Bipolar querying: some cognitive and decision theoretic inspirations

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Purpose of the paper:

- to take as a focus point our approach to bipolar queries in which:
    - a mechanism is provided for the inclusion of bipolar type user intentions and preferences via the required and desired querying conditions, and
    - handling them via the . . . and possibly . . . aggregation scheme,

- to extend the current perspective on bipolar queries from the point of view of some "non-orthodox" approaches to multicriteria decision making (Yager, 1992) to some new ideas by Grabisch, Greco and Pirlot (2008),
- to refer the ideas and line of reasoning to (some elements of) a new computing paradigm, affective computing, initiated by Rosalind Pickard (1997) at MIT,
- to indicate an intrinsic relation to some views on affects and judgments that are relevant in decision making, particularly to affective rationality due to Slovic at al. (2002) and Peters (2006).
- to indicate at a conceptual level a possibly fruitful link between bipolar queries meant as above and Casali, Godo and Sierra's (2008, 2009) recent approach to the use of a multiple valued logic based formalism for the representation of positive and negative desires in the context of intention modeling.

All that conceptually!

But:

- first, some more general remarks on fuzzy querying, and some history (for the younger generation . . .),
- . . .
- at the end, some suggestions for further research.

Presentation: more conceptual than technical

Based on joint works with: S. Zadrożny and G. De Tré

The roots:

- Fuzzy querying (DBMSs) are a "result" of Lotfi A. Zadeh's stay as a visiting scientist IBM Research – Almaden in San Jose, CA, in 1968, 1973, and 1977, and his close contacts with the late Edgar Frank "Ted" Codd,
- Zedeh's Ph.D. student, the late Valiollah Tahani, presented the first fuzzy querying solution (just fuzzy values and the min/max connectives) in 1977, . . .

What is our framework?

We have:

- a numerical relational database,

We wish to:

- find information according to our needs and intentions,
- we wish to use natural language (with imprecision) to articulate our needs and intentions.
- we think that fuzzy logic provides proper tools and techniques.

What is a fuzzy query (to a database)?

For instance, in a real estate database:

Example of an imprecise query

"We look for an inexpensive house"

An imprecisely specified price of the house can be:

- some values are fully satisfactory (e.g. less than EUR 200,000),
- some are impossible (e.g. more than EUR 300,000),
- the other ones are possible to some degree (e.g. in-between the above).

These are fuzzy queries initiated by Tahani (1977) developed during Zadeh's stay at IBM Almaden

Not interesting to us, too simple

More sophisticated fuzzy queries

Our work for the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria (late 1970s – mid-1990s)

A contract to develop a querying interface for imprecise (fuzzy) queries for a large database in the Large International Rivers Project (The Danube)

Problem:

Example of desired queries (by local authorities)

"List all localities in the watershed where there is a serious water pollution"

What is a serious water pollution?

Luckily enough we had various experts at IIASA (in water, environmental pollution, social sciences, psychology, etc.), and they have found that:

A serious water pollution is when:

"most of the important water pollution indicators considerably exceed some (fuzzily specified) thresholds"

Notice that:

A conceptual (no to speak about formal) representation of a real human perception of a relatively sophisticated, yet commonly encountered and widely used concept, i.e. a **serious water pollution** is "tricky"

One needs to reflect fine shades of meaning!

This is the key problem while trying to reflect needs and intentions!

Therefore, imprecision in:

- thresholds,
- "considerably exceed",

and non-conventional aggregation ("most of the important").

New type of flexible queries:
queries with linguistic quantifiers:
Kacprzyk and Ziółkowski (1986)
Kacprzyk, Ziółkowski and Zadrożny (1988)
Kacprzyk and Zadrożny (1994 - 2009): Windows based DBMSs, object-oriented, etc.
Bosc and his group, De Caluwe, De Tré, Chen (1995 - . . .)
etc.

Our fuzzy querying with linguistic quantifiers

First version:

- linguistic quantifier driven aggregation via Zadeh's classic calculus of linguistically quantified propositions: works very well!

Then: Yager's OWA operators, even the Sugeno and Choquet integrals

Many applications

Commercial success:

- used in some hotel reservation Web sites,
- a commercial software developed and marketed by a spin-off company at Carnegie Mellon University in Pittsburgh, PA.

An example: in a security threat context:

A serious security threat:

For almost all transactions of individual X on his/her credit card, most of the conditions hold: in exotic countries, numerous, far from his/her daily limit, to obscure companies

Therefore, the database query would be:

Find all individuals whose credits cards are seriously threatened

which is represented as:

Find all individuals for whose credit card. for almost all transactions most of the conditions: {exotic countries, numerous, far from his/her daily limit, to obscure companies} hold

Notice that a *fine shade of meaning* of a serious threat to credit cards has been reflected!
Found effective and efficient in practice!

Therefore:

We have develop queries with:

- a new way of reflecting user preferences (or intentions) in database querying,
- a "unorthodox" aggregation of partial scores.

So far so good but: can we do something else with respect to the users' preferences (intentions) and aggregation in our context?

Yes, many things, but here:

Bipolar queries (queries with preferences)

A representation of more fine shades of meaning

What is a bipolar query

For instance:

Example: crisp conditions

"Find a house cheaper than EUR 150,000 and possibly located not more than two blocks from a railroad station"

Thus, the house:

- must be less expensive than EUR 150,000 (the mandatory condition),
- satisfaction of the second condition (concerning location) is desired (the optional conditon).

Example: fuzzy conditions

"Find a cheap house and possibly located near a railroad station"

Bipolarity

In general, bipolarity means (here!) an explicit accounting for both:

- positive information, and
- negative information.

Bipolar nature of these conditions:

- negative: houses not satisfying it are rejected,
- positive: houses satisfying it are desired.

Two main problems:

- how to model these mandatory and optional conditions, within fuzzy logic (mainly how to compute the matching degree between the conditions and and tuples),
- how to aggregate matching degrees between the mandatory and optional conditions to determine the overall matching degree of the bipolar query.

Roots, relevant for our approach:

- Dubois and Prade (1988, 2002, 2008, 2009): variable weights, bipolar queries, positive and negative information and its modelling in the framework of possibility theory,
- Lacroix and Lavency (1988): an approach distinguishing required and preferred conditions (non fuzzy!)
- Bosc and Pivert (1992, 1993): a first "fuzzification" of this approach
- Yager (1992,1996): possibilistically qualified criteria in multicriteria decision making,
- Bordogna and Pasi (1995): aggregation in information retrieval,
- Kacprzyk and Zadrożny (since 2005): a deeper analysis and comparison of known approaches and a generalization towards queries with preferences (Chomicki, 2002).

Also, at a more conceptual level: Dujmović (1979) – partial absorption functions, and Tudorie (since 2006) – the "among" operator.

Bipolar queries: a formal representation

Notation

$T = \{t\}$ is a set of tuples to be queried;
$C(\cdot)$ is a (fuzzy) predicate corresponding to the negative (mandatory, necessary) condition,
$P(\cdot)$ is a (fuzzy) predicate corresponding to the positive (optional, possible) condition.

These predicates are identified with fuzzy sets on T, and $C(t)$ and $P(t)$ denote values of their membership functions.

Now, the source:

Lacroix and Lavency's (1988) interpretation of bipolar queries:

$$C(t) \text{ and possibly } P(t) \equiv C(t) \wedge (\exists s(C(s) \wedge P(s)) \longrightarrow P(t))$$

Quite intuitively appealing, not too complicated!

Bipolar queries – our first fuzzy extension

A fuzzy version (Zadrożny, 2005; Zadrożny and Kacprzyk, 2006 – ...):

$$\gamma(C, P, x, X) = \min(C(x), \max(1 - \max_{y \in X} \min(C(y), P(y)), P(x)))$$

conjunction	$\longmapsto$	min operator
disjunction	$\longmapsto$	max operator
existential quantifier	$\longmapsto$	max operator

Therefore, quite a straightforward fuzzification of the Lacroix and Lavency's approach:

- conceptually in line with popular fuzzy equivalents of basic logical operators,
- computationally effective and efficient.

Our main contribution:

In Zadrożny and Kacprzyk (2005 – ...): a further extension of queries with preferences towards:

Chomicki (2002, 2003, ...), University of Buffalo, NY

A new winnow operator is introduced selecting from a set of tuples such tuples which are non-dominated with respect to a given binary preference relation $R \subseteq T \times T$

And:

If $R(s, t)$ holds, then tuple s is said to dominate tuple t with respect to preference relation R.

Winnow operator – a formal definition

A winnow operator ω_R is defined as:

$$\omega_R(T) = \{t \in T : \neg\exists_{s \in T}\ R(s,t)\}$$

i.e., it selects a subset of the non-dominated tuples of T with respect to R.

And:

A query using the winnow operator is referred to as a query with preferences.

A growing interest in the use of the winnow operator (and also another one introduced by Chomicki, the *skyline* operator:

- in the flexible (fuzzy) querying community,
- among top people in (fuzzy) preference modeling (De Baets, Fodor, ...).

Winnow operator and bipolar queries

An example of a bipolar query:

Find a house cheaper than 150 000 $ (C, mandatory) and possibly located not more than two blocks from a railroad station (P, optional)

Let us define the following preference relation

$$R(t, s) \Leftrightarrow (t.\texttt{2station} \leq 2) \wedge (s.\texttt{2station} > 2)$$

Then, the following relational algebra query (σ_ϕ is the classical selection operator):

$$\omega_R(\sigma_{\texttt{price} \leq 150000}(\texttt{HOUSES}))$$

yields the same results as the original bipolar query.

Our fuzzification of the winnow operator

In Zadrożny and Kacprzyk (2006 – . . .):

Requirements

To express bipolar queries with fuzzy conditions C and P:

- R should be assumed to be a fuzzy preference relation,
- a fuzzy counterpart of the non-dominance concept has to be employed,
- the set of tuples T should be assumed to be a fuzzy set.

Zadrożny and Kacprzyk (2006)

The $\mu_{\omega_R(T)}(t)$, which is a degree of membership of the tuple t to the fuzzy set of tuples defined by $\omega_R(T)$, is:

$$\mu_{\omega_R(T)}(t) = \text{truth}(T(t) \land \forall_s \, (T(s) \rightarrow \neg R(s, t)))$$

The purpose of bipolar queries, queries with preferences, the (fuzzy) winnow operator, etc. is to:

give more tools to represent the human intentions and requirements/needs as to what should be retrieved in a more sophisticated way, expressing finer shades of meaning.

For instance, in a credit card security related context:

A serious security threat:

For almost all transactions of individual X on his/her credit card account, most of the conditions hold: in exotic countries, numerous, far from his/her daily limit AND POSSIBLY at strange times of the day and to obscure companies

Therefore:

So, the database query would be:

Find all individuals whose credits cards are seriously threatened

which is represented as:

Find all individuals for whose almost all transactions on their credit card accounts most of the conditions hold: in exotic countries, numerous, far from his/her daily limit AND POSSIBLY at strange times of the day and to obscure companies

and we should use our fuzzification of the Lacroix and Lavency queries with preferences or of the winnow operator, with a proper definition of the *t*-norm, *t*-conorm, negation and implication.

Notice that fine shades of meaning of a serious security threat to credit cards has been well, and more broadly reflected

What next?

A conceptually new approach to bipolar queries which will try to use some new ideas from social sciences, cognitive sciences, psychology, etc.

Our recent works:

Kacprzyk and Zadrożny (2010, 2011)

in which we use:

- elements of some works by Dubois and Prade, and their collaborators, not cited so far in the literature on bipolar queries,
- elements of logic based approach to the modeling of BDI (belief, desire, intention) by Godo and his collaborators,
- elements of non-standard, "behavioral-like" decision theoretic and analytic models.

A decision making connection

Decision making is a]mental process aimed at finding, and then implementing, a course of action which is considered the best, under the circumstances.

Basically, it contains:

- a set of options (courses of action),
- a preference relations (structure) over the set of options, often been expressed as an utility function,
- a rationality criterion often expressed as the maximization of an utility function.

Conceptually, this approach boils down to "cold-blooded" and deliberative decision making (cf. Shafir, Simonson and Tversky, 1993) as opposed to emotional and biased ways of making decisions by human being indicated by many psychologists, behavioral economists, cognitive scientists, etc. but considered to be "inferior" by formal decision theorists.

In recent years decision making and decision theoretic communities turned their attention to how affective feelings influence judgments and decision, and even mention affective rationality as a basic foundation of decision making and processes which is in contrast with a deliberative traditional utility maximization based rationality (cf. Slovic et al., 2002, Peters, 2006, etc.)

Moreover, a conceptually much larger field of affective science and then affective computing has emerged (cf. Picard, 1997).

Basically, affect is meant as the experience of feeling or emotion, and is a key element of an organism's interaction with stimuli.

Sometimes, affect also is referred to a facial, vocal, or gestural behavior that reflects an affect.

Affective science is basically concerned with the study of emotions or affects which involves their elicitation, experience and recognition.

Affective computing is a further step and deals with the study and development of systems and devices that can recognize, interpret, process, and simulate human affects.

we will try to go into this direction ...

The second field of our concern is database management systems (DBMSs), more specifically the very important and difficult problem of how to adequately reflect the user's intentions and preferences for the retrieval of information that is really sought (intended).

For the human being natural language is the only fuzzy natural means of articulation and communications, hence a query is usually first conceived in natural language, and then translated into a form required by a DBMS.

To reflect an inherent imprecision of natural language, fuzzy logic has found many successful applications in the modeling of syntax and semantics.

Attempts have also been made to attain an even higher human consistency, among them reflect bipolarity in human judgments and intention/preference articulation.

As found by social scientists, psychologists, cognitive scientists, etc., a human being in his/her assessments is usually using a bipolar scale:

- some degree of being negative, i.e., to be rejected,
- some degree of being positive, i.e., to be accepted.

A proper scale is therefore crucial and two scales are usually considered (cf. Grabisch, Greco and Pirlot, 2008):

- bipolar univariate,
- unipolar bivariate.

The former assumes one scale with three main levels of, respectively, negative, neutral and positive evaluation, gradually changing from one end of the scale to another

The latter assumes two more or less independent scales which separately account for positive and negative evaluation

Usually, $[-1, 1]$ and $[0, 1]$ are used to represent the scales in respective models of bipolarity.

We will use unipolar bivariate scales to handle bipolarity.

Bipolar assessments may concern:

- the whole objects or
- values of their features,

and the problem is how to aggregate them.

For the queries, this concerns the aggregation of bipolar evaluations of elementary conditions, and then how to order query results with respect to bipolar evaluations.

Our previous works on bipolar queries (cf. Zadrożny, 2004–2005, Zadrożny and Kacprzyk, 2006–2011, De Tré, Zadrożny and Kacprzyk, 2007–2010:

the main concern is:

how to deal with the aggregation of negative and positive assessments, assuming as the starting point the seminal work of Lacroix and Lavency (1987) who proposed a query composed of the required and just preferred conditions.

For instance:

"Find houses cheaper than USD 500,000 and possibly located not more than five blocks form a railroad station".

Data not satisfying the former condition (i.e., houses more expensive than USD 500,000) are rejected, while the dissatisfaction of the latter (i.e., being located farther than five blocks from the station) may be acceptable, provided there are no data satisfying both conditions simultaneously.

Thus, the former condition (its complement!) corresponds to a negative assessment, while the latter condition to a positive assessment

For the aggregation of the negative and positive evaluations, to come up with an evaluation on a univariate scale that yields an ordering of the tuples in an answer to the query, we have used fuzzy and possibilistic tools.

The key problem in bipolar queries is concerned with the user intentions and preferences.

The modeling of intentions and preferences is a well establishes field, notably in psychology, cognitive science, artificial intelligence, decision sciences, etc.

A new quality may be obtained if we combine results on bipolar queries with proper chosen results on intention and preference modeling.

In this paper we will use:

- some hints and solutions related to the use of affects in the context of preference modeling as, for instance, discussed by Peters (2006) in a slightly more general, decision analytic framework,
- and then, some elements of Grabisch, Greco and Pirlot (2008) to develop tools for the aggregation of required and desired conditions in the context of bipolar querying.

Multicriteria decision making is our concern because bipolar queries will be dealt with in a bicriteria decision making setting.

The literature on bipolarity and multicriteria decision making is quite rich and growing, both in:

- nonfuzzy settings (e.g. Tsoukiás et al., 2008–2010), and
- fuzzy and possibilistic settings, traced to early works of Yager (1992), Bordogna and Pasi (1005), and many papers by Dubois and Prade, and their collaborators (2008–2010).

Since this paper is meant to just indicate a possible new approach combining:

- multicriteria decision making in a bivariate bipolar context, which is explicitly and implicitly related to affects as meant in the decision theoretic context (cf. Peters, 2006),
- bipolar queries in our sense,

then we use Grabisch, Greco and Pirlot's (2008) approach in which a general bivariate bipolar multicriteria decision making model is proposed.

In Grabisch, Greco and Pirlot's (2008) model each option (alternative) is represented as a vector

$$x = [(x_1^+, x_1^-), \ldots, (x_n^+, x_n^-)]$$

where n is the number of criteria, and x_i^+ and x_i^- are the positive and negative, respectively, evaluation of alternative with respect to criterion i; these evaluations are real numbers from $[0, 1]$.
That is, x may be written as

$$x = [(x_1^+, \ldots, x_n^+, x_1^-, \ldots, x_n^-]$$

i.e. is formed by concatenating two vectors $x^+ = [(x_1^+, \ldots, x_n^+]$, and $x^- = [x_1^-, \ldots, x_n^-]$.

Since the evaluation is concerned with the positive and negative aspect, in the bivariate multicriteria setting we can use the so-called:

- comprehensive positive evaluation, $CPE(x)$,
- comprehensive negative evaluation, $CNE(x)$,

and their aggregation yields the comprehensive evaluation, $CE(x)$.

This can be written generally as

$$CPE(x) = F^+((x_1^+, \dots, x_n^+, x_1^-, \dots, x_n^-) \quad (1)$$

$$CNE(x) = F^-((x_1^+, \dots, x_n^+, x_1^-, \dots, x_n^-) \quad (2)$$

$$\begin{aligned} CE(x) &= \\ &= G(F^+((x_1^+, \dots, x_n^+, x_1^-, \dots, x_n^-), \\ &\quad F^-((x_1^+, \dots, x_n^+, x_1^-, \dots, x_n^-)) \end{aligned} \quad (3)$$

where $F^+, F^-, G : [0,1]^{2n} \longrightarrow [0,1]$,and F^+ and F^- are nondecreasing with respect to the first n arguments and nonincreasing with respect to the last n arguments, and G is nondecreasing in its first and nonincreasing in its second argument; this is in line with their very essence and intuition.

Bipolar queries

Different kinds of bipolar queries may be distinguished due to:

- the type of a bipolar scale used to express assessments,
- the level of data at which these assessments are given.

Concerning the first aspect, two types of scales are used (cf. Grabisch, Greco and Pirlot, 2008):

- a univariate bipolar scale in which the assessment is expressed as one number from a fixed interval, e.g., $[-1, 1]$, and this interval is divided into three zones expressing the negative (negative numbers), neutral (number 0) and positive (positive numbers) assessments, respectively, and
- a unipolar bivariate scale in which the positive and negative assessments are expressed separately on two unipolar scales, e.g. as two numbers from $[0, 1]$.

The negative and positive assessments are treated as corresponding to the required and preferred conditions, respectively, i.e. the former condition has to be satisfied necessarily and the latter only possible.

The negative assessment is identified with the degree to which the required condition is not satisfied.

The use of separate two unipolar scales provides effective and efficient means for our purposes.

This view of a bipolar query coincides with a bipolar view of multicriteria decision making as meant by Grabisch, Greco and Pirlot (2008).

The interpretation of both the assessments can be made operational in different ways, for example:

- in Dubois and Prade's (2008) approach it is imposed via the use of lexicographic order,
- in our approach it is based on the formalization of the "and possibly" connective along the lines presented in the paper of Lacroix and Lavency (1987).

The latter view is also more in line with the general bivariate multicriteria model by Grabisch, Greco and Pirlot (2008).

Concerning the second aspect, the (positive and negative) assessments may concern:

- particular values of the attribute domains, or
- the whole tuples.

Here, they are at the level of the whole tuples, i.e., providing a comprehensive evaluation of the negative and positive aspects of a given tuple separately, as two numbers from $[0, 1]$ calculated for each tuple as the degrees to which it satisfies two conditions specified by the user.

Thus, a bipolar query is here defined by the two conditions exemplified by:

> "Find a *cheap* house *and possibly* located *near* a railway station"

The negative assessment of a given house is here implicit and is identified with the degree to which it is not cheap, while the positive assessment is identified with the degree to which it is located near the station.

We identify the negative and positive assessments defining a bipolar query with the predicates (fuzzy sets) that represent them and denote them as C and P, respectively (more precisely: C denotes the negation of the respective predicate).

We denote the whole bipolar query as (C, P).

Here we discuss a final overall scalar evaluation of each tuple defined so that it preserves the semantics of the “and possibly” term.

This is an operator aggregating the matching degrees of C and P, but with respect to the content of the whole database (table) queried!

The semantics of the

$$C \text{ and possibly } P$$

condition is understood as follows.

If there is a total conflict between C and P, i.e., satisfying C means totally failing to satisfy P, the bipolar query reduces itself to the condition C.

If both conditions may be totally satisfied simultaneously, then the bipolar query reduces to a simple conjunction $C \wedge P$.

We will refer to such queries as bipolar queries with the "and possibly" operator or as to "C and possibly P" queries.

That is: it is a bipolar query involving bivariate unipolar scale with bipolarity expressed at the level of the whole tuple, and with a specific interpretation of the negative and positive assessments.

In the original (crisp, nonfuzzy) approach by Lacroix and Lavency the aggregation proceeds as:

A tuple t belongs to the answer set of a query (C, P) if it satisfies the (crisp) condition:

$$C(t) \text{ and possibly } P(t) \equiv C(t) \wedge \exists s(C(s) \wedge P(s)) \Rightarrow P(t)$$

If there is no conflict between P and C, i.e., there are tuples satisfying both of them, then the query turns into a conjunction of P and C, $C \wedge P$.

This is clearly in line with the general bivariate bipolar approach to multicriteria decision making mentioned since

$$
\begin{aligned}
CE(x) = & \\
= \quad & G(F^{+}((x_1^{+}, \ldots, x_n^{+}, x_1^{-}, \ldots, x_n^{-}), \\
& F^{-}((x_1^{+}, \ldots, x_n^{+}, x_1^{-}, \ldots, x_n^{-}))
\end{aligned}
$$

does basically serves the purpose of an overall evaluation that is in the present case equated with the "and possibly" aggregation operator.

In Zadrożny (2004 – . . .), Zadrożny and Kacprzyk (2006 – . . .), etc. we proposed a "fuzzification" of the Lacroix and Lavency approach, by a direct "fuzzification":

$$C(t) \textit{ and possibly } P(t) \equiv \\ C(t) \wedge (\exists s\ (C(s) \wedge P(s)) \Rightarrow P(t)) \quad (4)$$

We modeled the conjunction and disjunction by the *t*-norm and *t*-conorm, and considered the so-called De Morgan Triples $(\wedge, \vee, \neg)$ that comprise a *t*-norm operator $\wedge$, a *t*-conorm operator $\vee$ and a negation operator $\neg$, where $\neg(x \vee y) = \neg x \wedge \neg y$ holds.

We basically used:

$t - norms$		
$x \ \wedge_{min} \ y$	$= \min(x, y)$	*minimum*
$x \ \wedge_{\Pi} \ y$	$= x \cdot y$	*product*
$x \ \wedge_{W} \ y$	$= \max(0, x + y - 1)$	*Łukasiewicz*

$t - conorms$		
$x \ \vee_{max} \ y$	$= \max(x, y)$	*maximum*
$x \ \vee_{\Pi} \ y$	$= x + y - x \cdot y$	*probabilistic sum*
$x \ \vee_{W} \ y$	$= \min(1, x + y)$	*Łukasiewicz*

The negation operator $\neg$ in case of all the above De Morgan Triples is defined as:

$$\neg x = 1 - x$$

We will refer to the respective triple as, respectively, the MinMax, Π and W triples.

Notice that this is closely related to:

- the comprehensive negative evaluation, $CNE(x)$:

$$CNE(x) = F^{-}((x_1^{+}, \dots, x_n^{+}, x_1^{-}, \dots, x_n^{-})$$

  and

- the comprehensive positive evaluation, $CPE(x)$:

$$CPE(x) = F^{+}((x_1^{+}, \dots, x_n^{+}, x_1^{-}, \dots, x_n^{-})$$

What about the *t*-norm, *t*-conorm, and negation?

Well:

all people in the bipolar querying community analyze properties on the (fuzzy) logical, possibilistic, etc. formulas but nobody ask a question whether there may be problems with the use of the minimum, maximum, other *t*-norms and *t*-conorms, (fuzzy) implications, etc. in the database querying context,

and, on the other hand:

not many people in in the database community, working in our, formal and technical direction do not even know those, cited next, and related works.

There is some literature on this but not in our area:

- Janice M. Keenan, Psychological issues concerning implication: Comments on "Psychology of pragmatic implication: Information processing between the lines"by Harris and Monaco, Journal of Experimental Psychology, 107 (1), 23-27, 1978.
- Sharon L. Greene, Susan J. Devlin, Philip E. Cannata, Louis M. Gomez, No IFs, ANDs, or ORs: A study of database querying, International Journal of Man-Machine Studies, 32 (3), 303-326, 1990.
- Peter J.M.D. Essens, Carol A. McCann, Mark A. Hartevelt, An experimental study of the interpretation of logical operators in database querying, Acta Psychologica, 78 (1-3), 201-225, 1991.

Interesting findings, should be accounted for if we wish to develop implementable bipolar queries.

Concluding remarks

In this paper we tried to indicate a new connection between:

- affects, which are of crucial relevance in virtually all real world decision making processes, and are meant here more in the sense of affective rationality than affective computing,and
- bipolar queries, in the sense of our previous works which are conceptually based on the concept of bipolarity proposed by Dubois and Prade (2009) and on the concept of Lacroix and Lavency's (1987) queries with preferences.

Since at the heart of our method is multicriteria decision making, we proposed the use of some elements of Grabisch, Greco and Pirlot's (2008) bivariate bipolar approach to multicriteria decision making.

It seems that their general framework can be of relevance for our analysis.

In particular we think that the concept of the Choquet bi-integral proposed by them can be an appropriate tool for the aggregation of bivariate bipolar pieces of evidence that occur in the model.

However, since the comprehensive evaluation in the case of bipolar queries has the form of a logic formula, and not an additive, product, etc. function, a thorough analysis and a further study is needed.

What next?

So far:

- an approach to bipolar queries the dealing with which is meant to boil down to a proper representation of the and possibly type aggregation.

Now we wish to:

- indicate at a conceptual level a possibly fruitful link between bipolar queries meant as above and Casali, Godo and Sierra's (2008, 2009) recent approach to the use of a multiple valued logic based formalism for the representation of positive and negative desires in the context of intention modeling.

That is:

- The paper is unorthodox as it proposes and advocates a new research direction within an already established field of bipolar queries dealt with in a logical and possibilistic settings initiated by Dubois and Prade (2002, . . .).
- We think that relevant and far reaching findings of Cohen and Levesque's (1990) theory of intentions are proper because bipolar queries are all about a sophisticated modeling of the user's intentions,
- To stay in the field of broadly perceived flexible querying, we will not deal directly with Cohen and Levesque's theory but we will limit attention to a restricted logical perspective as proposed by Casali, Godo and Sierra.

Our concern is database management systems (DBMSs), more specifically the very important and difficult problem of how to adequately reflect the user's intentions and preferences for the retrieval of information that is really sought (intended).

For the human being natural language is the only fuzzy natural means of articulation and communications, hence a query is usually first conceived in natural language, and then translated into a form required by a DBMS.

To reflect an inherent imprecision of natural language, fuzzy logic is employed.

Attempts have also been made to attain an even higher human consistency, among them to reflect bipolarity in human judgments and intentions and preferences.

As found by social scientists, psychologists, cognitive scientists, etc., a human being in his/her assessments is usually using a bipolar scale:

- some degree of being negative, i.e., to be rejected,
- some degree of being positive, i.e., to be accepted.

A proper scale is therefore crucial and two scales are usually considered (cf. Grabisch, Greco and Pirlot, 2008):

- bipolar univariate,
- unipolar bivariate.

The former assumes one scale with three main levels of, respectively, negative, neutral and positive evaluation, gradually changing from one end of the scale to another

The latter assumes two more or less independent scales which separately account for positive and negative evaluation

Usually, $[-1, 1]$ and $[0, 1]$ are used to represent the scales in respective models of bipolarity.

We will use unipolar bivariate scales to handle bipolarity.

The key problem in bipolar queries is concerned with the user intentions and preferences that should be properly accounted for.

The modeling of intentions and preferences is a well establishes field, notably in psychology, cognitive science, artificial intelligence, decision sciences, etc.

A new quality may be obtained if we combine results on:

- bipolar queries.
- intention and preference modeling.

Therefore:

- bipolar queries are basically about the user's preferences and intentions!

A fruitful approach to their representation and handling may be to take advantage, and employ some elements of vast research results in the broadly perceived area of intention modeling, notably those related to preferences and desires.

Representation of desires: a logical framework

We use Casali, Godo and Sierra's (2008, 2009) logical framework for the representation of bipolar like preferences that has a clear relation to intention modeling, with the assumptions:

- preferences are essential for making decisions, and – from the perspective of multiagent systems – may be viewed as so called proactive attitudes in intentional agents,
- preferences can be viewed to be positive and negative,
- positive preferences (desires!) imply the agent may do what he/she intends to achieve via a plan of actions,
- negative preferences may represent restrictions, or rejections, over the possible worlds within which the agent is operating.

Using the so-called Belief-Desire-Intention (BDI) architecture (or software model), which provides a mechanism for separating the activity of selecting a plan from the execution of currently active plans, and employing the concept of an intentional agent (cf. Rao and Georgeff, 1991), desires represent the ideal agent preferences no matter what the agent's current perception of the environment and the cost involved in achieving them are.

For us, in this respect what we need are the works by Benferhat, Dubois, Kaci and Prade (2001, 2005) on the modeling of preferences in terms of positive and negative testimonies in the framework of possibilistic logic.

The basic philosophy behind those works is also used in our works on bipolar queries!

Casali, Godo and Sierra (2008, 2009) follow to some extent the above approach and suggest a logical formalism to represent both the positive and negative agent desires:

- the positive desires represent what the agent would like to happen (accepts), while the negative desires correspond to what the agent does not want to happen (rejects),

and to both the positive and negative desires we can assign a grade of acceptance and grade of rejection, respectively.

Casali, Godo and Sierra first extend the works by Benferhat, Dubois, Kaci and Prade (2001 – 2006) by providing a sound and complete axiomatization within their logical framework, and then present a logical system for intentions and prove it to be expressive enough to describe how the positive and negative desires can lead to intentions possessed by agents.

This is done by defining:

- first a modal-like language to express graded positive and negative desires with its corresponding semantics, and then
- a layered set of axioms to describe the behavior of preferences.

The degrees of desires are dealt with in Hájek's (1998) general multiple valued logic framework.

Then, based on that representations of positive and negative desires, the authors extend their logical framework to represent the agent's intentions, hence also the agents' preferences.

Basically, the idea of Cohen and Levesque's (1990) fundamental approach to the representations of intentions is followed in that the intentions result from the agent's beliefs and desires, and possibly some other (utilitarian) information.

The authors, via a multivalued representation of the strength of intentions, can then assign to intentions a graded measure of the cost–benefit relation involved in the agent actions toward the intended goal.

Finally, they provide some insights on how the positive and negative desires, possibly with other information, can eventually lead to the plan to be pursued.

It is easy to see that the essence of Casali, Godo and Sierra's approach closely parallels the essence of our approach to bipolar querying, but provide some concepts that yield a new quality.

These new qualities will be briefly indicated now, and a cross-fertilization can be visible.

First, we identify a (database) query with a condition expressing what the user is looking for, i.e. his or her intention.
It can be argued, which is well founded on results of psychological research, that the user often has in mind in fact two types of conditions:

- *negative* which when met contribute to the rejection of data, and
- *positive* which when met contribute to the acceptance of data.

Thus the former conditions provide the *negative* information indicating what should be avoided, while the latter provide the *positive* information indicating what is preferred.

This view of bipolarity is very general and treats negative and positive evaluations as completely independent of each other and equal in their importance for the overall evaluation of a piece of data.

However, in the literature on bipolar queries most often a special interpretation of the negative and positive conditions is assumed. Namely, the negative and positive assessments are treated as corresponding to required and desired conditions, respectively.

The former condition has to be satisfied necessarily and the latter only if possible. The negative assessment in this interpretation is identified with the degree to which the required condition is not satisfied.

Casali, Godo and Sierra:

- also consider the representation of positive and negative conditions meant in the most general sense,
- however, besides such a basic schema for preferences (desires) representation they devise also some logical means (additional axioms) to express some dependencies between negative and positive desires.

Our previous works on bipolar queries have been based on the formalization of the "and possibly" connective along the lines of Lacroix and Lavency.

The unipolar bivariate scale is adopted, however the positive condition is here of a somewhat secondary importance. Such conditions, if they are crisp, define therefore two sets of data items:

- **rejected**, **infeasible**, etc., or, equivalently, taking a complement of the former, **acceptable**, **satisfactory**, **feasible**, etc., and
- **preferred**, **desired**, etc.

In the context relevant to our work, this may be conveniently interpreted in terms of two different types of the user's intentions or preferences, related to the **mandatory** and **optional**, or **necessary** and **preferred**, . . . requirements.

Another important aspect of bipolarity which should be taken into account is that the assessments may concern:

- particular values of the attribute domains, or
- the whole tuples.

In the former case the user partitions the domains of the selected attributes into subsets, defined by fuzzy sets, of elements with positive, negative and neutral gradual assessments.

In the latter case, the same is done for the whole set of tuples, and again the partition of the set of tuples is defined by fuzzy sets (fuzzy conditions) defined with reference to possibly many attributes, i.e., defined in the space of the Cartesian product of the domains of several attributes. For example, the user may identify negatively assessed houses as those satisfying the compound condition “expensive and small”.

We assume here that the user expresses his or her bipolar preferences using the **unipolar bivariate scales** at the **level of the whole tuples**, i.e., providing a comprehensive evaluation of negative and positive traits of a given tuple separately, as two numbers from $[0, 1]$ calculated for each tuple as (a function of) the degrees to which it satisfies two conditions specified by the user.

Now: we discuss an overall scalar evaluation of each tuple defined so that it preserves the "required/desired" semantics of bipolar queries which is expressed using the "and possibly" connective. This is meant as an operator aggregating the matching degrees of conditions C and P, but with respect to the content of the whole database.

The semantics of the

$$C \text{ and possibly } P$$

condition is to be understood as follows. If there is a total conflict between conditions C and P, i.e., satisfying C means totally failing to satisfy P, the bipolar query reduces itself to the condition C. On the other hand, if both conditions may be totally satisfied simultaneously, then the bipolar query reduces to a simple conjunction $C \wedge P$. Thus, the most interesting are those intermediate cases which may be characterized by a degree of conflict between the conditions C and P.

This approach is different than a straightforward approach that the accounting for the positive and negative conditions in bipolar queries is to maximize the degree of satisfaction of the positive condition and to maximize the degree of satisfaction of the complement of the negative condition, which can then boil down to a proper weighted or unweighted aggregation!

First of all, due to the very nature of bipolar univariate scales assumed the complement of the positive condition is not necessarily the negative condition, and vice versa.

Second, it is difficult to say how the positive and negative information should be aggregated, and some type of affect or attitude is here decisive, somehow in the spirit of the traditional risk aversion, risk neutrality or risk proneness.

In our paper, however, we follow a different, not multiobjective optimization, or multicriteria decision making, oriented path but a logic based approach. It contains some weighting of the positive and negative conditions but the weights depend on the entire contents of the database which is clearly a result of the semantics of bipolarity employed.

Therefore, it would have been too large a simplification when, first, the problem would have been equated with the straightforward maximizations of the positive and the complement of the negative conditions, weighted through directly derived weights.

Moreover, that straightforward approach may only be effectively employed under clear-cut semantics of the conditions exemplified by a monetary value.

Required/desired semantics - a modal logic based representation

Here we propose to model the required/desired semantics of bipolar queries using elements of fuzzy modal logic.

We are inspired by Casali, Godo and Sierra but our approach is very different.

We adopt the language of the standard propositional modal logic with one modality symbol $\Diamond$ but interpret it in the framework of the flexible fuzzy querying of database in the following way:

The Kripke model (W, R, V) for the modal language is identified with the current instance of a database T (in turn identified with a single table/relation, for simplicity). In particular:

- the set of worlds W comprises tuples of the relation T,
- the accessibility relation R is assumed to be equal to $W \times W$,
- the valuation V yields for each propositional variable p a fuzzy set $V(p)$ in W and $\mu_{V(p)}(w) \in [0, 1]$ denotes degree to which p is true in $w \in W$.

Propositional variables represent atomic conditions used in queries.

Valuation V is defined as: if p represents an atomic condition "price IS High" then:

$$\mu_{V(p)}(w) = \mu_{High}(w[price])$$

where μ_{High} is the membership function of a fuzzy set representing the linguistic term "High" and $w[price]$ denotes the value of the attribute "price" at the world (tuple) w.

Under such an interpretation we can define the "and possibly" connective as:

$$c \textit{ and possibly } p \equiv c \wedge (\Diamond(c \wedge p) \Rightarrow p) \tag{5}$$

where c and p represent the required and desired conditions which are assumed atomic for simplicity.

So, we obtain a definition of the "and possibly" connective which is more concise and represents the semantics of this connective in a more apparent way.

We have also shown a close relation of our view of bipolar queries and the "and possibly" aggregation with our fuzzy version of the Chomicki winnow operator via the so-called De Morgan Triples $(\wedge, \vee, \neg)$ that comprise a t-norm operator $\wedge$, a t-conorm operator $\vee$ and a negation operator $\neg$, where $\neg(x \vee y) = \neg x \wedge \neg y$ holds, and analyzed a full array of them.

It seems that some elements of Casali, Godo and Sierra's approach to reflect a bipolar nature of human intentions can be of use in our context as their bipolar desire models contain, first of all, positive and negative preference distributions over the possible worlds which are used to give semantics to the positive and negative desires.

This can help extend our approach in which such modal formulas involving the usual truth functions for the Łukasiewicz connectives may be useful.

They use some Pavelka logic which is a generalization of Łukasiewicz's infinitely valued logic.

However, in our analysis we go beyond the standard definitions of the connectives due to Łukasiewicz. Hence, this needs a further study.

Therefore:

- We tried to indicate at a conceptual level that our works on bipolar queries which are based on the concept of bipolarity proposed by Dubois and Prade, can benefit from some works on the use of:
    - some new directions in decision theory and analysis related to affect and judgment, affective rationality, and some other directions which stem from behavioral analyzes rather than from formal ones,
    - a multiple valued logic based formalism for the representation of positive and negative desires in the context of intention modeling proposed by Casali, Godo and Sierra which also has roots in some related works originating from Dubois and Prade's group.

It seems that while our approach to bipolar queries may be more constructive and application focused:

- the approach to the reflection of affect and judgment may be a significant step towards a human centric setting,
- the approach to positive and negative desires may be more general and formal as it uses a more elaborated logical calculus which has a higher expressive power.

In general:

- this may be a step towards overcoming an "inbreeding" type of activities we have in our area (i.e., no reaching out to other fields like cognitive science and psychology), and hence no cross-fertilization.

What next?

Many undertakings, exemplified by:

- inclusion of more sophisticated preference structures (e.g., De Baets, Fodor, . . .),
- a balanced and constructive attempts to include further connectives, implications, etc., notably taking into account not only formal properties by many works on the psychology and cognition of operators in the querying context,
- a deeper analysis of the multicriteria decision making link since many well developed tools and techniques are available,
- a deeper analysis of the BDI link,
- etc.

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