Modeling and Querying Evidential Databases: First Steps towards a Strong Representation System

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Outline

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Imperfect Information

Imperfection

- Uncertainty
- Imprecision

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Example

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Theories and database models of Imperfection

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- Probability Theory [Laplace, 1812]
- Possibility Theory [Zadeh, 1978]
- Fuzzy sets Theory [Zadeh,1965]
- Evidence Theory [Dempster, 1967; Shafer, 1976]

Probabilistic Databases

ID	*Weather*	*Probability*
1	rainy	0.6
2	sunny	0.4

(R.Cavallo, M.Pittarelli,1987)

Possibilistic Databases

ID	*Weather*	*Possibility*
1	rainy	1
2	sunny	0.4

[H.Prade, C.testemale, 1984]

Evidential Databases

ID	*Weather*	*Confidence Level*
1	Rainy 0.5 Sunny 0.5	[0.3 1]
2	{Sunny ; Rainy} 1	[0.5 0.5]

[S.K.Lee, 1992]

Theory of Evidence

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- Introduced by Dempster in 1967 and formalized by Shafer in 1976.
- Popularized by Smets in 1988 with the Transferable Belief Model (TBM).
- Theory of evidence provides an explicit representation of *uncertainty*, *imprecision* and *inconsistency*.

Evidential Databases

Evidential Databases

An *Evidential Database* (EDB) on its *compact form* has N tuples and D attributes. The value of an attribute c for an object l is called *evidential value*, V_{lc}.

ID	Disease	Symptom	CL
1	Diabetes 1	Fatigue 0.4 {Fatigue, Nausea} 0.6	[0.3 ; 0.9]

Evidential Databases

Mass Function

A mass function, m, is a mapping from 2^{Θ} to [0;1]. The basic belief mass of an hypothesis x, $m(x)$ represents the degree of truth about that hypothesis x such that:

$$\sum_{x \subseteq \Theta} m^{\Theta}(x) = 1$$

ID	Disease	Symptom	CL
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Evidential Databases

Confidence Level

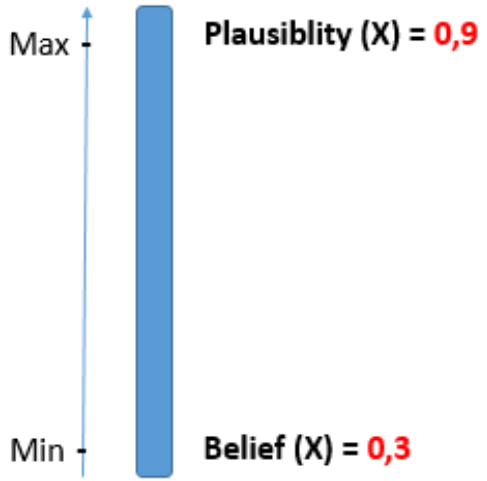
A confidence level CL is a measure that quantifies the degree of belief bel and plausibility pl about the existence of each tuple in the database, $CL = \{[bel, pl] | bel, pl \in [0, 1]; bel \leq pl\}$.

ID	Disease	Symptom	CL
1	Diabetes 1	Fatigue 0.4 {Fatigue, Nausea} 0.6	[0.3 ; 0.9]

Belief Function

The *belief function*, *bel*, is the minimal degree of belief given to an hypothesis x.

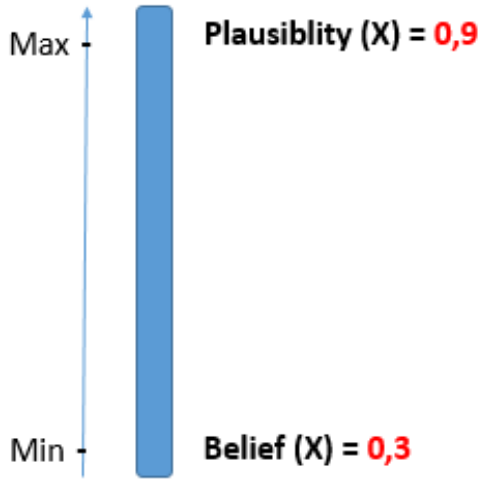
$$bel(x) = \sum_{y,x \subseteq \Theta : y \subseteq x} m(y)$$



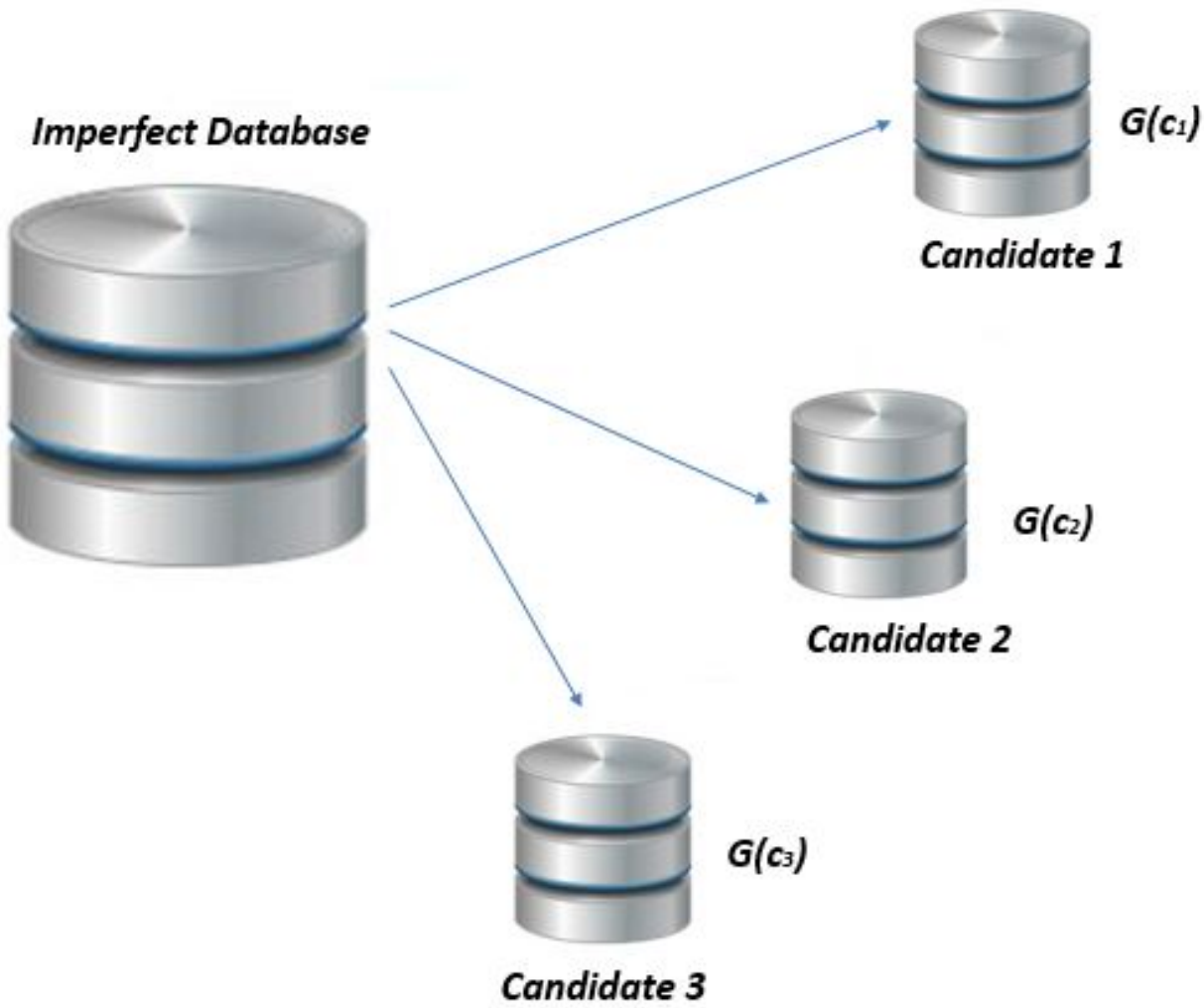
Plausibility Function

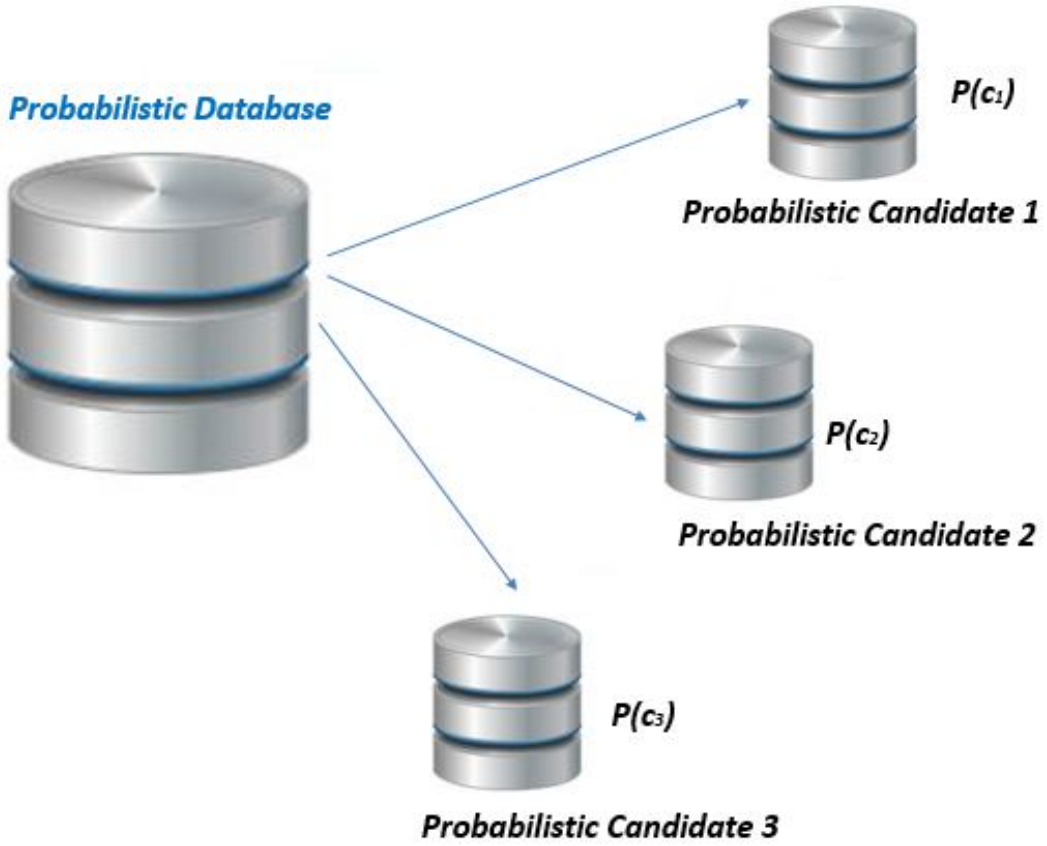
The *plausibility function*, *pl*, is the maximal amount of belief on the hypothesis x.

$$pl(x) = \sum_{y, x \subseteq \Theta : x \cap y \neq \varnothing} m(y)$$

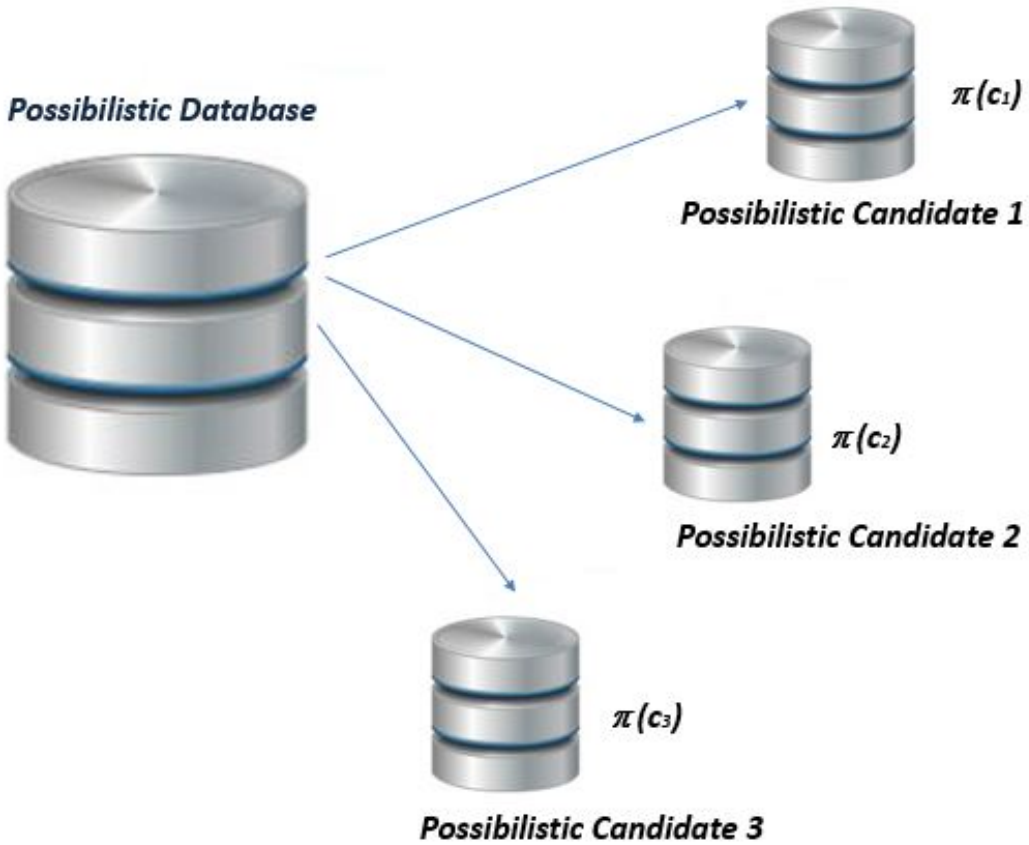


Outline


Imperfect Database
G(c1)
Candidate 1
G(c2)
Candidate 2
G(c3)
Candidate 3



[Abiteboul, Kanellakis and Grahne, 1991]



[Bosc, Liétard and Pivert, 2002]


Evidential Database


?

Generating Possible Worlds from an EDB: Example

EDB

ID	Disease	BloodType
1	Anemia 1	B 0.3 {B, O} 0.7
2	{Asthma, Flu} 1	A 1

Generating Possible Worlds from an EDB: Example

W_1

ID	Disease	BloodType
1	Anemia	B
2	Asthma	A

W_2

ID	Disease	BloodType
1	Anemia	B
2	Flu	A

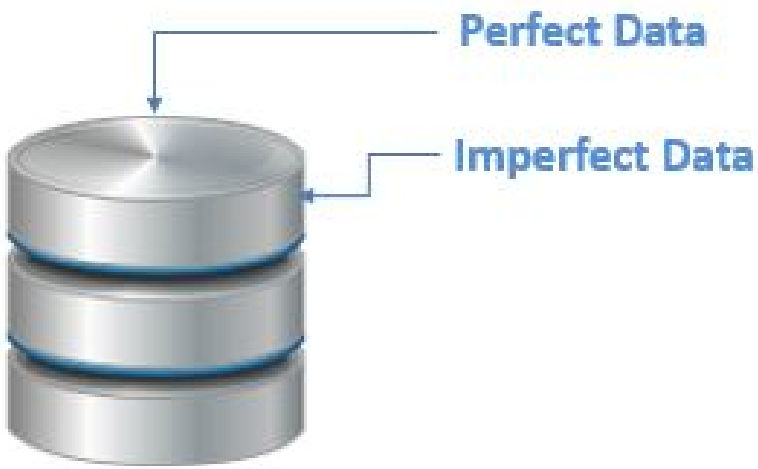
W_3

ID	Disease	BloodType
1	Anemia	O
2	Asthma	A

W_4

ID	Disease	BloodType
1	Anemia	O
2	Flu	A

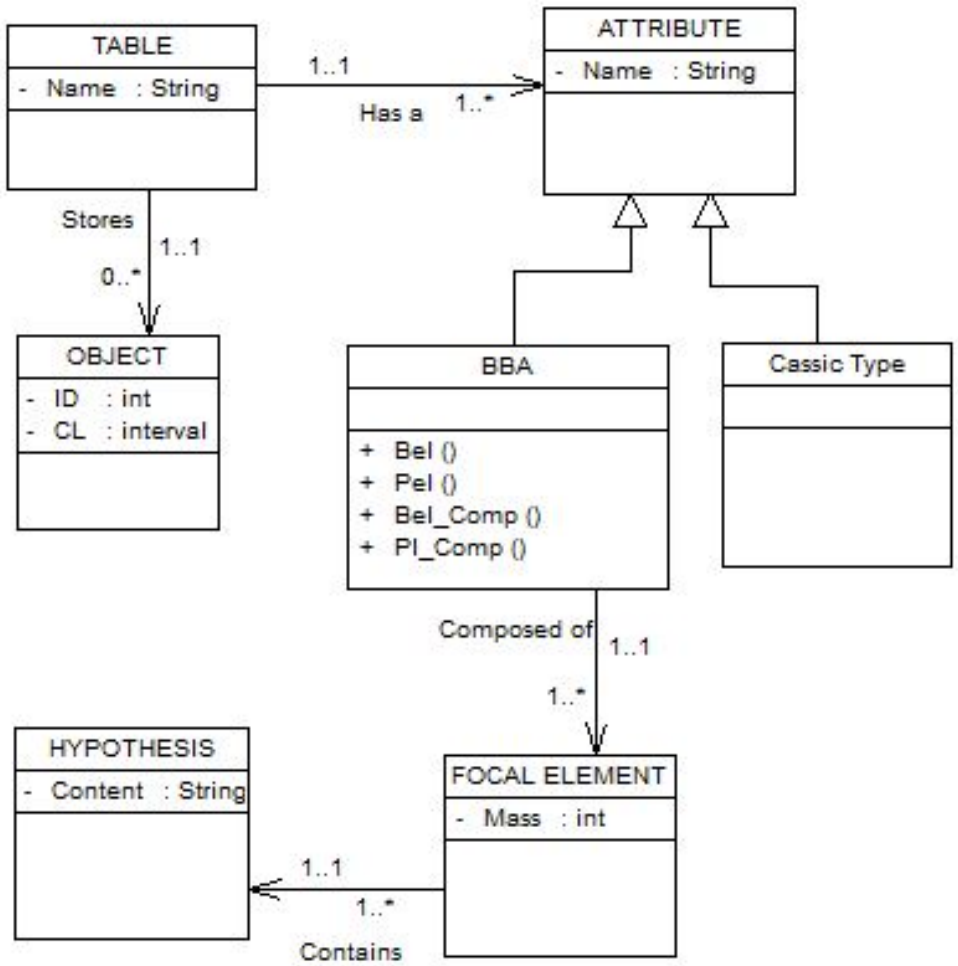
$$m(\{W_1; W_2\}) = 0.3 \qquad m(\{W_1; W_2; W_3; W_4\}) = 0.7$$



Evidential Database

The non existence of an implementation of an Evidential Database in the literature

Evidential Database Design



Implementation

SQL3 implementation:

- Facilitate the complex structure of an evidential database
- Optimize the I/O cost
- Accelerate the information extraction thanks to the indexes

Implementation

Table: Contribution of caches to queries re-execution

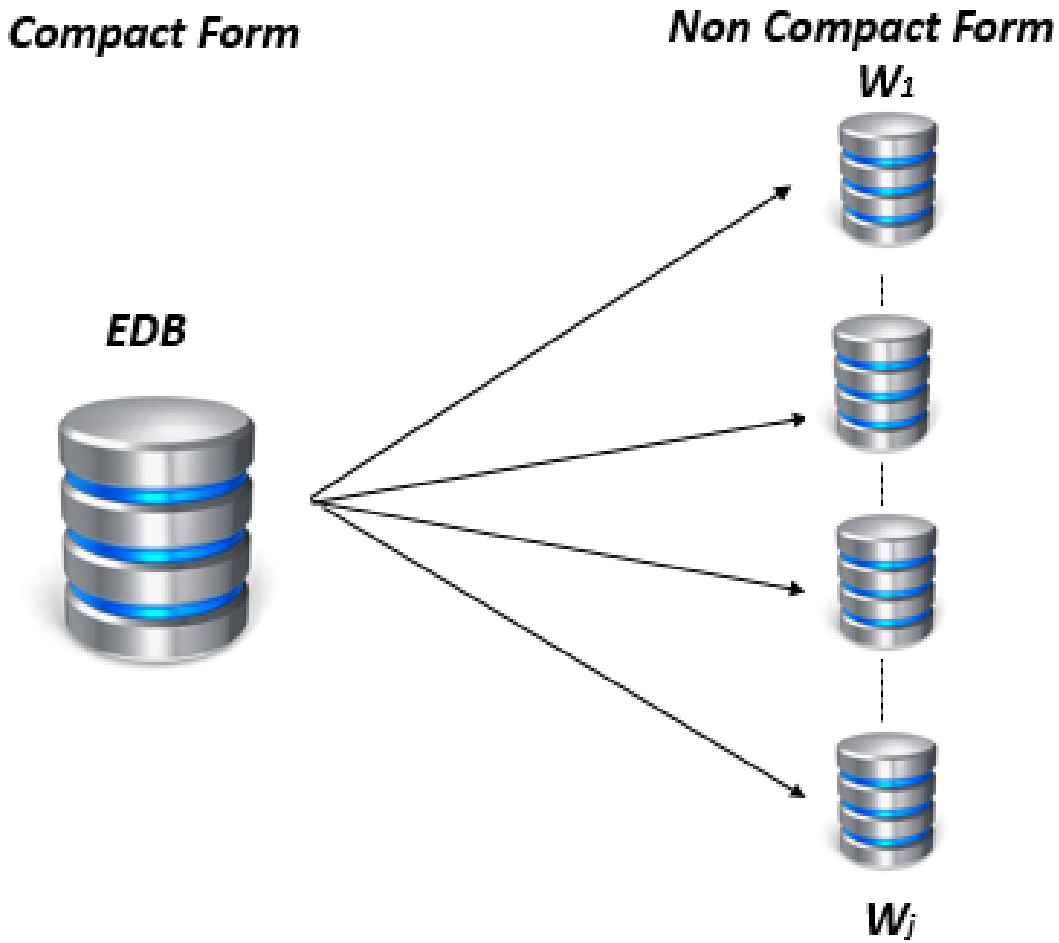
Database size	**First execution time (s)**	**Next executions' times (s)**
1000	0.2	0.03
5000	0.8	0.04
10 000	4.1	0.06
50 000	5.8	0.12
70 000	6.4	0.16
100 000	17	1.2

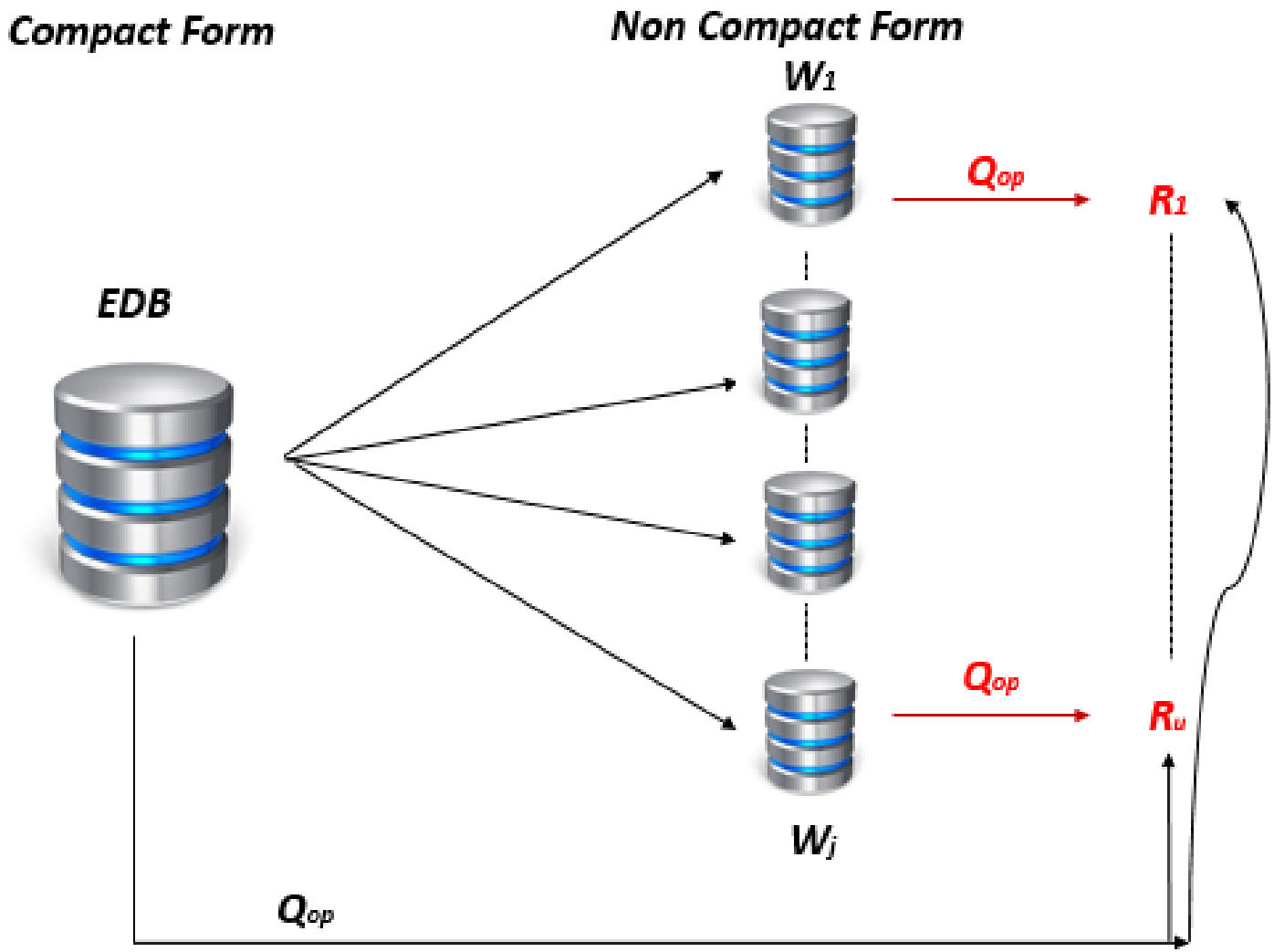
Outline

$\Longrightarrow$ The compact form is the only feasible model in practice but the non-compact form is **fundamental** to prove if the model is a **Strong Representation System**.

Strong Representation System

A model is a *strong representation system* (SRS), when the result of querying *the compact form* is *equivalent* to the result of querying the set of *its possible worlds (the non-compact form)*.


Compact Form
Non Compact Form
W_1
EDB
W_j


Compact Form
Non Compact Form
W_1
Q_{op}
R_1
EDB
Q_{op}
R_u
W_j
Q_{op}

Querying Possible Worlds

Definition

Let Q be the query processed on each possible world W_j. Querying each possible world W_j, gives a possible answer $R = Q(W_j)$

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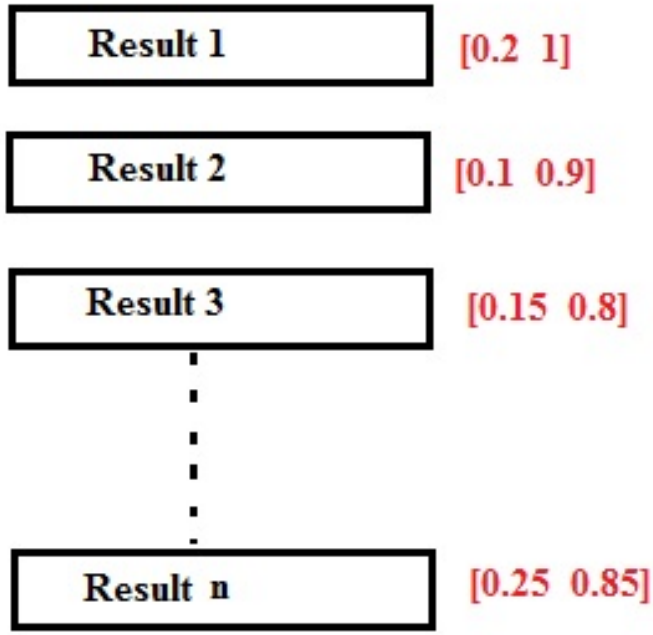
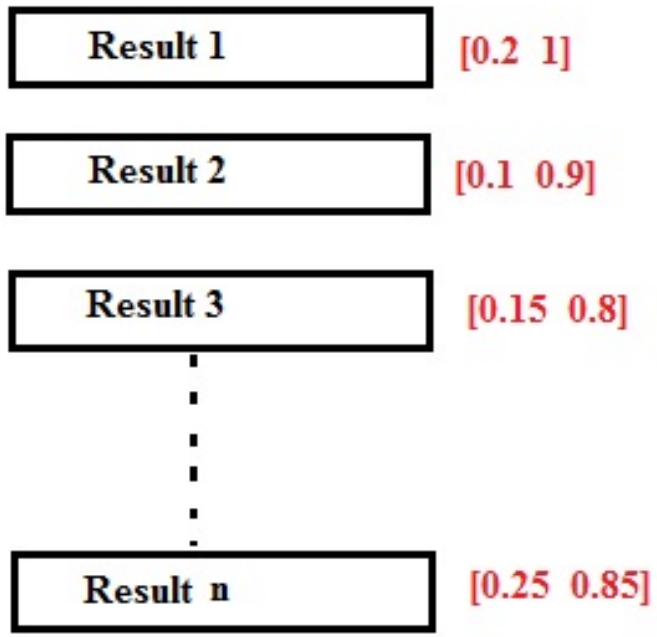
- Extended Evidential Select Operator
- Extended Evidential Project Operator

Evidential Database



Which are the k best results ?

How to rank them ?



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- Order queries' results in order to give only the most interesting answers.
- Top-k queries order answers using a score function that returns the k important answers with the highest scores.











H-index






H-index







H-index


ID	BookRate	CL
1	b_1 0.3 $\{b_2, b_3\}$ 0.7	[0.5 ; 1]
2	b_2 0.5 b_4 0.5	[0.3 ; 0.8]
3	$\{b_1, b_2, b_3\}$ 1	[1 ; 1]
4	b_3 1	[0.5; 0.9]

Top-k Query

The top-2 most appreciated books for readers ?

- Introduced Evidential Score

item	EvidentialScore
b_1	R_1=[0.0375 ; 0.325]
b_2	R_2=[0.0375 ; 0.525]
b_3	R_3= [0.125 ; 0.65]
b_4	R_4= [0.0375 ; 0.1]

- Adopted Preference Degree Equation

item	EvidentialScore
b_1	R_1=[0.0375 ; 0.325]
b_2	R_2=[0.0375 ; 0.525]
b_3	R_3= [0.125 ; 0.65]
b_4	R_4= [0.0375 ; 0.1]

Final Ranking

$b_3 \succ b_2 \succ b_1 \succ b_4$.
The Top-2 appreciated books are :

- b_3 with a confidence level [0.125 ; 0.65]
- b_2 with a confidence level [0.0375 ; 0.525]

- Defined A new Semantic for Imperfect Databases

Etop-2 Semantics

Books b_3 and b_2 are the 2 most appreciated credible answers from the set of results.

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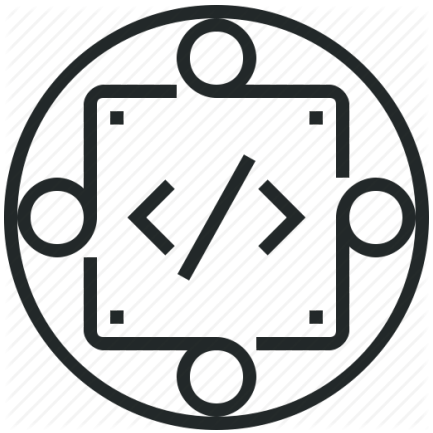
- We implemented the Evidential Database model on its compact form.
- We introduced two extended relational evidential queries: Selection and Projection.
- We introduced a new imperfect top-k query, called Evidential Top-k Query.

Future Works

- Implementation of Etop-k queries.



Future Works

- Proof of the Strong Representation System for Evidential Databases.

A		B	
a_1	1	$\{b_1, b_2\}$	0.2
		b_1	0.8
$\{a_1, a_2\}$	1	b_2	1

A	B
a_1	b_1
a_1	b_2

A	B
a_1	b_1
a_2	b_2

A	B
a_1	b_2
a_1	b_2

A	B
a_1	b_2
a_2	b_2

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Thank You