Little attention has been paid to Zadeh's theory from the application point of view, and we think that more effort should be made within the fuzzy community to implement and use it.

.

Acknowledgment

We are grateful for the support that we have received from Prof. Lotfi Zadeh during our visit at the Berkeley Initiative in Soft Computing (BISC) in 2004 and 2005. Special thanks go to the other scholars at BISC who have contributed to this research by creating an excellent interdisciplinary and international research environment: Souad Souafi-Bensafi, Sergio Guadarrama Cotado and Martine De Cock.

References

[1] L.A. Zadeh, "A fuzzy algorithmic approach to the definition of complex or imprecise concepts", *Int. J. Man-Machine Studies*, No 8, pp. 249-291, 1976.

[2] L. A. Zadeh, "Preciated Natural language – PNL", *AI Magazine*, pp. 74-91, Fall 2004.

[3] L. A. Zadeh, "From computing with numbers to computing with words-from manipulation of measurements to manipulation of perceptions", *IEEE Transactions on circuits and systems - I Fundamental theory and applications*, vol. 45, No 1, pp. 105-119, January 1999.

[4] L. A. Zadeh, "A New Direction in AI – Toward a Computational Theory of Perceptions", *AI Magazine*, vol. 22, No. 1, pp. 73-84, Spring 2001.

[5] M. Baliamoune, "On the measurement of human well being: fuzzy sets theory and Sen's capability approach", WIDER (World Institute for Economic development), Research Paper2004/16, February 2004. Available: http://www.wider.unu.edu/publications/rps/rps2004/rp2004-016.pdf

[6] D. W. Dwyer, "Productivity Races I: Are Some Productivity Measures Better Than Others?", US Census Bureau, Economic Studies, 97-2, December 1996, Available: http://ideas.repec.org/p/wop/censes/97-2.html

[7] L.A. Zadeh, "Outline of a new approach to the analysis of complex systems and decision processes", *IEEE transaction on systems, Man and Cybernetics*, vol. SMC-3, n.1, pp. 28-44,1973.

[8] C.C. Ragin, *Fuzzy-Set Social Science*. Chicago: The University of Chicago Press, 2000.

[9] R.R. Yager, *Simultaneous solution of fuzzy models: an application to economic equilibrium analysis. Fuzzy sets and Systems*, pp. 339-349, 2000.

[10] P. De Wilde, "Fuzzy utility and equilibria", *IEEE transaction on systems, Man and Cybernetics-Part B: Cybernetics*, vol. 34, No 4, pp. 1774-1785, 2003.

[11] D.Garagic, and J.B. Cruz Jr, "An approach to Fuzzy Noncooperative Nash Games", *Journal of Optimization Theory and Applications*, vol 118, No 3. pp. 475-491, 2003.

[12] D. Marcek, "Generating Fuzzy Rules for financial Time Series by NN with Supervised competitive Learning Techniques", Proc. FSSCEF2004, San Petersburg, vol 1, pp. 81-88.

[13] C. Stroomer and D.E.A. Giles, "Income convergence and trade Openness: Fuzzy Clustering and time Series Evidence". Department of Economics, University of Victoria, 2003, Econometrics Working Paper EWP0304.

[14] D.E.A Giles, and R. Draeseke, "Econometric Modelling Using Pattern Recognition via the Fuzzy C Means algorithm", in D.E.A. Giles (ed.), Computer-Aided econometrics, Marcel Dekker, New York, pp. 407-450, 2003.

[15] S. Kooths, "Modelling Rule- and experience Based Expectations Using Neuro-Fuzzy systems, presented at the Computing In economics and Finance, CEF 1999.

[16] F-T. Lin and J-S. Yao, "Applying Genetic algorithms to solve The fuzzy Optimal Profit Problem", *Journal of Information Science and Engineering,* 18, pp. 563-580, 2002.

[17] Niskanen, V., "Empiric considerations on the fuzzy metric-truth approach", *Fuzzy Sets and Systems*,1998, No 95, pp.349-367.

[18] N. G. Mankiw, K. J. Forbes, and H. S. Rosen, "Report of the president", United Staes Government Printing Office, Washington, 2004.

[19] D.W. Gillen, W.G. Morrison and C. Stewart, Air Travel Demand Elasticities: Concepts, Issues and Measurement, Final Report, 2003, Available: http://www.fin.gc.ca/consultresp/Airtravel/airtravStdy_e.html

[20] H..J. Zimmermann, *Fuzzy Set Theory*, Kluwer Academia, 1991, pp. 69-90.

[21] G. Klir, and T.A. Folger, *Fuzzy Sets, Uncertainty and Information*, Prentice Hall, pp. 65-77, 1988.

[22] D. Driankov, H. Hellendoorn, and M. Reinfrank, *An Introduction to Fuzzy Control*, Springer Verlag, pp.61-73, 1993.

[23] G. Bojadziev and M. Bojadziev, *Fuzzy Sets, Fuzzy Logic, Applications*, World Scientific, 1995, pp.141-158.

[24] V. Kecman, Support Vector Machines, Neural Networks and Fuzzy Logic Models: Learning and Soft Computing, The MIT Press, Cambridge, MA, pp. 374-382, 2001.

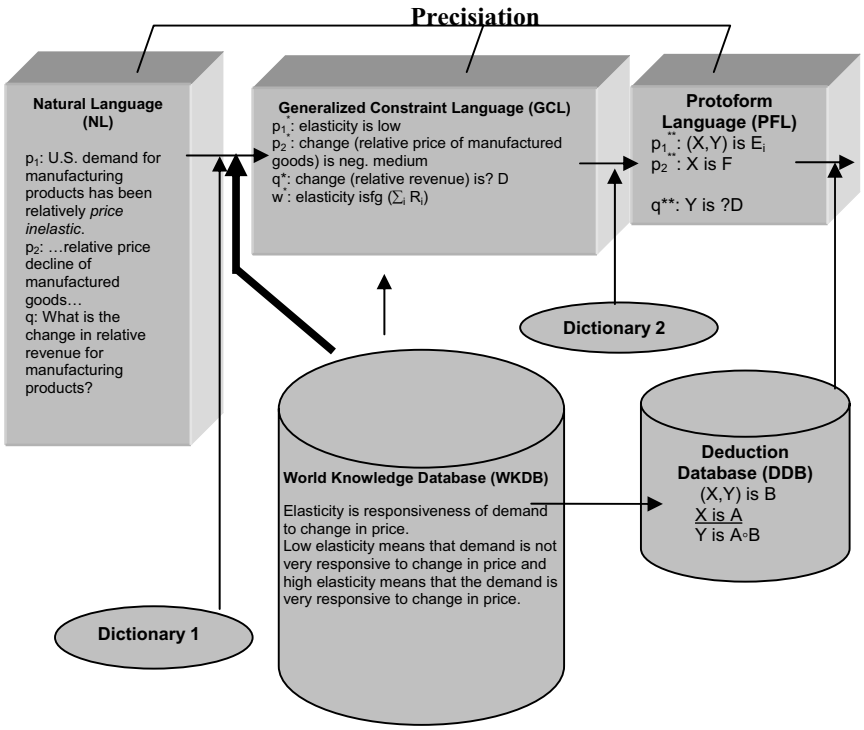

Fig. 1. Basic Structure of PNL

	Relational Matrix for Rule 7-9									Range for change in price	Change in price = approximately -50%	Range for Change in revenue	Estimated Change in Revenue
Revenue\Price	Low								High				
Low	0	0	0	0	0	0	0	0	0	-1	0	-1	0
	0	0.5	0.5	0.5	0	0	0	0	0	-0.75	0.5	-0.75	0.5
	0	0.5	1	0.5	0	0	0	0	0	-0.5	1	-5	1
	0	0.5	0.5	0.5	0.5	0.5	0	0	0	-0.25	0.5	-0.25	0.5
	0	0	0	0.5	1	0.5	0	0	0	0	0	0	0.5
	0	0	0	0.5	0.5	0.5	0.5	0.5	0	0.25	0	0.25	0.5
	0	0	0	0	0	0.5	1	0.5	0	0.5	0	0.5	0
	0	0	0	0	0	0.5	0.5	0.5	0	0.75	0	0.75	0
High	0	0	0	0	0	0	0	0	0	1	0	1	0

Fig. 2. Fuzzy relationship between change in price and change in revenue

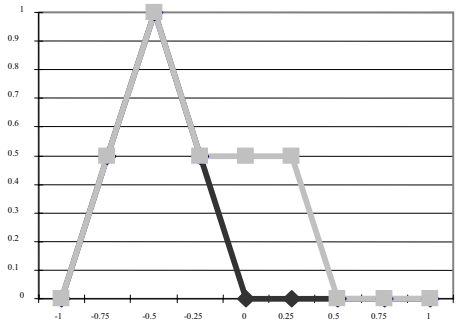

Fig. 3. Change in revenue for negative change in price and inelastic demand
(Grey: Change in Revenue, Black: Change in price)