A Hybrid Model Schema Matching Using Constraint-Based and Instance-Based

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ABSTRACT

Schema matching is an important process in the Enterprise Information Integration (EII) which is at the level of the back end to solve the problems due to the schematic heterogeneity. This paper is a summary of preliminary result work of the model development stage as part of research on the development of models and prototype of hybrid schema matching that combines two methods, namely constraint-based and instance-based. The discussion includes a general description of the proposed models and the development of models, start from requirement analysis, data type conversion, matching mechanism, database support, constraints and instance extraction, matching and compute the similarity, preliminary result, user verification, verified result, dataset for testing, as well as the performance measurement. Based on result experiment on 36 datasets of heterogeneous RDBMS, it obtained the highest P value is 100.00% while the lowest is 71.43%; The highest R value is 100.00% while the lowest is 75.00%; and F-Measure highest value is 100.00% while the lowest is 81.48%. Unsuccessful matching on the model still happens, including use of an id attribute with data type as autoincrement; using codes that are defined in the same way but different meanings; and if encountered in common instance with the same definition but different meaning.

Keyword:
Constraint-based
Heterogeneous database
Hybrid model
Instance-based
Schema matching

INTRODUCTION

Schema matching is a matching process inter-schema to find similar relationship of pair of attributes [1], or arrange mapping and matching schema in two application systems [2]. Schema matching is a solution of Enterprise Information Integration (EII) [3] which is done at back end level to solve the problems of schematic heterogeneity [4], that is a different naming (type, format, and precision) in the schema definitions [5]. Technically, schema matching is an integration process on heterogeneous database and will produce a generalization or specialization in the database [6]. Schema matching plays important role in applications that requires interoperability between systems with heterogeneous data sources [7]. Schema matching is a main problem on developing the relationship between elements in the two database schema [2],[8]–[11]. Schema matching was originally done manually on a specific application domain [12], so it is needed a new model that is more general and appropriate for the application and different schema languages [13]. The main problem of schema matching is often found not clear naming in the schema, difficulties in synonyms naming, and schema language differences so that the matching method may not provide 100%
right in the result [2]. The schema matching cannot be done automatically because the mapping of computing is usually corrected by the user to obtain the correct verified results [14]-[15].

Development model and software on schema matching are still open to find proper ways to combine existing methods [11],[16]. The use of combinational matchers [17]-[18], can be implemented in hybrid or in composite [16-17]. Hybrid model is also called intra-matcher parallelism [19] using some criteria concurrently matching [13],[20]-[21] to give results and better performance than using individual matcher [17]. Simple concept of hybrid matcher is to combine two different methods simultaneously processed, while the composite matcher combines two methods that are processed in a sequence. Schema matching using a hybrid matcher was applied in CLIO [22]-[26], CUPID [18], and SYM [27]. While the schema matching using a composite matcher found in SEMINT [21],[28]-[29], LSD [30], Cupid [18], COMA [14], COMA++ [15], COMA 3.0 [31]-[32], IMAP [33], PROTOPLASM [34]-[37], FALCON-AO [2],[38], and ASMOV [39]. Refers to [40]-[41], development of new schema matching models and prototype is still open especially on hybrid models. The next section describes the proposed a new hybrid model schema matching that was developed based on constraint-based and instance-based.

2. THE PROPOSED MODEL

The proposed model of hybrid schema matching is by combining two methods (constraint-based and instance-based) implemented simultaneously. Constraint-based and instance-based are methods categories according to [11],[16]), in which involves the DTM (data type matcher), CM (constraint matcher), and IDM (instance data matcher) methods (categories according to [42]). Generally, the proposed model is developed referring to the general model of data processing, consisting of 4 sections, namely input, process, output, and verification and evaluation as shown in Figure 1. The description of each section are as follows:

1. **Input**, receives input by DBSource (as a reference database) and DBTarget (database to be matched), the type of DBMS, extracting constraints, data type conversion, extracting instances, and checking the similarity inter attributes in DBSource and DBTarget.

2. **Process**, conducting matching process, which match each attribute in DBSource with each attribute in DBTarget and then calculate the value of similarity ($SIM_{MN}$) on each possible pair matched attributes, and determine a pair of attributes declare matched.

3. **Output**, show the similarity mapping pair of attributes pair of attributes s, that is pairs of attributes that has the $SIM_{MN}^{MAX}$ and $SIM_{MN}=1$, namely a preliminary result.

4. **Verification and Evaluation**. Verification is the process to determine whether the preliminary results generated by the model are correct or still need to be manually corrected by the user. Thus, the process is supervised approach. Preliminary result has been verified by the user produces the verified result in the form of mapping pair of attributes s that are valid. Evaluation process is performed to calculate the values of model performance parameters, which are P (Precision), R (Recall), and F (F-measure). The values of P, R, and F are calculated by comparing the preliminary result and the verified result.

![Figure 1. The proposed model of hybrid schema matching](image)

3. MODEL IN DETAIL

3.1. Requirement Analysis

Requirement analysis is conducted on five aspects that are functional requirement, input document, output document, database, and model evaluation. Functional requirements of the proposed model are as follows:

1. Input of The model is DBSource and DBTarget.

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2. The model can extract information schema to find the names of the tables, attribute names, and constraints (type, width, domain, nullable, unique) in DBSource and DBTarget.
3. The model can convert the data types on the attributes used by the DBMS on DBSource and DBTarget into new data type used by the model.
4. The model can extract instances in DBSource and DBTarget.
5. The model can match and compute the value of similarity between each pair of attributes on DBSource and DBTarget.
6. The model is able to determine the pair of attributes, by comparing the value of SIM\text{MM} of each pair of attributes and find a partner with the largest similarity value (SIM\text{MM}\text{MAX}) or a pair of attributes with the similarity value is equal to 1 (SIM\text{MM}=1).
7. The model can receive the user verification to the preliminary result similarity mapping pair of attributes.
8. The model can calculate and show the value of the parameter that indicates the effectiveness of the model.

Input documents required by the model include:
1. User name, date of analysis, the type of DBMS, domain of application, and size of DBSource and DBTarget.
2. Information schema document which contains the database name, table names, attribute names, and constraints in DBSource and DBTarget, and instances in DBSource and DBTarget.
3. User verification on the preliminary result.

Requirements output of documents generated by the model are as follows;
1. Information about the user, the type of DBMS, database name, database size, table names, attribute names, and constraints and instances in DBSource and DBTarget.
2. Results of the data type conversion according used in the model.
3. The SIM\text{MM}\text{MAX} value for each attributes pair, and the preliminary result and verified result similarity mapping.
4. The test results of the model parameters that are P, R, and F.

3.2. Data Type Conversion

Data type conversion is required to change the data type on the DBMS used by DBSource and DBTarget into new data type used by the model. This process is meant to facilitate the matching process. For example, in the MySQL, data type char(n) or varchar(n) will be converted into string, while the data type int(n) or float(n,d) will be converted into numeric.

3.3. Matching Mechanism and Computing the Similarity of Attribute Pair

Matching mechanism and similarity value calculation carried out at every possible pair attribute in DBSource (AS\text{i}) and in DBSource (AT\text{i}), and every pair will provide a SIM\text{MM} value. Each type of constraints (type, width, domain, nullable, unique) and the matching instances will be given a value according to weight that predetermined, whereas if it does not match then it will be assigned a null value. Constraints on DBTarget are the same as constraints on DBSource if both have the same constraints definitions. Meanwhile, the same instance will be stated if the instance in DBTarget appears in DBSource. A matching mechanism and computing the SIM\text{MM} is shown in Figure 2.

![Figure 2. Matching mechanism and computing the similarity value (SIM\text{MM})](image-url)
3.4. Support Database

All of data input, process, and results on the proposed hybrid model will be stored into a relational database model named dbhybridschematch. The dbhybridschematch consists of 15 tables in the third norm form, which the use of each tables as listed in Table 1. The support database is intended to minimize the computational load, especially during the last process of matching.

3.5. Information Schema

Information schema in a database contain all the metadata information of all database objects stored, example for the proposed model has 28 tables in the information schema. Some of the information that can be explored from the information schema and useful in the process of matching schema, such as table, table constraints, referential constraints, and statistics. Thus, the proposed model does not use XML as an intermediary language ever developed by [43],[44].

3.6. Constraint and Instance Extraction

A constraint extraction is a process to obtain the data type, width, domain value, nullable, as well as on the unique nature of each attribute in DBSource and DBTarget. Constraints can be explored from table constraints in the information schema or directly from each table in the database. In many cases, database designers often are not explicitly defined the constraints, so it will not be found in the information schema and it will be ignored in the matching process. An instance extraction is a process to obtain instances on each attribute in DBSource and DBTarget. The instance can be explored from each table that is in DBSource and DBTarget. Normally, the number of instances in each table is equal to the multiplication of the number of records with the number of attributes. However, no guarantee that the value is correct, so it is necessary to find the correct number of instances.

| Usage                                      | Table Name                             |
|--------------------------------------------|----------------------------------------|
| Store the user application data            | mst_user                               |
| Store the data types of DBMS               | mst_dbms_type                          |
| Store the conversion of origin data types  | mst_data                               |
| to the data types used by the DBMS in the  | _type_conversion                       |
| model                                       | mst_application_domain                 |
| Store the alternative matching criteria     | mst_alt_weight_match                   |
| weights (type, width, domain, nullable,    |                                        |
| unique, & instance) which specified by the |                                        |
| user                                       | mst_alt_string_size_match              |
| Store data about a database on DBSource    | source_database                        |
| Store data about the tables in DBSource    | source_table                           |
| Store data constraints (type, width,       | source_attribute                      |
| domain, nullable, unique) and instance for |                                        |
| each attribute in DBSource                 | target_database                        |
| Store data about a database on DBTarget    | target_table                           |
| Store data constraints (type, width,       | target_attribute                      |
| domain, nullable, unique) & instance for    |                                        |
| each attribute in DBTarget                 |                                        |
| Store the preliminary result for all       | matching_preliminary                   |
| alternative weighting criteria & differences|                                        |
| size of string that has not been verified  |                                        |
| by the user                                | matching_final                         |
| Store the verified result for all          |                                        |
| alternative weighting criteria & differences|                                        |
| size of string that has been               |                                        |
| verified by the user                       |                                        |
| Store the summary data of preliminary and  | matching_report                        |
| verified result, & the evaluation of       |                                        |
| schema matching model                      |                                        |

3.7. Computing the Value of Similarity Pair of Attribute (SIM_{attr})

The value of SIM_{attr} for each pair of attributes on DBSource and DBTarget is determined based on the similarity of the constraints (data type, width, domain value, nullable, unique) and instances. Problems that happen in the process of matching are no limited and very open database designers to specify and define the size of the data in string data type. To overcome it, the proposed model provides features that allow the user to choose an alternative difference data size (width) of the string data types before the matching process is done. Options provided include, ALT_1 (default) the string size of attribute in DBSource and DBTarget must be exactly the same; ALT_2 the string size of attribute in DBSource and DBTarget has the difference width is 5; ALT_3 the string size of attribute in DBSource and DBTarget has the difference width is 15; and ALT_4 the string size of attribute in DBSource and DBTarget has the difference width is 25. SIM_{attr} value calculation process also faces problems related to the administration of the weight value to each matching criteria. Assuming that the similarity pair of attributes can be specified by constraint or instance only, or both simultaneously, then the proposed model provides features that allow users to select alternative values on the weight of the matching criteria before the calculation is done. By default
(INDEX_1), the weights used in each matching criteria is 0.1 on the constraints (type, width, domain, nullable, unique) and 0.5 on the instance. The values are given with the assumption that the matching process will be done only based on the similarity constraints or instances only. The second alternative (INDEX_2), the weights used in each matching criteria is 0.17. This value is given on the assumption that each criterion has the same role in determining the similarity of attributes.

Different combinations on the choice of string size and weight to the matching criteria will give 8 different results on SIMMN and SIMMNMAX as shown in Table 2. These results will be useful as a material for evaluating the performance of the model and determining the best alternative combinations. SIMMN value is in the range between 0 and 1, where for SIMMN=1 means that the value of an attribute on DBSource match with the attributes on DBTarget, for SIMMN=0 means the attribute on DBSource not match with the attributes on DBTarget, and to value 0<SIMMN<1 means that the attributes on DBSource matches with the attributes on DBTarget with similarity level is SIMMN.

Table 2. Combination of string size, index of matching criteria, and similarity value

| Alternative of the string size (width) | INDEX_1 (Default) | INDEX_2 |
|---------------------------------------|-------------------|---------|
| ALT_1 (Default)                       | SIMMNMAX11        | SIMMNMAX12 |
| ALT_2                                 | SIMMNMAX11        | SIMMNMAX12 |
| ALT_3                                 | SIMMNMAX11        | SIMMNMAX12 |
| ALT_4                                 | SIMMNMAX11        | SIMMNMAX12 |

3.8. Preliminary Result, User Verification, and Verified Result

The model developed provides a list of pair of attribute and similarity value generated by the model namely preliminary result. Pair of attributes is declared match if it has value SIMNN=1 or SIMMNMAX between each pair of attributes. User verification is done by providing an assessment and then determines whether the results of mapping similarity of each pair of attributes have been as expected. The results of the assessment will give users 4 types of possible values, namely TP (true positive), FP (false positive), FN (false negative), or TN (true negative) as shown in Table 3 [45]-[46]. Verified result of the model is mapping of schema matching results that have been verified by the user, and the values of the parameters P, R, and F which showed the model’s performance.

Table 3. The contingency table for examining result of hybrid model schema matching

| Relevant | Non Relevant |
|----------|-------------|
| Retrieved| True Positive| False Positive |
| Not Retrieved| False Negative| True Negative |

3.9. The Dataset

Hybrid model schema matching will be tested using the test data in the form of a relational database models that meets the heterogeneous nature, form it is has differences in terms of application domains, as well as different DBMS being used. The proposed model is tested on 30 database in relational models that are fulfilled the criteria of heterogeneous, that is, different DBMS platforms (MS Access and MySQL) and different application domains (academic application in higher education and high school, egovernment, and commerce). The largest data capacity is 172,441.6 KB while the smallest is 12.2 KB; the largest table number is 163 while the smallest is 2 tables; the largest number of attributes is 1,642, while fewest is 16; as well as the the largest number of instances is 3,596,857 while fewest is 231, as shown in Table 4. The entire database for testing models derived from survey at 11 institutions, including the universities, government institutions, senior high schools, software developers company, and commercial enterprises.
Table 4. The datasets for testing of proposed hybrid model schema matching

| No | Database Name | DBMS Name | Application Domain | Capacity (KB) | Σ Table | Σ Attribute | Σ Instance |
|----|---------------|-----------|--------------------|--------------|---------|------------|-----------|
| 1  | db01_sipt_admission | MS Access | HE Academic | 75.0 | 25 | 193 | 199,064 |
| 2  | db02_sipt_academic | MS Access | HE Academic | 42.6 | 69 | 451 | 135,319 |
| 3  | db03_sipt_payroll | MS Access | HE Academic | 12.2 | 16 | 97 | 8,827 |
| 4  | db04_sipt_employ | MS Access | HE Academic | 17.8 | 16 | 97 | 6,607 |
| 5  | db05_sipt_tax_pph | MS Access | HE Academic | 1,331.2 | 10 | 57 | 627 |
| 6  | db06_sipt_research | MS Access | HE Academic | 326.6 | 9 | 63 | 3,150 |
| 7  | db07_sipt_labwork_registration | MS Access | HE Academic | 171,056.7 | 26 | 162 | 443,448 |
| 8  | db08_sipt_library | MS Access | HE Academic | 9,932.8 | 53 | 435 | 188,415 |
| 9  | db09_sipt_menwa_registration | MS Access | HE Academic | 144.00 | 8 | 42 | 231 |
| 10 | db10_nuptk | MySQL | Egoverment | 240.0 | 53 | 607 | 1,700,195 |
| 11 | db11_poor_dss | MySQL | Egoverment | 214.0 | 14 | 64 | 429,602 |
| 12 | db12_office_letter | MySQL | Egoverment | 224.1 | 8 | 71 | 710 |
| 13 | db13_lisence | MySQL | Egoverment | 578.5 | 2 | 31 | 6,200 |
| 14 | db14_lisence_sms | MySQL | Egoverment | 172,441.6 | 140 | 687 | 3,596,857 |
| 15 | db15_dpt_bgcipto | MySQL | Egoverment | 79,796.9 | 4 | 19 | 2,721 |
| 16 | db16_quickcount_bgcipto | MySQL | Egoverment | 138,854.4 | 15 | 88 | 7,313 |
| 17 | db17_dpt_kp | MS Access | Egoverment | 76,697.6 | 7 | 46 | 334,270 |
| 18 | db18_hs_sinisa | MySQL | HS Academic | 77,246.0 | 6 | 71 | 2,010 |
| 19 | db19_hs_sipp | MySQL | HS Academic | 656.4 | 18 | 151 | 737,909 |
| 20 | db20_hs_pub | MySQL | HS Academic | 540.6 | 10 | 63 | 564 |
| 21 | db21_hs_schoolgrade | MySQL | HS Academic | 49,049.6 | 22 | 190 | 12,391 |
| 22 | db22_hs_schoolgrade_online | MySQL | HS Academic | 256.2 | 4 | 27 | 567 |
| 23 | db23_hs_raport | MySQL | HS Academic | 1,024.0 | 44 | 311 | 745,655 |
| 24 | db24_hs_eraport | MySQL | HS Academic | 4,558.4 | 32 | 233 | 381,900 |
| 25 | db25_hs_ewebm2pwt | MySQL | HS Academic | 2,047.5 | 100 | 1,642 | 980,475 |
| 26 | db26_elearning | MySQL | HS Academic | 78.8 | 163 | 1,423 | 163,645 |
| 27 | db27_elearning_homeschooling | MySQL | HS Academic | 1,433.6 | 105 | 748 | 20,205 |
| 28 | db28_motorcycle_loan | MySQL | Commerce | 432.0 | 10 | 57 | 3,879 |
| 29 | db29_cust_telkomvision | MySQL | Commerce | 75.0 | 5 | 31 | 2,916 |
| 30 | db30_rsmitra_pharmacy | MySQL | Commerce | 42.6 | 14 | 66 | 7,453 |

3.10. Performance Measurement

Evaluation of the model is run to measure the model performance. The evaluation will be run using the parameters \( P \), \( R \), and \( F \) obtained from the simulation of prototypes on test data. The values of these parameters are calculated based on the value of true positive (TP), false positive (FP), false negative (FN), and true negative (TN) as the evaluation of performance used in the information retrieval (IR) field research [45]-[46], and then calculated the value of precision (P), recall (R), and f-measure (F) using equation (1) for \( P \), (2) for the \( R \), and (3) to \( F \) \[7\],[15],[21],[39],[42],[47]-[53], that is:

\[
\text{Precision} = \frac{TP}{TP + FP}
\]

\[
\text{Recall} = \frac{TP}{TP + FN}
\]

\[
\text{F - Measure} = \frac{2 \times \text{Recall} \times \text{Precision}}{\text{Recall} + \text{Precision}}
\]

4. RESULT AND DISCUSSION

Hybrid model schema matching has been tested for 36 times in pair of DBSource and DBTarget. Test was performed by using the default matching mechanism that is a combination of ALT_1 and INDEX_1, in three variations of pair of DBSource and DBTarget. The first test was conducted 30 times in pair of similar DBSource and DBTarget, the second test was conducted 3 times in pair of DBSource and DBTarget in the same application domain, and the last test was performed three times in pair of DBSource and DBTarget in different application domains.

The first experimental step is to read two databases through the import process, it acts as DBSource and another as DBTarget. If the type of DBMS on DBSource and DBTarget different from the DBMS used in the model, it is necessary do the data type conversion as described in Section 3.2. The next step, the data constraints are obtained based on the extraction of the information schema in DBSource and DBTarget, while the database instance is extracted from each of these databases. The process is...
continuing to do matching and calculation SIMMN across all possible pairs of attributes in DBSource and DBTarget, then determining the pair proved a match that which has maximum SIMMN value. The end of this step will generate an output called preliminary result containing pairs of attributes declared matched and the SIMMN value. A preliminary result is verified by a user thereby providing the verified result. The verification process performed on each pair of attributes in the preliminary result. Each verification process generates values of TP, FP, FN, or TN as stipulated in Table 3. Based on such values, it was then computed across values of P, R, and F which indicates the performance of the proposed model.

By using equation (1), (2), and (3), it has been obtained the experimental result values the highest P value was 100.00% while the lowest was 71.43% (Figure 3 (a)); the highest R value was 100.00% while the lowest was 75.00% (Figure 3 (b)); and the highest F-Measure value is 100.00% while the lowest was 81.48% (Figure 3 (c)).

The highest P value was 100% obtained on the four matching experiments on the similar DBSource and DBTarget, namely db12_office_letter, db15_dpt:bgcipto, db22_hs_schoolgrade_online, and db29_cust_telekomvision, while the lowest P value was 71.43% obtained in experiments on the same DBSource and DBTarget at db13_lisence. The highest R value was 100% obtained on the four matching experiments on the similar DBSource and DBTarget, namely db13_lisence, db15_dpt:bgcipto, db17_dpt:kp, and db30_ramitra_pharmacy, while the lowest R value was 75.00% obtained in matching experiment on the similar DBSource and DBTarget at db29_telekomvision. The highest F value was 100% obtained on the matching pairs on the similar DBSource and DBTarget, namely db15_dpt:bgcipto, while the lowest F value was 81.48% obtained in experiment on the different application domain for DBSource and DBTarget, i.e. on the matching between db02_sipt_academic as DBSource and db08_sipt_library as DBTarget. Based on the experimental results known that errors in the results of hybrid models schema matching occurs in three cases, i.e. the use of an id attribute with data type auto increment; the use of code on data that is defined in the same way (type, width, domain, nullable, unique) but has a different meanings; and if encountered the same instances and the data defined in the same way but actually have different meanings.

Compared with the results of the hybrid schema matching models having been developed previously by [26] which obtained a value of P = 70.00%, R = 75.00%, and F = NA and [27] which obtained a value of P = 90.00%, R = 80.00, and F = 84.00%; it means that the proposed model has fairly good result. To increase the value F-Measure, the proposed model would still be enhanced by providing variation of weighting on constraints, where in general constraint of data type is more dominant as a determinant in common pair of
attributes than constraint of width; and constraint of domain value is more decisive than the constraint of width; whereas constraint of nullable and unique have a similar roles. This research also will be further developed to implement the model into a software prototype by applying all size variations at length of character (ALT_1, ALT_2, ALT_3, and ALT_4) and the variety weights used on each matching criteria (INDEX_2 and INDEX_2). The model will be re-evaluated to determine whether there is influence of variety length of data and variety weights used on each matching criteria, in order to know the best variation to obtain the most precise results on the model of schema matching. Improvement efforts are expected to be able to increase the value by F, so that the proposed model can generate similarity on mapping pair of attributes better.

5. CONCLUSION

A hybrid model schema matching by combining the two methods of constraint-based and instance-based simultaneously has been developed. The model has four main parts, namely input, process, output, and verification and evaluation. Based on experiment known that the proposed model has fairly good result, compared with the results of the hybrid schema matching models the have been developed by previously researcher. Errors results on the proposed model occurs in three cases, including use of an id attribute with data type as auto increment; using codes that are defined in the same way (type, width, domain, nullable, unique) but differences meanings; and if encountered in common instances with the same definitions on the attributes but different meaning. Our future work are to providing variation of weighting on constraints and instances, so that the model can generate similarity on mapping attribute pair better.

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