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Automatically Mapping and Integrating Multiple Data Entry Forms into a Database

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in ER 2011

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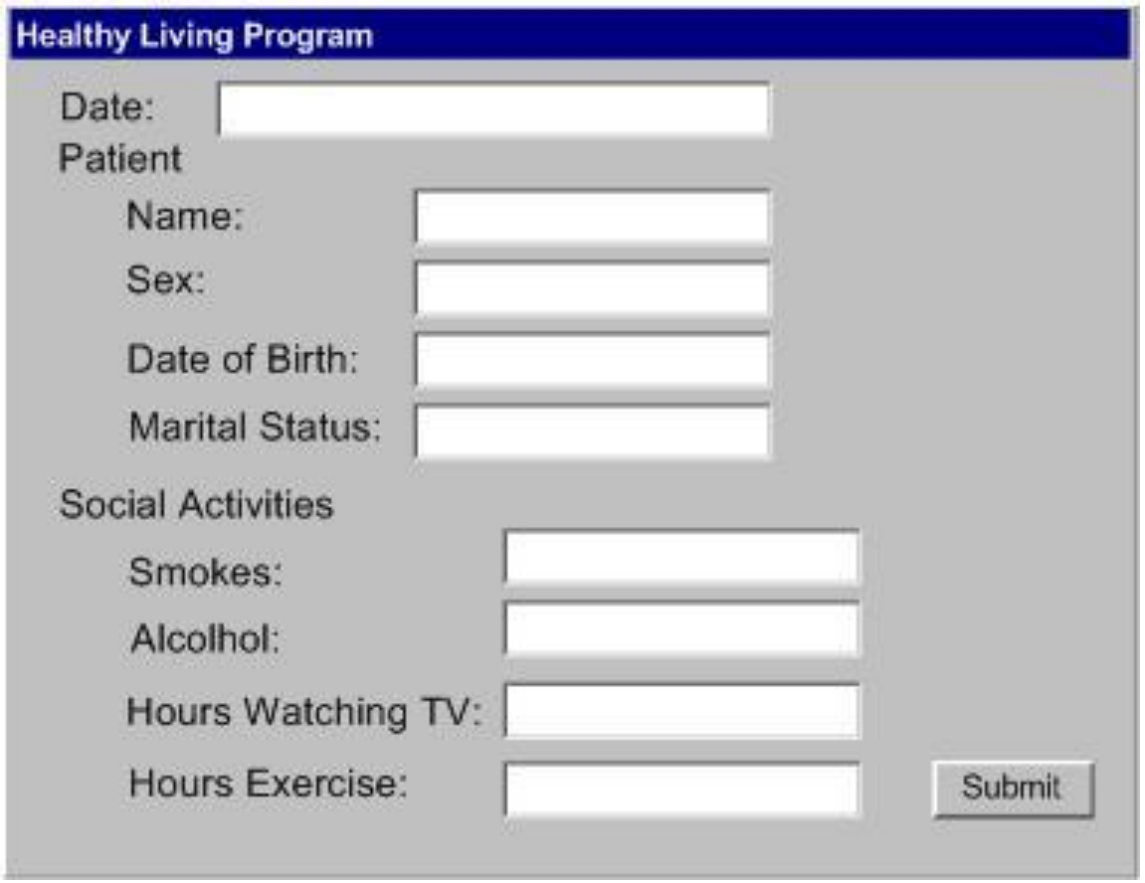
Motivation:
Populating Databases



- Form is a popular way for gathering data into database…

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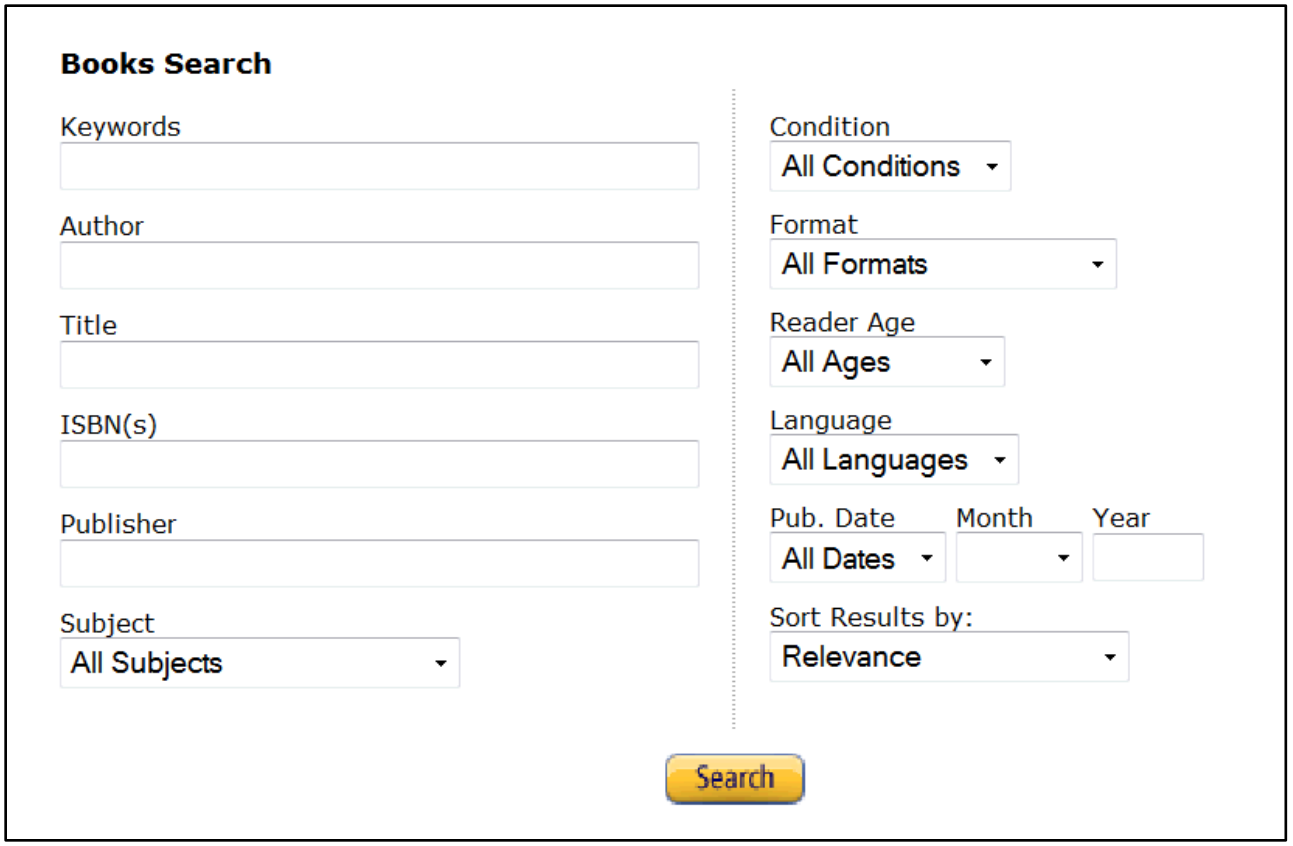
Motivation:
Querying Databases



- Or for querying databases.

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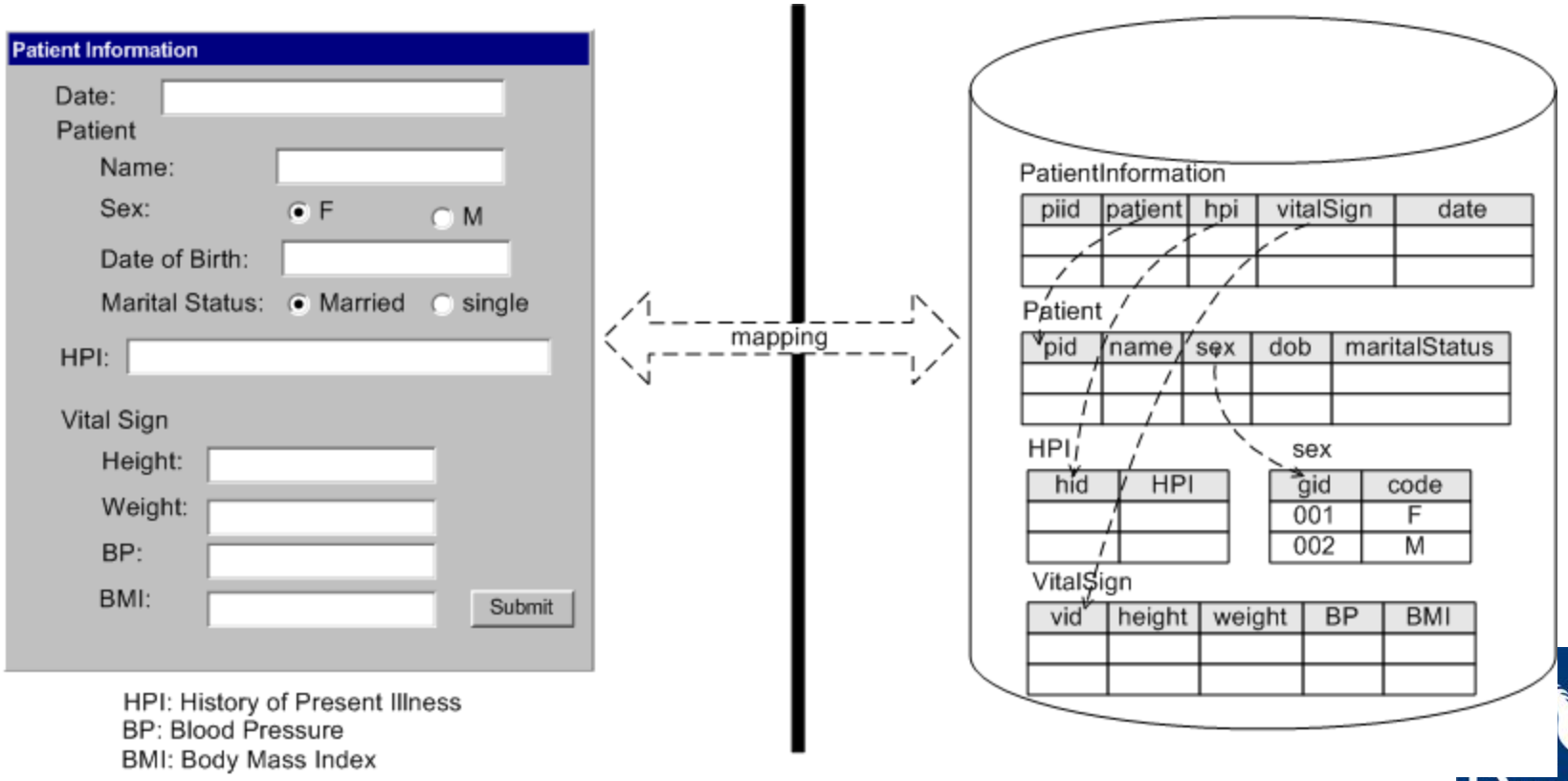
Motivation:

Behind the door



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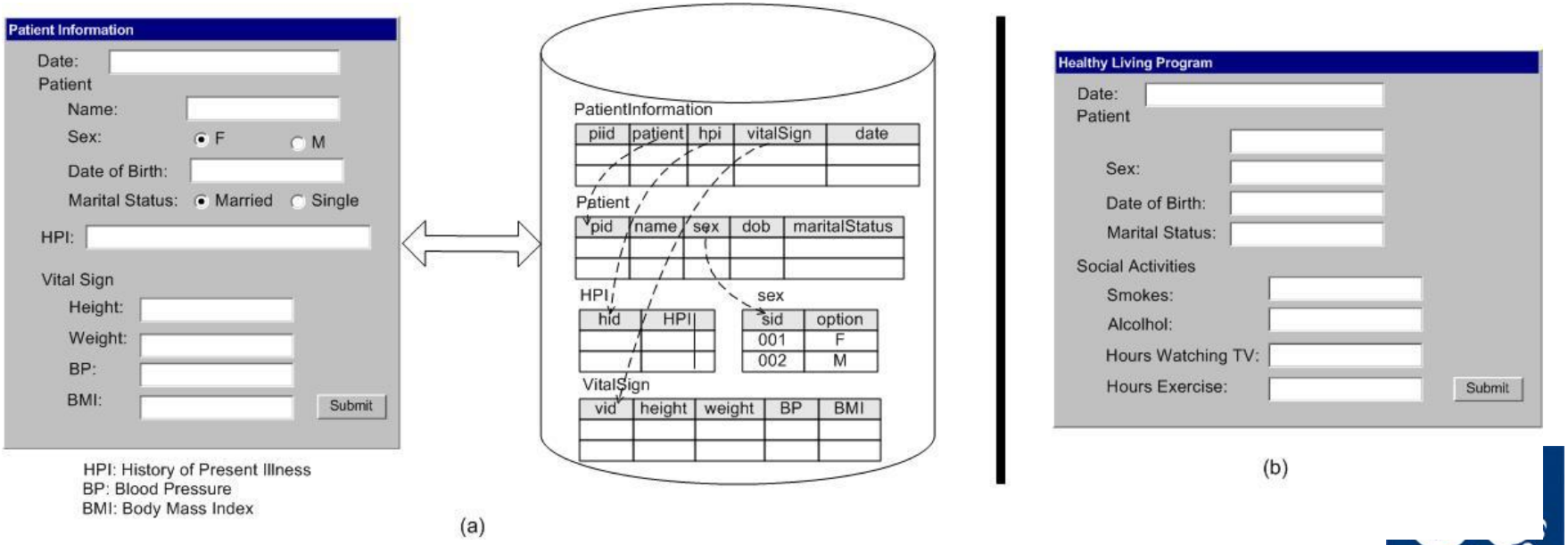
Motivation:

Evolving Requirements and Multiple forms over a Database



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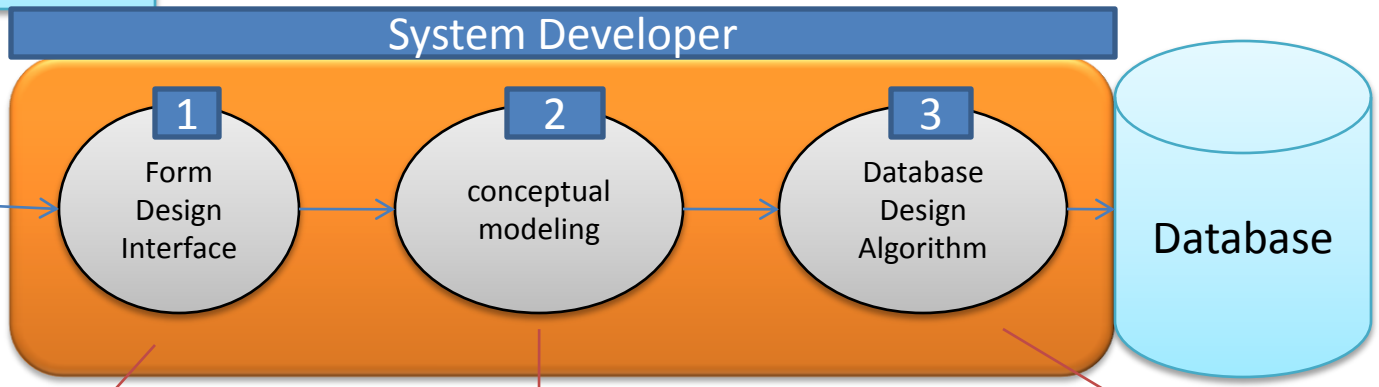
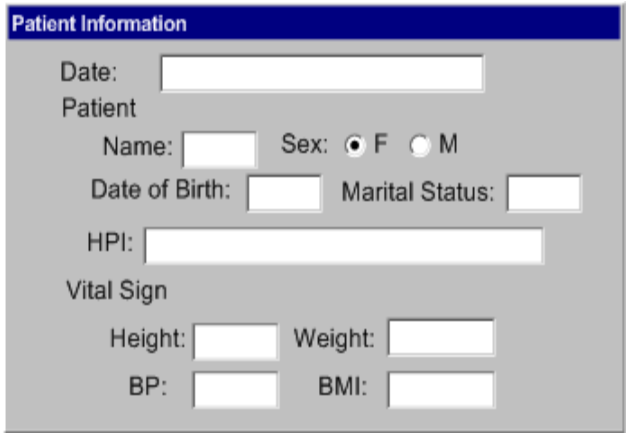
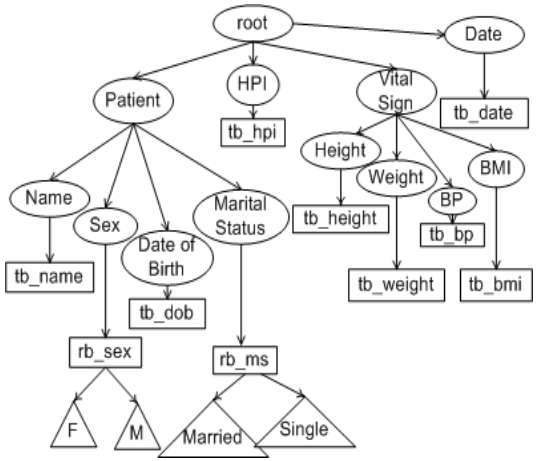
Motivation: Costly and Inefficient in Building Systems

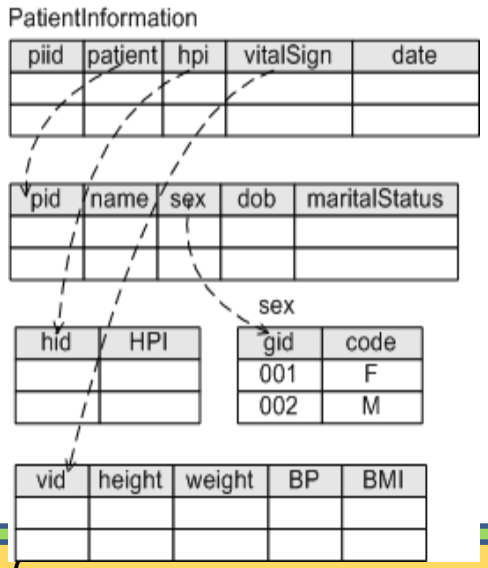
I want to collect patient's information, personal and vital signs, etc

User









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Aim: Supporting Non-Technical Users to Use Structured Databases

- Automatically map and integrate user-created forms to structured databases.
- Reduce the barrier of efficient data gathering and analysis for non-technical users.

user

Patient-Physician Form

Patient

Name

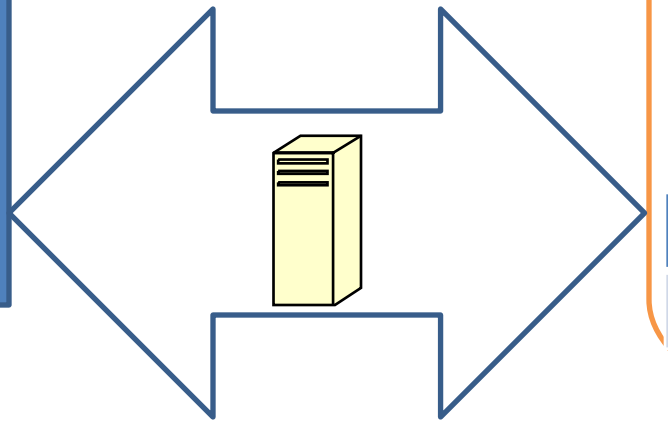
Age

Address

Physician

Name

Contact



PatientPhysician

ID	Patient	Physician

Physician

ID	Name	Contact

Patient

ID	Name	Age	Address

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The *form2db* Problem

- To map and integrate multiple forms into an existing structured database:
  - to allow non-technical users to express their information needs through graphical forms.
  - to automatically extract a formal structure from the user-created forms.
  - to automatically create databases or maps form elements to existing databases.

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The FormMapper System

- A fully automatic solution that accepts user-created data entry forms, and maps and integrates them into an existing database:
  - accepts sophisticated forms as input,
  - automatically captures the semantic relationships among form elements,
  - automatically links form elements to the elements in the hidden database,
  - automatically extends the hidden database for unmatched form elements.

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Challenges

- As a user interface, a form consists of a collection of form elements :
  - text label, text box, radio buttons, and check boxes
  - organized based on the user's visual preference
  - different form layouts may correspond to the same set of entities and relationships.
- The first challenge is *how to automatically extract a formal structure from a form (or multiple forms)* for creating a database or linking the form elements to an existing database.

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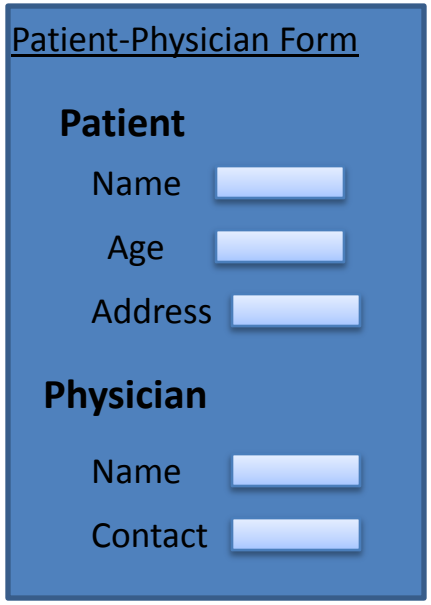
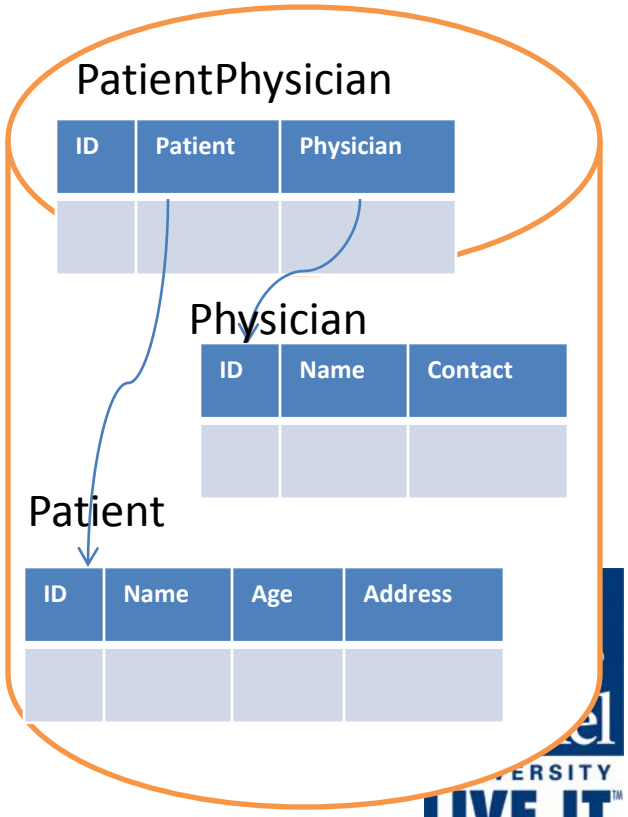
Challenges

- The second challenge is *how to automatically link form(s) to existing databases*.



- Schema mapping, more generally, model mapping is a long-standing problem
- Current solutions for database schema matching and mapping are semi-automatic and require human judgment and intervention.



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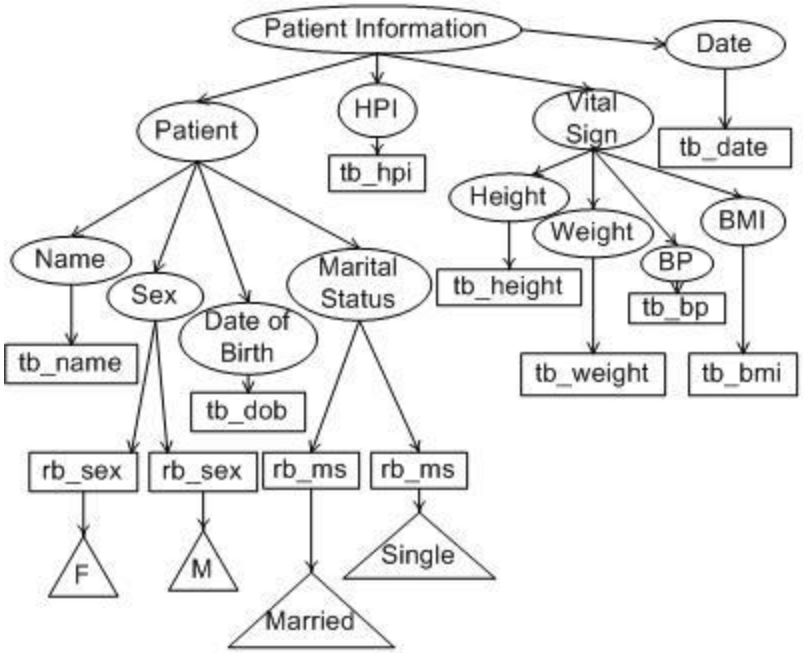
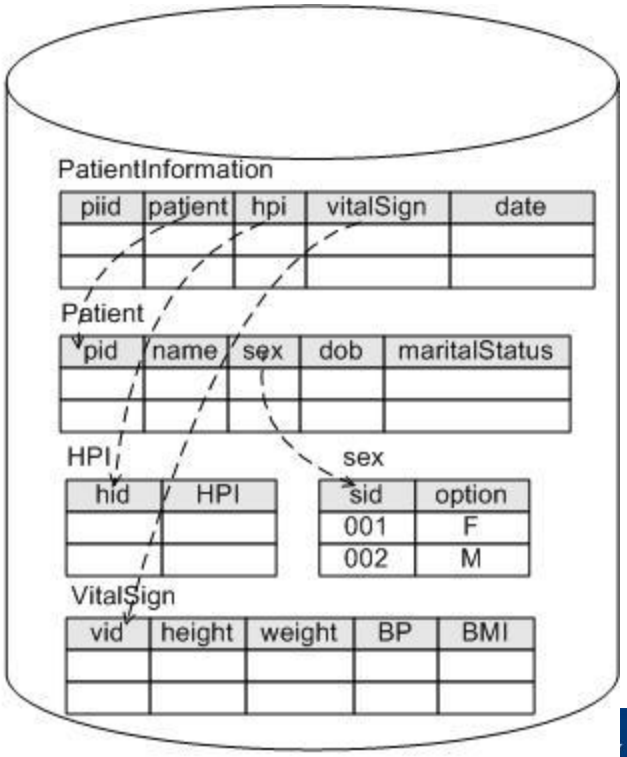
Tree Extraction:

Form Tree





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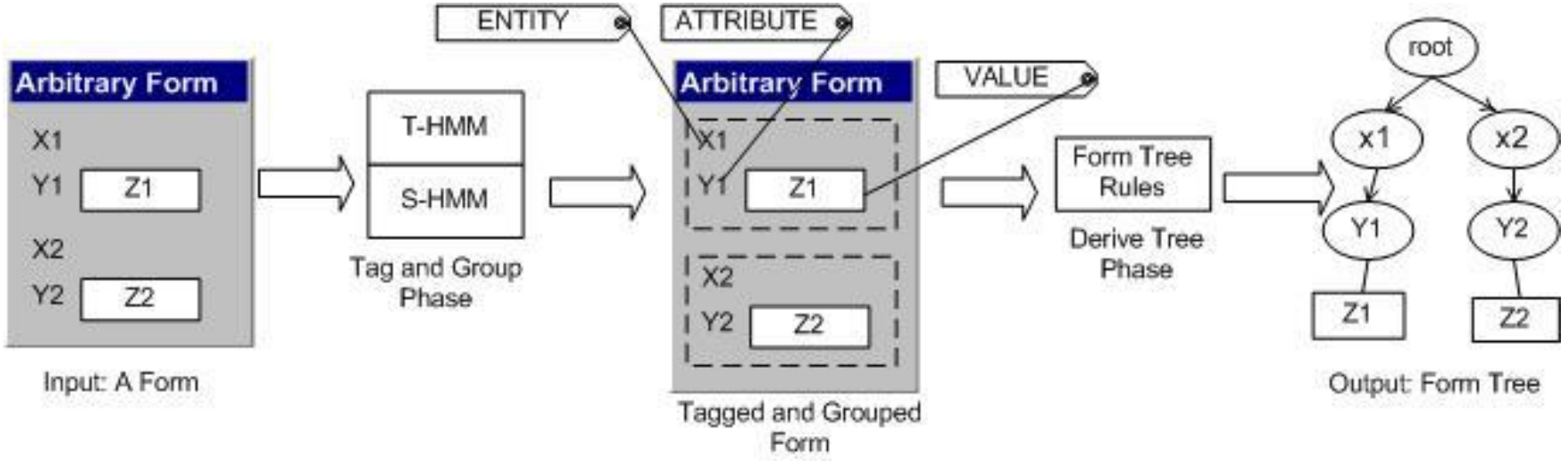
Tree Extraction

- A machine learning technique for automatically extracting a form tree.



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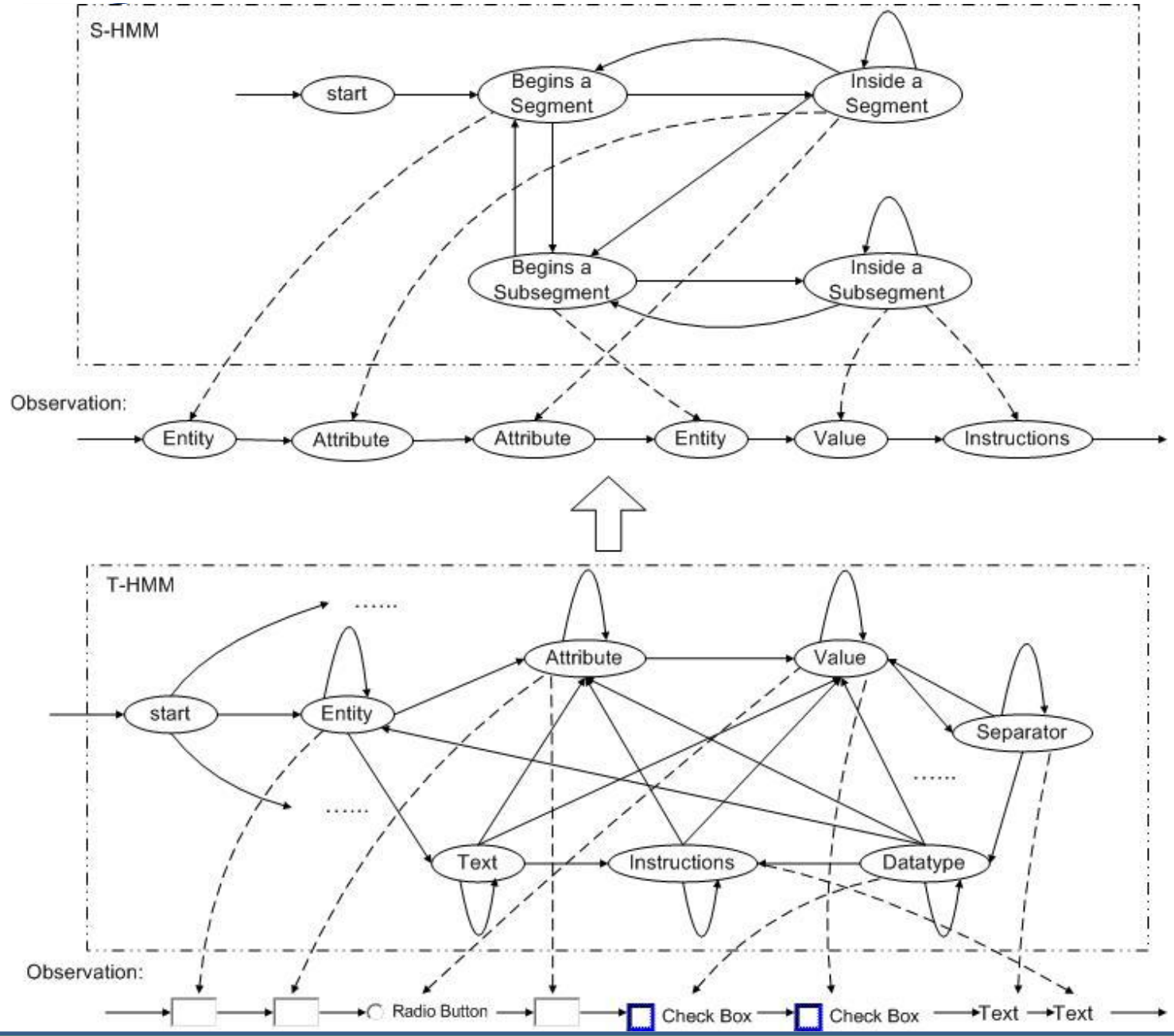
Using HMMs: T-HMM and S-HMM



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Integrating Forms to Database

- Rely on syntactic matches between the elements in forms and the database.
  - discover a set of initial element correspondences.
  - derive a new database from the given form tree.
  - clean up the initial correspondences.
  - extend the existing database for the unmapped elements.

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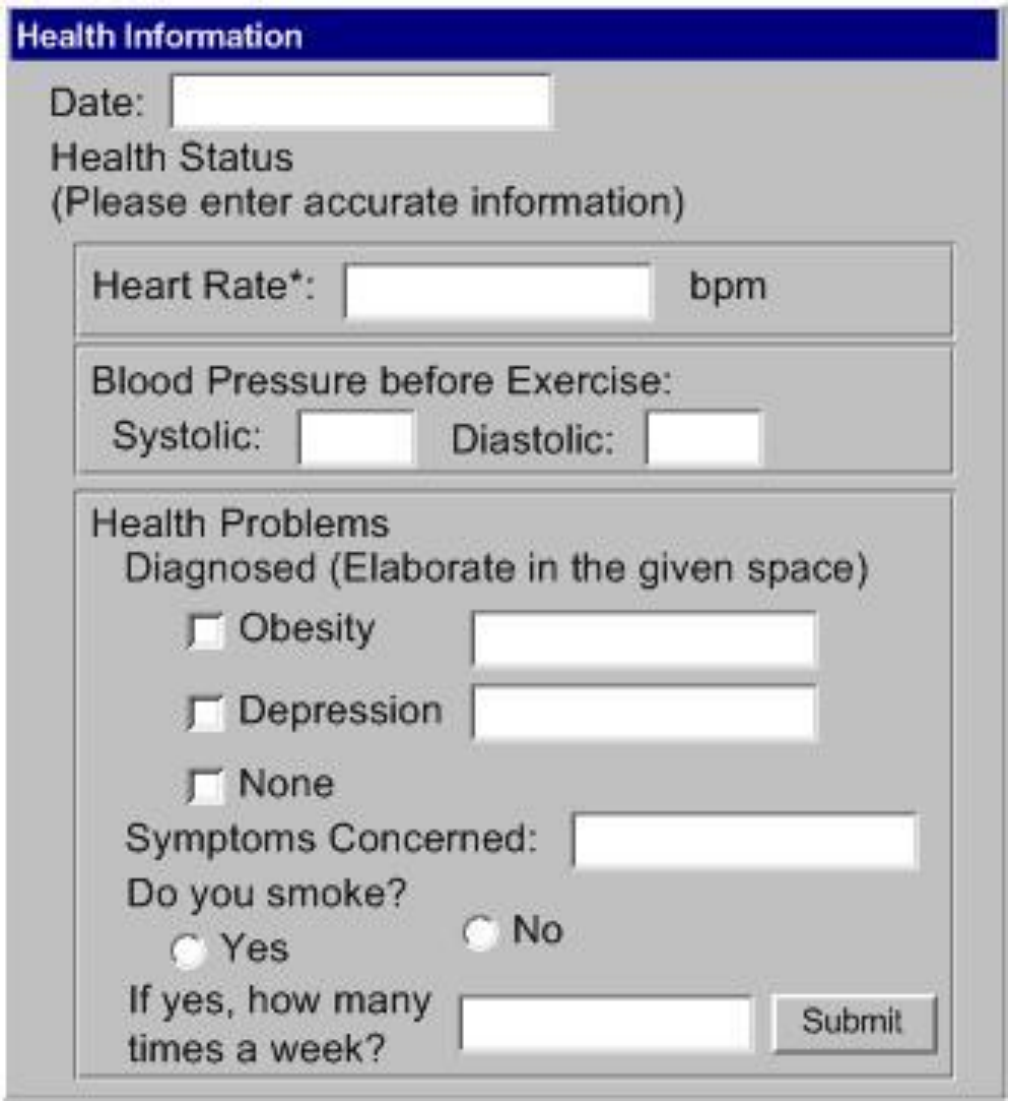
Birthing Algorithm: Issues in complex forms



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Birthing Algorithm: Requirements

- Requirement 1:
  - All the user-specified elements and values should be captured in the database.
- Requirement 2:
  - All the hierarchical relationships among logical and value elements should be maintained in the database.
- Requirement 3:
  - Requirements 1 and 2 considered, tables should be merged for query efficiency.

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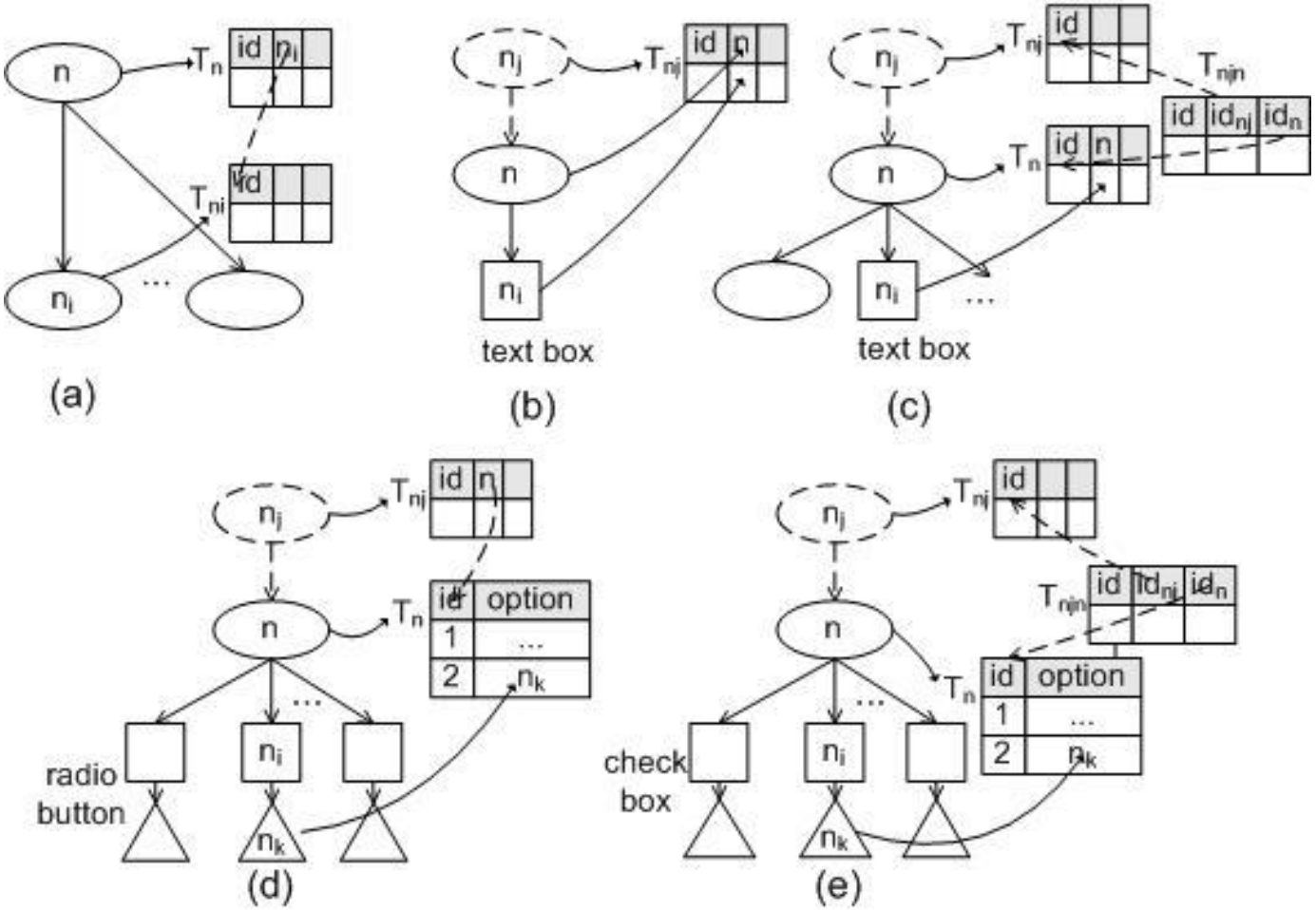
Birthing Algorithm: Patterns



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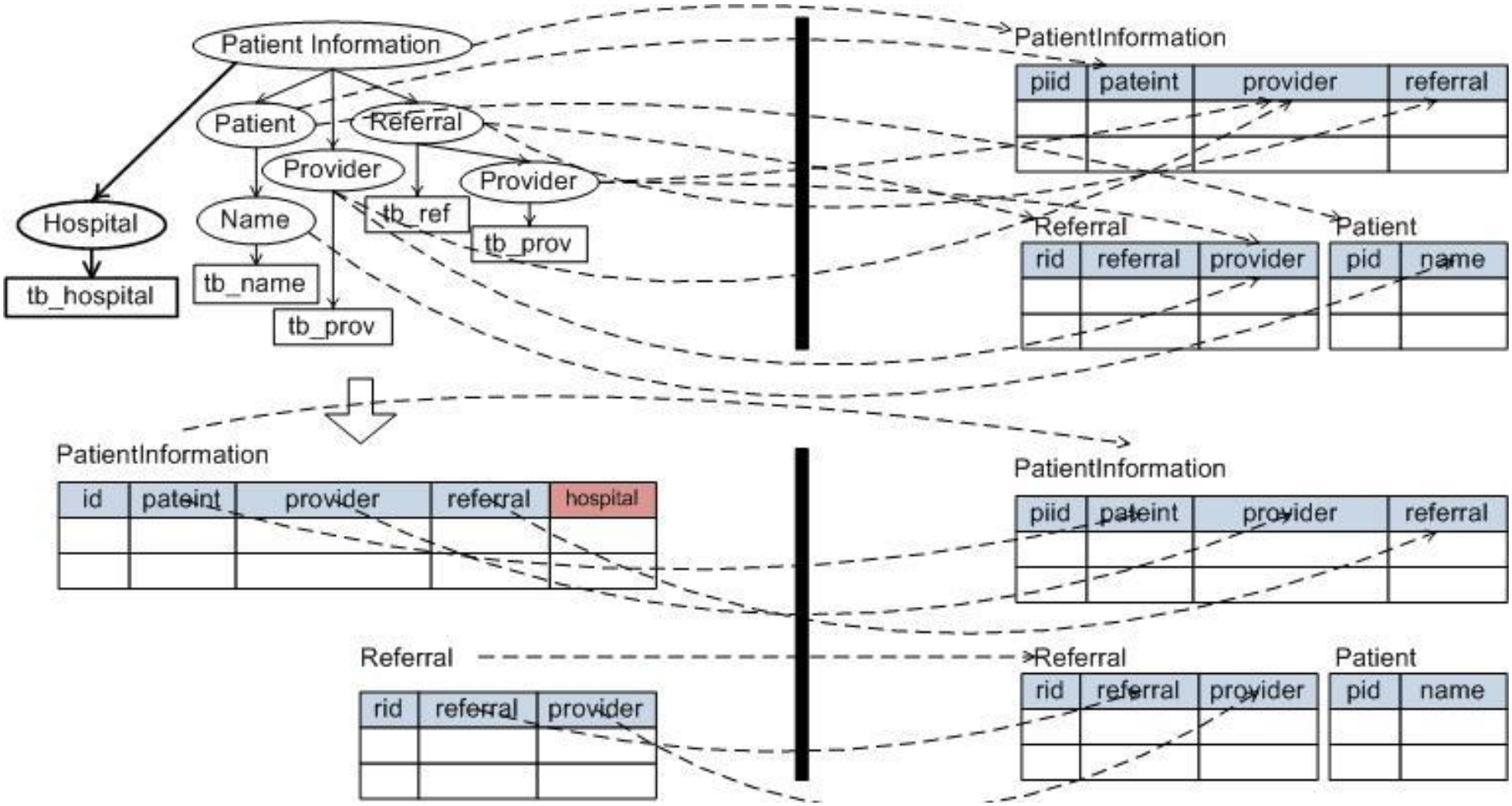
Merging Algorithm



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Merging Algorithm: optimization

- Adding a column to an existing table
  - a lot of NULL values to the table.
- Creating a new table for new columns
  - the number of tables is increased.
- To balance the trade-off between reducing the number of tables (joins) and reducing NULL values
  - a user-defined quality tuning factor qf: (0<= qf <= 1).
    - qf = 0 indicates a high preference to reducing NULL values,
    - qf = 1 indicates a high preference to reducing the number of tables.

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Merging Algorithm: optimization

- Compare qf with a numeric metric null value ratio (nvr) to make decision:
  - nvr = ((m-h)+(n-h)) /(n+(m-h))
    - m and n are the numbers of columns of tables; h is the number of shared columns.
  - If the nvr is lower than qf, we merge the two tables,
  - otherwise, we create a new table.

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Experiments:
HMM

- Data set:
  - 52 encounter forms in the healthcare domain from three healthcare organizations.
  - form sizes vary from 50 elements to 183 elements.
  - manually labeled with semantic tags as training examples.
- HMM training: k-fold cross-validation for training and testing.
- Measurement:
  - extraction accuracy = the percentage of the correctly extracted parent-child relationships.
- Results:
  - average accuracy was 96%.
  - average time for generating a tree structure was within one second.

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Experiments:
Merging

- Gold standard:
  - databases created by human experts.
- Experimentation:
  - a set of forms is put in a random order.
  - applied the system to them one by one starting with an empty database.
- Results:
  - on an average, 87% of system generated databases are considered to be “matched” to the “gold standard” databases.
  - average time for creating or integrating dbs is
  - 3 seconds

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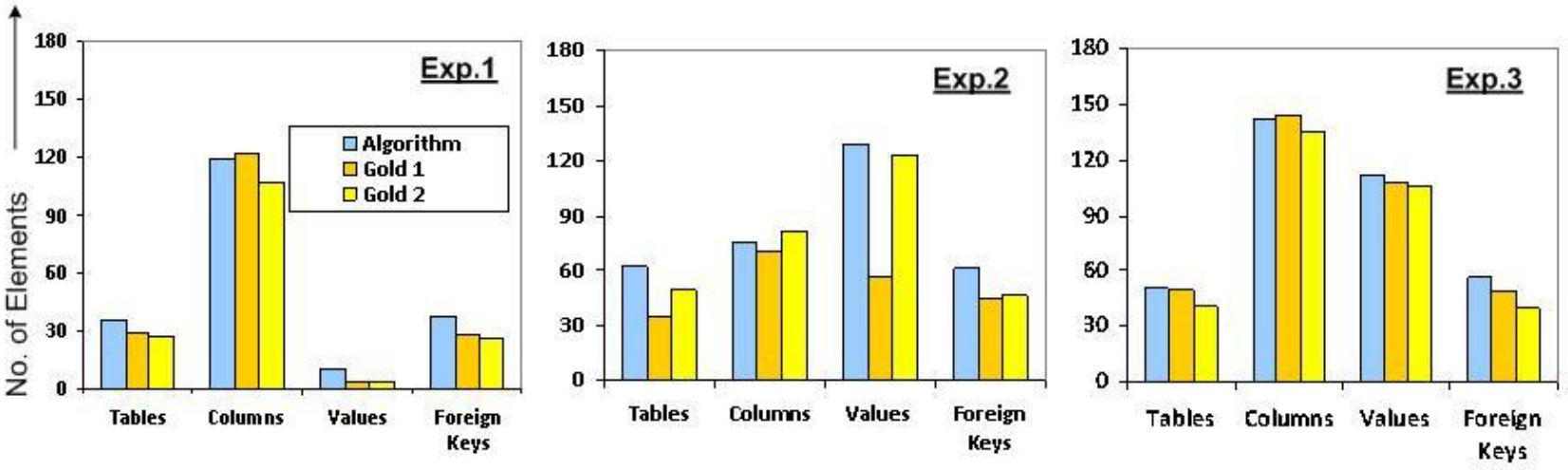
Experiments:
Discrepancies

- Missing correspondences.
- Human judgment based on a personal understanding of the domain semantics:
  - for example, many-to-one relationships from the category-subcategory relationships on forms based on personal domain knowledge.



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Conclusions and Future Work

- Alleviate the birthing pain.
- With the fully automatic solution, users do not need a clear knowledge of the final structure of a database.
- The structure of the database grows automatically, however, in a principled way with certain characteristics.
- Generate databases with “good” properties by only taking as input the forms – promising and have the potential to replace human developers.
- In future, to exploit a wide variety of information and large-scale sophisticated machine learning models to tackle semantic heterogeneity.

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