An extended solution to recommend fuzzy MDX queries for decision-makers by a collaborative filtering profile

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Abstract: Education decision-makers need to analyse the success rate of the baccalaureate according to different criteria. In this paper, we propose to extend our previous solution where we have defined only three terms in natural language. Our extended solution consists modelling a data warehouse according to the Fasel model. It allows the recommendation of MDX queries which contain these terms in natural language according to the decision-maker's profile. We present an overview of the work related to our subject and we present the fuzzy data model together with the meta tables and the modelling of the membership functions. Finally, we present our results. Furthermore, we have carried out a comparative study between the use of SQL and MDX requests and we have concluded that the use of MDX made the system more efficient.

Keywords: decision support systems; data warehouse; MDX; profile; fuzzy logic; recommendation.

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1 Introduction

The baccalaureate is the national exam taken by high school students to gain access to higher education in many countries including Algeria where this work is undertaken. A continuous analysis of the exam results by the national education decision-makers of the results is important; to improve the baccalaureate success rate. Existing software are unable to provide reliable and timely analysis. We have developed an initial version of our system (Hammouche et al., 2016) that was distributed for use by a sample of the decision-makers to obtain early feedback. Their remarks and feedback, led us to the development of this new version of the system and the improvements are mainly on the expansion of the number of predicates used in queries to get better results from our system. Indeed, the enrichment of our previous solution with four new predicates made it possible to reduce ambiguities and facilitate the querying of the baccalaureate data warehouse. The outputs of our system are a set of recommendations made to users to help them find the most appropriate answers to their information needs (Negre, 2015). In this paper, we aim to find a similarity between the current user profile and previous profiles in order to recommend interesting queries for the decision-making process. We use a collaborative filtering technique to recommend requests to users.

The remaining of the paper is organised as follows: we begin with a summary of the different works on the recommendation and the ambiguity resolution that we have studied, then we present our extended solution and we conclude with a conclusions.

2 Related works

The existing recommendation systems are generally classified in two categories, those using methods based on the content and those using methods based on collaborative filtering.

From the analysis of the reviewed work summarised in Table 1, we found that:

- Approach: Lack of a generic personalisation approach and lack of a hybrid approach that integrates personalisation request and recommendation for OLAP analyses.
- Algorithm: No work considers preferences to generate recommendations.
- System: With the exception of the work of Bellatreche, all works support a single language request and are dependent on the visualisation structure.

Table 1 Summary of related recommendation work

Author	*Principle*	*Advantages/disadvantages*
Bellatreche et al. (2005, 2006), Bellatreche (2003)	Personalisation queries and displays the result	The major advantage of this approach is the lack of access to fact tables during the process of personalisation. However, the downside is the loading in memory of the dimension tables during this process. This raises a performance issue.
Ravat and Teste (2009), Ravat et al. (2007)	Personalisation queries by expansion	It does not process incomplete queries. The major downside of this approach is in the subjectivity of the accuracy of the query threshold which determines the dimension attributes to display. Although this approach allows recommending dimension attributes, it does not represent an assistance approach to the query formulation.
Giacometti et al. (2009a, 2008, 2009b)	Recommending the following query in an OLAP analysis	The disadvantage is the lack of consideration of the user when generating recommendations.
Golfarelli and Rizzi (2009)	Addressing the problem of large or empty results	Advantages concern reducing the volume of the result and the expressivity of the preference model. The main disadvantages are the manual and cognitive effort of formulation of preferences and the need to run more intermediate queries to answer a single user query.
Garrigôs et al. (2009)	The personalisation mechanism starts from the warehouse design stage	The approach only affects the conceptual level but not the implementation model or storing the profile or its operation algorithm for personalisation.
Jerbi (2012), Jerbi et al. (2009)	It is based on the independent OLAP analysis model	The disadvantage is the problem of optimisation of the algorithms used to limit the number of accesses to the meta base. For benefits, it helps the decision-maker in the OLAP navigation.
Khemiri (2015), Khemiri et al. (2012)	Guide the user to build the query interactively	The major advantage is the interactivity and assistance of construction queries, making it easier. And the downside is that the FIMIOQR system considers only the following SQL statements: select, where, group by, having, order by.

Based on these findings, we adopted the collaborative profile filtering.

Table 2 Summary of ambiguity in decision requests related work

Author	*Principle*	*Solution based on/structure of data used/language*	*Advantages/disadvantages*
Laurent et al. (2000), Laurent (2001, 2003), Favre et al. (2011)	Fuzzy multidimensional database and its use in data mining	Fuzzy logic and data warehouse/meta table/SQL	Advantages: it defines a model of representation of potentially imperfect data by extending the definitions of all classical entities of multidimensional databases and the fuzzy cubes are manipulated using traditional operators of extended multidimensional databases to take into account imperfect values and vague criteria. Disadvantages: the choice of cubes to build is a difficult problem.
Smits et al. (2013)	Presentation flexibility and personalisation when querying relational databases	Fuzzy logic and fuzzy interrogation/meta table/PostegreSQL_f, SQL_F	ReqFlex is an intuitive user interface to the definition of preferences and the construction of fuzzy queries.
Fasel (2009)	The integration of fuzzy concepts and the design of fuzzy data warehouse	Fuzzy data warehouse /meta table/SQL and FCQL	Advantages: the query can be made with the natural language. Disadvantages: the evaluation of the success of the approach and its effect on decision-making in complex systems is missing.
Pitarch et al. (2010, 2009)	A medical data warehouse that records vital parameters (blood pressure) of patients in an intensive care unit	Fuzzy data warehouse/meta table/SQL	Advantages: this mode of representation makes it possible to represent different contexts composed of different structures. It is a generic approach that allows the easy addition of contexts, in other words new knowledge. Contexts are stored in the same table. Disadvantages: the algorithm of construction of view constitutes a first proposition for the exploitation of this type of knowledge. It deserves to be refined in the construction of the cubes, to take in input other parameters.
Aloui and Touzi (2015)	A new approach for flexible queries using fuzzy ontologies	Fuzzy ontology/meta data/OWL and OWL DL SQL and SQLF	Advantages: interpret the best possible solution for the user's request. Disadvantages: existing algorithms do not take into account the semantics of the data.

From the results obtained for the ambiguity analysis as summarised in Table 2, we opted for the use of fuzzy logic for handling inaccuracy and uncertainties in queries and we adopted Fasel model for the design of the baccalaureate fuzzy data warehouse.

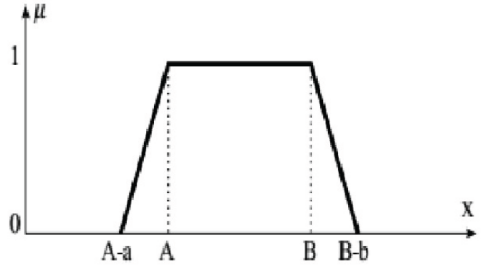
3 Background on fuzzy set theory

Fuzzy logic is an extension of the Boolean logic developed by Zadeh (1965) based on his mathematical theory of fuzzy sets, which is a generalisation of the theory of classical sets (Bouchon-Meunier, 1995). By introducing the notion of degree in the verification of a condition, thus allowing a condition to be in a state other than true or false. Fuzzy logic confers a very appreciable flexibility on the reasoning which uses it, which makes it possible taking into account inaccuracies and uncertainties. One of the advantages of fuzzy logic for formalising human reasoning is that the rules are stated in natural language. In the theory of fuzzy sets, Zadeh (1965) attempts to introduce the notion of weighted membership (Bouchon-Meunier, 1995; Dubois and Prade, 2000; Chouiref et al., 2014). There are different kinds of membership functions; the simplest one is a trapezoidal representation, where

$$\begin{cases} 0 \text{ if } x < A-a \text{ or } B-b \\ 1 \text{ if } A < x < B \\ 1+(x-A)/a \text{ if } A-a < x < A \\ 1-(B-x)/b \text{ if } B < x < B-b \end{cases}$$

The (A, B, a, b) notation, often used in computer applications; is the simplest representation of a fuzzy interval.

Figure 1 Trapezoidal membership functions examples

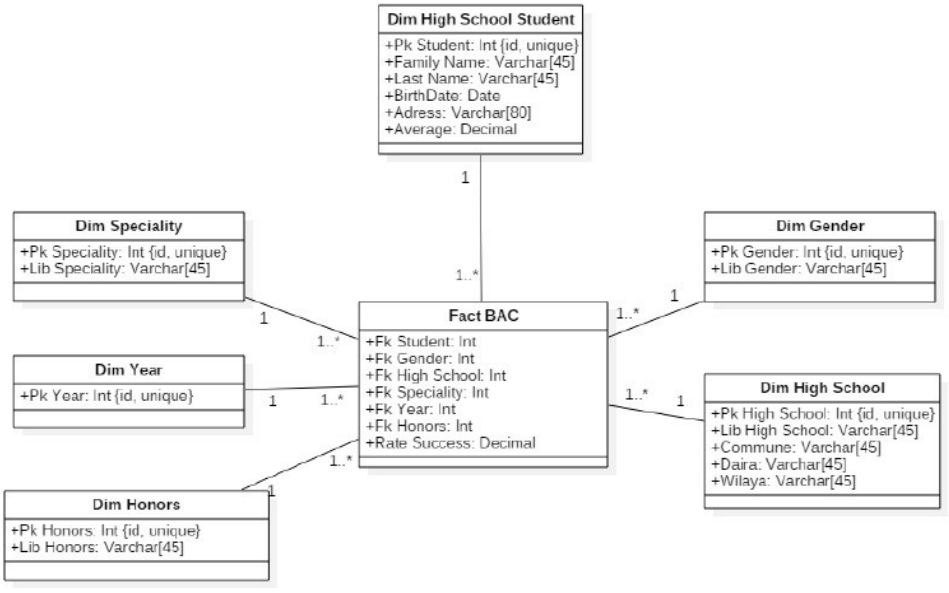


4 The detailed proposed solution

We designed the baccalaureate star model. In this model, we have a single fact table 'FactBAC' and six dimension tables: 'Dimhighschoolstudent', 'DimSpeciality', 'Dimyear', 'DimSex' and 'DimHonors'. The measure baccalaureate success rate by the axis 'high school', 'speciality', 'sex' and 'honours'. The measure to analyse is: the baccalaureate success rate according to different dimensions: mention, gender, etc.

The fuzzy data warehouse modelling approach adopted is that presented by Fasel (2009) based on the addition of a meta-data structure to the existing relational model. The idea of this abstraction is to add a new fuzzy dimension to the existing relational model without restructuring the data warehouse. In this way, the linguistic concepts can be integrated for the interpretation of the numerical values (measures) of a fact table, for this purpose, analysts can avoid different interpretations for the same indicator by interpreting the same figure approximately. In the same way without the concept of aggregation (data summary), not being affected in the dimensions because the fuzzy concepts are deployed in a meta-table structure completely independent of the multidimensional model of the data warehouse. An evaluation of the indicators (measures) via linguistic concepts was necessary in order to define a metadata which takes into account this new concept in the baccalaureate data warehouse.

Figure 2 The baccalaureate data warehouse star model



Source: Hammouche et al. (2017)

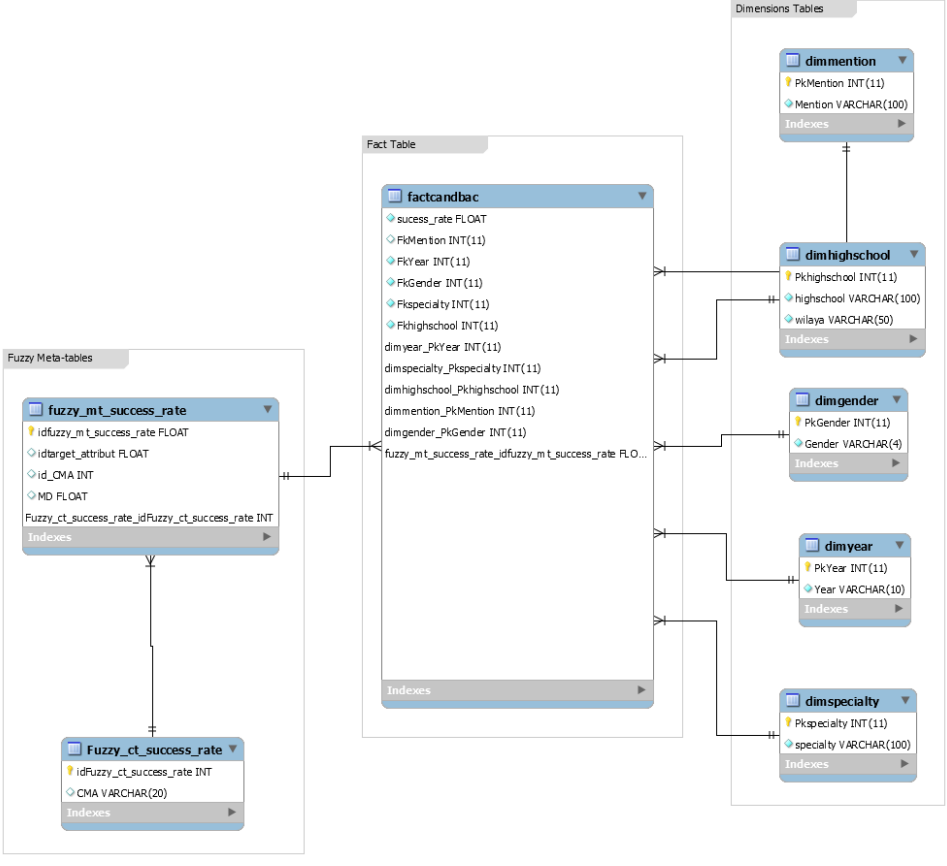
The definition of linguistic concepts with the degrees of belonging of the target attributes to the different values is based on the expertise of decision-makers and analysts in the field of education which made it possible to bring out the closest numerical value to an evaluation of linguistic term and the linear trend function which defines the degrees of belonging of a value to a linguistic concept. We integrated seven fuzzy predicates namely: absolutely high, rather high, somewhat high, medium, somewhat low, rather low and absolutely low.

We define the seven membership functions: fabsolutelyhigh(x), fratherhigh(x), fsomewhathigh(x), fmedium(x), fsomewhatlow(x), fratherlow(x) and fabsolutelylow(x) for the seven fuzzy predicates defined above.

The membership functions are:

- fabsolutelyhigh(x) → [0.1]
- fratherhigh(x) → [0.1]
- fsomewhathigh(x) → [0.1]
- fmedium(x) → [0.1]
- fsomewhatlow(x) → [0.1]
- fratherlow(x) → [0.1]
- fabsolutelylow(x) → [0.1].

Figure 3 The fuzzy baccalaureate data warehouse (see online version for colours)



Our solution allows browsing cubes for each type of user profile and making appropriate OLAP analyses using the MDX language. The multidimensional navigation is personalised based on the profile and we recommend to the decision-maker adequate materialised views according to his profile. This recommendation is made following three user groups: admin, city general manager and high school general manager. Meta table 'User_Test' contains: id user, username, password, profile user (function), reference user (geographical responsibility). User management is done by checking the current

profile from the three groups (classes) of predefined users in the meta table and through a recommendation algorithm that allows dynamically change the XML schema OLAP cube according to each user profile access, we obtain as a result of analysis a cube materialised view which helps the user in his decision-making (Hammouche et al., 2016).

Table 3 The membership functions

The membership function	*Values and intervals*
Absolutely high	$Y = 0$ in [0, 80]
	$y = 0.1x - 8$ in [80,90]
	$y = 1$ in [90, 100]
Rather high	$y = 0$ in [0, 70]
	$y = 0.1x - 7$ in [70, 80]
	$y = 1$ in [80,90]
	$y = -0.1x + 10$ in [90, 100]
Somewhat high	$y = 0$ in [0, 50]
	$y = 0.1x - 5$ in [50, 60]
	$y = 1$ in [60, 80]
	$y = -0.1x + 9$ in [80, 90]
	$y = 0$ in [90, 100]
Medium	$y = 0$ in [0, 40]
	$y = 0.1x - 4$ in [40, 50]
	$y = 1$ in [50, 60]
	$y = -0.1x + 7$ in [60, 70]
	$y = 0$ in [70, 100]
Somewhat low	$y = 0$ in [0, 30]
	$y = 0.1x - 3$ in [30, 40]
	$y = 1$ in [40, 50]
	$y = -0.1x + 6$ in [50, 60]
	$y = 0$ in [60, 100]
Rather low	$y = 0$ in [0, 10]
	$y = 0.1x - 1$ in [10, 20]
	$y = 1$ in [20, 40]
	$y = -0.1x + 5$ in [40, 50]
Absolutely low	$y = 1$ in [0, 20]

The steps of the algorithm are as follows:

1 The user types on any web browser the application link using APACHE TOMCAT.

2 Entering username and password.

3 Testing the identification of the user.

4 If the identification is validated then go to 5, otherwise go to 2.

5 Retrieving other information about the user profile (user group, user ID) from the meta table 'User_Test'.

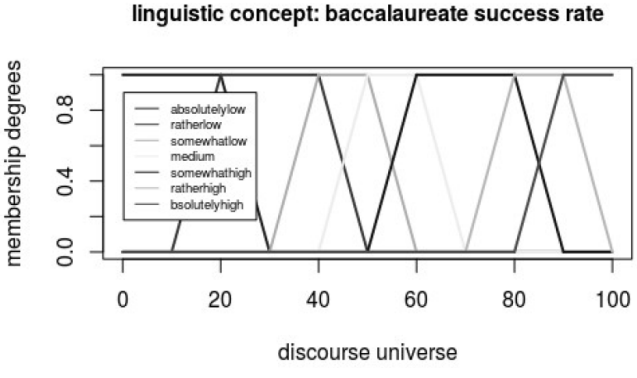
6 User profile shipping (group plus user reference user) to:
- Main menu of the application 'BI analysis for BAC success' to customise the page hypertext links MDX queries.
- Insertion the user profile in the XML schema in a node or tag on the role (after that, the XML schema of the cube is customisable according to the connected user and thus its personalisation becomes dynamic and automatic).

7 Save the new modified XML schema.

8 Showing results from custom MDX queries as materialised views in the web pages.

9 End.

Figure 4 The linguistic concepts



5 Results and discussion

We analyse the fuzzy baccalaureate data warehouse results of the last five years of the city of Ain Defla. We defined three types of profiles admin (administrator or super user), city general manager and high school general manager in the city. This solution allows the recommendation and the security and the confidentiality of the data warehouse, as for example a high school general manager in the city of Chlef cannot display data of another school in the same or another city. We present for the profile dw (city general manager) with reference 44 the content and the outcome of each MDX query.

Recommended MDX query

Profile: city general manager 44.

MDX query:

SELECT {[Measures].[successrate]} **ON COLUMNS,**

FILTER([highschool].[DesLyc].Members, ([Measures].[Eval] = "**somewhathigh**"))
ON ROWS

FROM CubeBacDW **WHERE** [Annee].[2014]

1 Query with somewhat high:

Beyond 79.31, the success rate is not considered to be somewhat high.

2 Query with medium:

The success rate below 47.83 is not considered medium.

3 Query with somewhat low:

The success rate below 39.47 is not considered somewhat low.

Table 4 List of high schools with somewhat high success rate

High school	*Successrate*	*Relationship degree*	*Fkyear*
Bouchareb Tahar I High school	97.22	0	2014
Hamza ben abdelMoutaleb I High school	95	0	2014
Ben douha Boualem High school	83.33	0.66	2014
Bouchareb Tahar II High school	82.35	0.75	2014
Hamza ben abdelMoutaleb II High school	79.31	1	2014
Larbi BenMhidi High school	78.79	1	2014
Hamza ben abdelMoutaleb III High school	77.78	1	2014
Ain Essoltane High school	77.78	1	2014
Bouchareb Tahar III High school	76.47	1	2014

Table 5 List of high schools with medium success rate

High school	*Successrate*	*Relationship degree*	*Fkyear*
Ferache Ahmed Ellouhi High school	60	1	2014
Larbi BenMhidi High school	54.17	1	2014
Hamza ben abdelMoutaleb High school	50	1	2014
Mohamed Boudiaf High school	45.16	0.51	2014
Ain Esoltane High school	63.64	1	2014
Hamza ben abdelMoutaleb I High school	57.14	1	2014
Ben Douha Boualem High school	50	1	2014
Mohamed Boudiaf I High school	46.34	0.63	2014
Larbi BenMhidi I High school	60	1	2014
Ain Esoltane I High school	53.40	1	2014
Ferache Ahmed Ellouhi I High school	48.72	0.87	2014
Bouchareb Tahar I High school	61.64	0.84	2014
Ben Douha Boualem I High school	54.67	1	2014
Ferache Ahmed Ellouhi II High school	50	1	2014
Mohamed Boudiaf II High school	45.45	0.54	2014
Ben Douha Boualem II High school	59.69	1	2014
Ain Esoltane II High school	52.63	1	2014
Ferache Ahmed Ellouhi II High school	47.83	0.78	2014
Ain EsoltaneIII High school	32.43	0	2014
Larbi BenMhidi II High school	69.23	0.07	2014

Table 6 List of high schools with somewhat low success rate

High school	*Successrate*	*Relationship degree*	*Fkyear*
Larbi BenMhidi High school	54.17	0.58	2014
Hamza ben abdelMoutaleb High school	50	1	2014
Mohamed Boudiaf High school	45.16	1	2014
Bouchareb Tahar I High school	40	1	2014
Ben Douha Boualem High school	50	1	2014
Mohamed Boudiaf I High school	46.34	1	2014
Larbi BenMhidi I High school	41.67	1	2014
Bouchareb Tahar I High school	38.46	0.84	2014
Ain Esoltane High school	53.49	0.65	2014
Ferache Ahmed Ellouhi High school	48.72	1	2014
Mohamed Boudiaf II High school	44.12	1	2014
Ben Douha Boualem High school	40	1	2014
Ben Douha Boualem I High school	54.67	0.53	2014
Ferache Ahmed Ellouhi I High school	50	1	2014
Mohamed Boudiaf III High school	45.45	1	2014
Ain Esoltane I High school	40.54	1	2014
Hamza ben abdelMoutaleb I High school	37.5	0.75	2014
Ain Esoltane II High school	52.63	0.73	2014
Ferache Ahmed Ellouhi II High school	47.63	1	2014
Ben Douha Boualem II High school	43.75	1	2014
Ferache Ahmed Ellouhi III High school	39.47	0.94	2014
Ain Esoltane III High school	32.43	0.24	2014
Larbi BenMhidi II High school	69.23	0	2014

For each type of profile, we have a main page that contains the MDX queries. We present for the profile dw (city general manager) with reference 44 the content and the outcome of each MDX query. With this enriched solution, the system returns the results to us with more precision in particular for medium since with qualifier, the system does not display the schools very close to medium and they are displayed before or after, i.e., with somewhat high or somewhat low.

6 Performance of the system

To analyse the performance of our system, a benchmark test between the MDX and the SQL language was done. This test compares their execution times.

This test shows that the execution time is better with the use of MDX queries compared to the use of SQL queries during the querying of the baccalaureate data warehouse, which validates our choice regarding the use of MDX queries, especially

since our system is called to be generalised throughout the national territory and make analyses over several years of data.

We conducted a survey and recorded feedbacks from the decision-makers who operated our system. The decision-makers noted our system in several ways: presentation, navigation, ease of use, correct answer to expectations, satisfaction of needs, on a scale of 0 to 10 very good 10, good 9, fair 7 and 8, average 5 and 6, insufficient 3 and 4, and very poor 0 and 2. In two periods: with only three predicates published in solution (Hammouche et al., 2016) and with the enriched solution presented in this paper. And the returns have been more satisfying with this enriched solution. Decision-makers are more satisfied with the extended system.

Table 7 Results of the benchmark test

Number of tuples	*MDX execution time (sec)*	*SQL execution time (sec)*
10,000	0.387	1.79
20,000	1.537	2.29
30,000	0.687	2.79
50,000	0.837	3.29
80,000	0.987	3.79
130,000	1.137	4.29
210,000	1.287	4.79
340,000	1.437	5.29
550,000	1.587	5.79
890,000	1.737	6.29
1,440,000	1.887	6.79
2,330,000	2.037	7.29

Decision-makers from different high schools in Ain Defla city experimented with the first version which allowed us to improve it towards this enriched version, in particular for the 'medium' results as we explained in the results and discussion section.

We have not yet generalised the solution to evaluate it on the whole national territory, this is what constitutes the limit of our work. Other feedback would allow us to improve the content.

7 Conclusions and future developments

Business intelligence technologies allow having a detailed view of performance indicators to analyse the data produced by a company or in an administration, as in our case study. We found that little research work has dealt with personalising OLAP analysis and the absence of generic models based on the preferences of the decision-maker. We proposed an enriched solution to analyse the baccalaureate results. This solution is based on personalisation and recommendation of queries according to the user profile.

Our system can meet the needs of the decision-makers interested in the analysis of the baccalaureate results by offering three types of analyses: the first is standard using the MDX QUERY ROLAP, the second by the introduction of the concepts of fuzzy logic,

which is the MDX FUZZY QUERY and the last type recommended MDX QUERY where a recommendation algorithm allows to change the cube schema dynamically according to the user's profile (personalising) and recommends the interesting cube of the views (collaborative filtering recommendation).

This extended solution based on personalisation and recommendation queries according to the user profile has better satisfied users. Our solution allows the integration of a set of vague terms in decision requests. Some prospects emerge like the integration of other elements related to the user profile, the integration of optimisation algorithms, the operation of the software created with the baccalaureate results of all the 48 cities, after defining different profiles recommendation requests.

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