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I-MAGIC Implementation Guide

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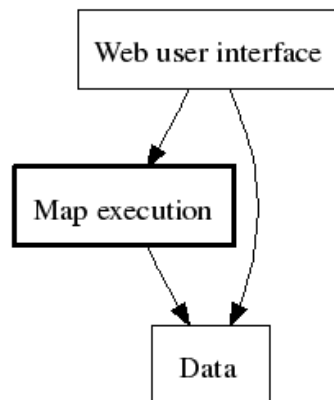
1. Introduction

The I-MAGIC demo tool is a demonstration application of the SNOMED CT to ICD-10-CM rule-based map (the “Map”) as a web application written in Java. I-MAGIC’s user enters some problems a patient has and I-MAGIC translates them to ICD-10-CM codes, asking for additional information along the way if necessary to bridge the differences between SNOMED CT and ICD-10-CM.

I-MAGIC delivers a rough answer immediately, and improves that answer by following a cycle of incremental refinement, culminating in the best possible answer.

I-MAGIC’s interaction cycle works like this:

1. The user submits a problem list and patient facts.
2. I-MAGIC applies the Map to each problem individually.
3. User gets a rough answer.
4. I-MAGIC invites refinement of problem and patient facts.
5. User answers the questions – refining the patient facts.
6. I-MAGIC *reapplies* the Map to each problem.
7. Repeat if necessary.



To accomplish this, I-MAGIC uses “model-view-controller” software architecture.

The *model* is a minimalistic Map execution strategy: it maps *one* problem at a time.

The *view* asks the user questions and accepts the answers.

The *controller* connects the view and model, submitting the problems on the problem list for mapping one at a time. The model, the Map execution module of I-MAGIC, is the main subject of this Guide.

2. Data Sources

I-MAGIC requires 3 data sources, ICD-10-CM, SNOMED CT, and the Map.

A. ICD-10-CM

The official release of ICD-10-CM 2011 can be obtained from the NCHS website

<http://www.cdc.gov/nchs/icd/icd10cm.htm>

The “Full_Tabular.xml” file is all you need.

Hierarchy

The file describes a tree structure that is up to seven levels deep:

- ICD10CM.tabular
 - chapter
 - section
 - diag (sample name: “S13”)
 - diag (sample name: “S13.1”)
 - diag (sample name: “S13.10”)
 - diag (sample name: “S13.101”)

Chapters and sections do not matter in mapping, but the tree of diags is crucial.

In the tree structure, ICD-10-CM refers to diags at the “final level of subdivision”, such as “S13.101”, as “codes”. But not all “codes” are valid codes for reporting because further 7th character extension is required. For example, a seventh-character menu applies to all of S13, so “S13.101” is not a “valid code” until a seventh character has been appended: e.g., S13.101A.

The nuances of mapping arise at the fringes of subdivision. To help describe the I-MAGIC algorithms, we will introduce two additional, slightly more precise, terms:

- **Leaves** are the final level of subdivision. (Thus: All leaves are codes. Not all codes are leaves. Not all leaves are valid codes.)
- The **parent** of a leaf (or “**leaf-parent**”) is the ICD-10-CM diag that most immediately contains the leaf.

Coding notes

The tree also includes notes – codeFirst, codeAlso, and useAdditionalCode. Some notes are already applied in the determination of the target code when the Map is created, but other notes may need to be displayed to the user for consideration. The Map flags the result codes that still require the user’s attention to notes.

Laterality and trimester: menus of siblings

The tree includes many leaf-parents that contain leaves that differ only, or mainly, by laterality (“left”, “right”, or “unspecified”), or trimester (“first trimester”, “second trimester”, etc.). The Map generally uses the “unspecified” leaf code as the mapTarget, together with map advice to consider refining laterality or trimester specification. In practice, the advice means to consider using any sibling of the “unspecified” leaf. For example, the Map associates SNOMED CT’s “Malignant neoplasm of lower lobe, unspecified bronchus or lung” with ICD-10-CM’s “C34.30”, with advice to “consider laterality”:

- C34.3 Malignant neoplasm of lower lobe, bronchus or lung
 - **C34.30** Malignant neoplasm of lower lobe, **unspecified** bronchus or lung
 - C34.31 Malignant neoplasm of lower lobe, **right** bronchus or lung
 - C34.32 Malignant neoplasm of lower lobe, **left** bronchus or lung

ICD-10-CM happens to contain many sets of siblings (diags) whose differences follow one of a very small number of patterns. One example is “xyz, *first trimester*”, “xyz, *second trimester*”, “xyz, *third trimester*”. I-MAGIC identifies the distinct patterns – ignoring the order of the choices – and assigns an identifier to each one. When mapping, I-MAGIC reapplies, or “ports”, an answer from one leaf to another under certain circumstances (see below).

Fetus and episode of care: menus of code extensions

As with laterality and trimester, ICD-10-CM contains many repetitions of a few distinct seventh-character-extension menus. I-MAGIC identifies the distinct menus and assigns an identifier to each one. When mapping, I-MAGIC can reapply an answer from one leaf to another under certain circumstances (see below),

B. SNOMED CT

The SNOMED CT files can be downloaded here:

<http://www.nlm.nih.gov/research/umls/licensedcontent/snomedctfiles.html>

The conceptId and preferred name of a SNOMED CT concept are used for display. In I-MAGIC, in order to facilitate the search for SNOMED CT terms, we augment the native SNOMED CT synonyms with all English synonyms from the UMLS. The search function is powered by the Lucene text search library, providing multi-word prefix search and ranking the results by the default ranking algorithm. Hierarchical information of SNOMED CT is also used in evaluation of the map rules.

C. The Map

The SNOMED CT to ICD-10-CM map can be downloaded here:

http://www.nlm.nih.gov/research/umls/mapping_projects/snomedct_to_icd10cm.html

The Map’s human readable “tab-separated values” (.tsv) file is all you need. In particular, I-MAGIC uses the following columns for mapping:

| Column | Sample Value | Usage |
|------------------------------|--|--|
| referencedComponentId | 1023001 | SNOMED code: joins with SNOMED CT |
| mapGroup | 1 | Sequence for reporting results |
| mapPriority | 1 | Sequence for evaluating rules |
| mapTarget | P28.4 | ICD-10-CM code: joins with ICD-10-CM |
| mapRule | IFA 445518008 age at onset of clinical finding (observable entity) <= 298 .0 days | Conditions under which to map the SNOMED CT code to the ICD-10-CM code |
| mapAdvice | IF AGE AT ONSET OF CLINICAL FINDING BEFORE 298 .0 DAYS OF LIFE -CHOOSE P28.4; MAP OF SOURCE CONCEPT IS CONTEXT DEPENDENT | Mapping logic control and information for display (see below) |

Concepts, Groups, Rules, and Predicates

The Map has a hierarchical structure. For any given “referencedComponentId” (a component is a SNOMED CT concept), the Map sets forth one or more map groups, each of which contains one or more rules, each of which in turn contains one or more conditional predicates.

- ➔ Component
 - Groups
 - Rules
 - Predicates

For example, here is the hierarchical structure of concept 36440009:

| Component | Group | Priority | Rule(s) |
|-----------|-------|----------|---|
| 36440009 | 1 | 1 | IFA 445518008 age at onset of clinical finding (observable entity) >= 189 .0 years |
| | | 2 | IFA 445518008 age at onset of clinical finding (observable entity) <= 298 .0 days |
| | | 3 | OTHERWISE TRUE |

The hierarchical structure groups the tab-separated fields as follows:

| | | | |
|---|----------------------------------|--|---|
| Component fields: referencedComponentId | Group fields: mapGroup | Rule fields: mapPriority mapTarget mapAdvice | Predicate fields: (parsed from mapRule) |
|---|----------------------------------|--|---|

mapTarget

The mapTarget follows one of these cases:

- A valid ICD-10-CM code
- An ICD-10-CM leaf plus a “?” placeholder for the required seventh character
- (blank)

The Map uses capital letters in ICD-10-CM codes, which is unambiguous but requires a case-blind join with ICD-10-CM. For example, the Map refers to “S06.9X0”; ICD-10-CM has “S06.9x0”.

mapAdvice

The mapAdvice contains one or more statements (separated by a vertical bar). Some of the statements flag the kinds of refinement to apply to the mapTarget. I-MAGIC categorizes those statements as “logic advice” and implements them algorithmically. Some other statements do not influence the logic path within I-MAGIC, but are to be shown to I-MAGIC’s user. I-MAGIC categorizes those statements as “information advice”. Besides logic advice and information advice, there may be other statements in mapAdvice, but I-MAGIC does not use them. The following table enumerates the mapAdvice that I-MAGIC uses, and how it’s categorized:

| Advice text | Category |
|---|-------------|
| CONSIDER ADDITIONAL CODE TO IDENTIFY SPECIFIC CONDITION OR DISEASE | Logic |
| CONSIDER LATERALITY SPECIFICATION | Logic |
| CONSIDER TRIMESTER SPECIFICATION | Logic |
| CONSIDER WHICH FETUS IS AFFECTED BY THE MATERNAL CONDITION | Logic |
| EPISODE OF CARE INFORMATION NEEDED | Logic |
| MAP IS CONTEXT DEPENDENT FOR GENDER | Logic |
| POSSIBLE REQUIREMENT FOR AN EXTERNAL CAUSE CODE | Information |
| THIS IS A MANIFESTATION CODE FOR USE IN A SECONDARY POSITION | Information |
| THIS IS AN EXTERNAL CAUSE CODE FOR USE IN A SECONDARY POSITION | Information |
| THIS IS AN INFECTIOUS AGENT CODE FOR USE IN A SECONDARY POSITION | Information |
| USE AS PRIMARY CODE ONLY IF SITE OF BURN UNSPECIFIED, OTHERWISE USE AS A SUPPLEMENTARY CODE WITH CATEGORIES T20-T25 (Burns) | Information |

Predicates

I-MAGIC interprets the mapRule into Predicates in two steps:

1. Split at delimiter (“;” or “AND”)
2. Match the first possible pattern (regular expression) in the following table:

| Pattern (regular expression) | Sample | Predicate |
|------------------------------|---|-----------------------|
| IFA 1086007 \ .* | IFA 1086007 Female (finding... | FEMALE=1 |
| IFA 248153007 \ .* | IFA 248153007 Male (finding... | FEMALE=0 |
| IFA 445518008 \ . *? \ (.*) | IFA 445518008 age ... <= 298.0 days | AGE <i>op n units</i> |
| IFA ([0-9]+) \ .* | IFA 40751003 Persistent ... | IFA <i>snomedCode</i> |
| (?:OTHERWISE)?TRUE | TRUE | TRUE |

I-MAGIC uses a single Predicate form, with a True or False argument, to represent the Male and Female findings.

The age comparison operators are <= and >=. The age in the Map is a whole number, but the Map specifies it with precision to the tenths (“.0”) to clarify the comparison. The units in the Map are days and years.

Multiple Groups

Each map group may contribute an ICD-10-CM code to the result. Some map groups conclude without a mapping. This may happen in two ways:

- The first mapRule that applies has an empty mapTarget.
- The group does not have any mapRule that applies.

A result of “no mapping” from the *first* map group for the concept is very significant. It means that the Map does not relate the SNOMED CT concept to ICD-10-CM code(s). On the other hand, the second, third, and subsequent map groups contribute to the mapping result only if they yield a code; a “no mapping” result beyond the first map group should simply be thrown away.

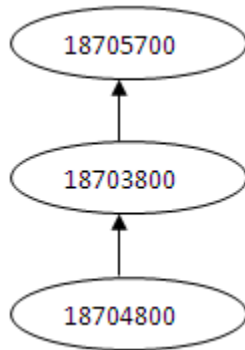
Comorbidities

The “IFA...” comorbidity predicates, scattered though they may be throughout all map groups for a mapped concept, are descendants of the mapped concept.

For example, consider Histoplasmosis with meningitis (only the first map group is shown):

| Group | Priority | Predicate(s) |
|-------|----------|---|
| 1 | 1 | IFA 187048004 Histoplasma duboisii with meningitis (disorder) |
| | 2 | IFA 187038001 Histoplasma capsulatum with meningitis (disorder) |
| | 3 | OTHERWISE TRUE |

In SNOMED CT, Histoplasmosis with meningitis (187057005) and the refinement choices have a multi-level relationship, as illustrated by this partial diagram with arrows leading from concepts to their ancestors:

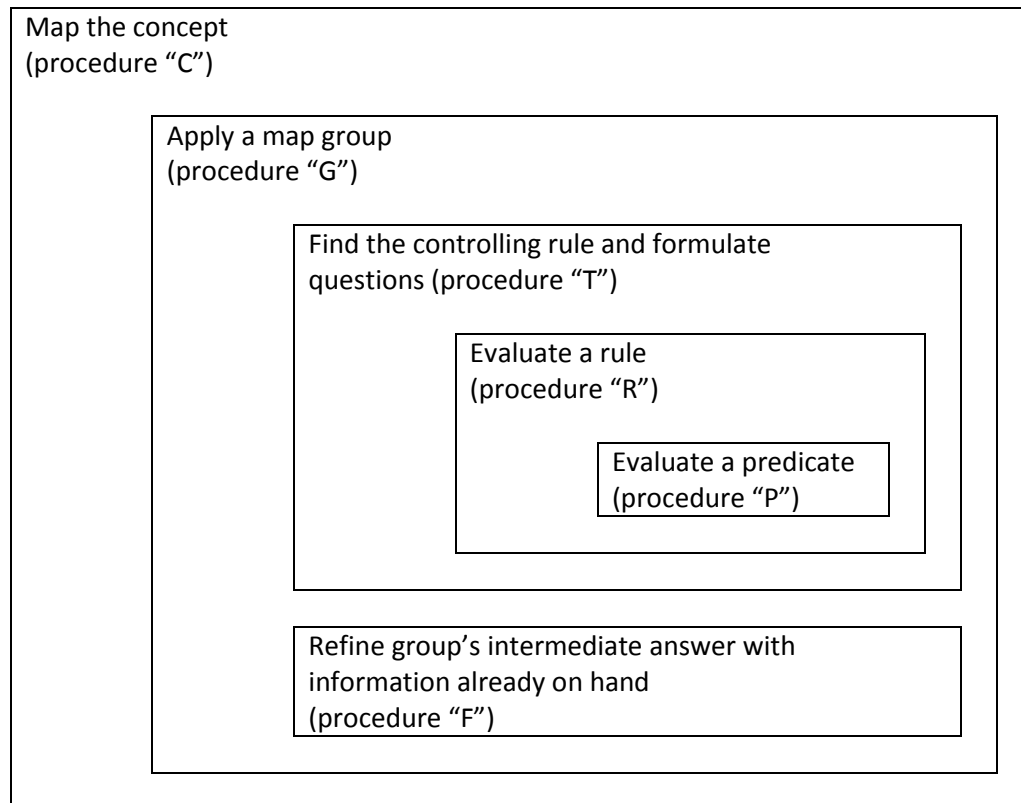


Within a map group, the Map lists the most-specific concept as the first rule.

3. Procedure of Mapping

In the Map, a concept mapping is made of mapGroups, which in turn are made of rules, which in turn contain predicates. Applying the Map requires drilling down according to the hierarchical structure: in order to map a concept, it is necessary to apply each of its map groups; in order to apply a group, it is necessary to apply its rules; in order to apply a rule, it is necessary to evaluate its predicates. Meanwhile, the results bubble up and out.

The following diagram shows how the algorithms “nest” within one another.



Here are the procedures. A brief example follows the procedures.

Procedure “C”

To map a concept to ICD-10-CM, I-MAGIC uses the following procedure. The result will be (a) a list of codes-and-advice and (b) a set of questions to ask to enable refinement of the codes.

1. Identify the mapped component: Look up the SNOMED CT code in the Map. You will find a list of map groups.
2. Taking the map groups in order (starting with mapGroup=1), apply each map group. (See procedure “G” below.)
3. The product of Procedure “C” is the list of code-and-advice pairs (excluding no-code results from groups other than the first), and the set of questions that arose from step 2.

Procedure “G”

To apply a map group, I-MAGIC uses the following procedure. The result will be an ICD-10-CM code (or mapTarget), mapAdvice, and a set of questions:

1. Find the controlling rule and the questions to ask that might improve the selection of a controlling rule. (See procedure “T” below.)
2. The intermediate answer for the map group is the mapTarget of the controlling rule.
3. Refine the intermediate answer (See procedure “F” below.)

Procedure “T”

To find the controlling rule and identify questions that will help further refinement, I-MAGIC uses the following procedure:

1. Make an empty list for questions.
2. Evaluate the rule whose mapPriority=1. (See procedure “R” below.)
3. Act on the evaluation:
 - a. If the rule applies, then it is the controlling rule. Done!
 - b. If evaluating the rule resulted in questions instead of a code, add the questions to the list.
4. Go on to the next rule. If there are no more rules, then the result is just the list of questions.

Procedure “R”

To evaluate a rule, I-MAGIC uses the following procedure. The result will be or (c) “do not know whether the rule applies; please answer the following questions: ...”

1. Evaluate the rule’s predicates individually. (See procedure “P” below.)
 - a. If *any* predicate is False, then the result is “Does Not Apply”.
 - b. If *all* predicates are True, then the result is “Applies”.
 - c. Otherwise, the result is the set of questions that arose from evaluating the predicates.

Procedure “P”

To evaluate a predicate, I-MAGIC uses the following procedure. The result will be (a) “True”, (b) “False”, or (c) “do not know whether it is True or False; please answer the following question...”

1. If the predicate is “Always true”, the result is True. Done! Otherwise, continue:
2. Make the predicate into a question.
 - a. Comorbidity: “Does the patient have SNOMED code nnnnnn – yes or no?”
 - b. Gender: “Is the patient male or female?”
 - c. Age: “What was the patient’s age?”
3. Examine the patient facts. Is the answer to the question there?
 - a. Comorbidity: If the answer is there, return it (Yes = True, No = False). If not, check the SNOMED CT hierarchy: If the patient facts include a No for any ancestor of the condition, then the answer is False. If the patient facts include a Yes for any descendant of the condition, then the answer is True.
 - b. Gender: If the patient facts include gender, then the result is True if the patient is the required gender, False otherwise.
 - c. Age: If the patient facts include age, then compare the patient’s age with the predicate to get the result of True or False.
4. Otherwise, the result is the question, which needs to be posed to the user.

Procedure “F”

To refine a map group’s intermediate answer using information already on hand, I-MAGIC uses the following procedure. The result will be (a) a possibly refined ICD-10-CM code, and (b) questions to ask to improve the refinement.

1. If the advice includes “Consider Laterality”: Grasp the ICD-10-CM leaf node corresponding to the mapTarget. Then look one level up the ICD-10-CM tree to find the leaf’s parent. Make the advice into a question: “Which child of the target’s leaf-parent best fits the patient?” Examine the patient facts. Is the answer to the question there? If the answer is there, adjust the ICD-10-CM code and discard the refinement advice. Otherwise, add the question to the list of questions to pose.
2. If the advice includes “Consider Trimester”: Grasp the ICD-10-CM leaf node corresponding to the mapTarget. Look one level up the ICD-10-CM tree to find the leaf’s parent. The menu of trimester choices consists of the names of the parent’s children, less their common prefix. Form a question from the I-MAGIC identifier of the pattern of choices: “Which choice from (menu ID) applies, if any?” Examine the patient facts. Is the answer to the question there? If the answer is there, adjust the ICD-10-CM code and discard the refinement advice. Otherwise, add the question to the list of questions to pose.
3. If the advice includes either “Fetus” or “Episode”: March up the ICD-10-CM hierarchy to find the nearest seventh character definition. Form a question from the menu’s I-MAGIC identifier and the problem SNOMED CT code: “Which of the choices from (menu ID) applies to (SNOMED CT problem)?” Examine the patient facts. Is the answer to the question there? If the answer is there, adjust the ICD-10-CM code and discard the refinement advice. Otherwise, add the question to the list of questions to pose.

In summary

A mapRule predicate must be *true* (with respect to the patient), *false*, or *undecided*. It is undecided if the on-hand knowledge of the patient does not address it one way or the other.

A rule is *applicable*, *inapplicable*, or *undecided*, depending on how its mapRule predicates relate to the patient information. If all predicates are true with respect to the patient information, then the rule is applicable. If any predicate is false, then the rule is inapplicable. If the predicates are undecided or a mixture of true and undecided, then the rule is undecided.

In a map group:

- The *controlling rule* is the applicable rule with the lowest mapPriority number.
- If there is a controlling rule, then all rules after it (with higher mapPriority number) are *unimportant*.
- All rules that are not unimportant are *important*.

- The undecided predicates of undecided important rules imply *refinement questions*. The questions will gather additional patient information, so that a subsequent run of the rules might produce a more specific answer.

Resolving a map group yields the map target and map advice of the controlling rule, plus the refinement questions from the undecided predicates of undecided important rules. The map target code may be replaced by a more specific code, depending on known facts about the patient and the user's response to the refinement questions.

The result is finished if there are no refinement questions. The result may be subject to refinement if there are questions. Refinement is *mandatory* if the result has questions and does not include a valid code.

Example

As an example, consider Chorioamnionitis.

Inputs

1. Problem: **11612004**
2. Questions already asked, and answers thereto: **None**

The concept has one group. We examine the first rule in the group. We examine the rule's predicate. The rule has only True predicates, so the rule applies. The mapTarget is O41.1290 and there is some refinement advice. We turn the refinement advice into questions. We look in the patient facts for answers to those questions. The answers are not there, so we pose the questions for the user to answer.

Results:

Outputs

1. **mapTarget:** O41.1290
2. **mapAdvice:** Fetus, Trimester
3. **Questions** to ask about the patient:
 - a. trimester of pregnancy (first trimester, second trimester, third trimester, or unspecified trimester)
 - b. ICD-10-CM seventh character from the menu used by O41 among others, for use with problem 11612004? (Note: The question must specify the problem because the *answer* does not apply to any *other problem*, even if the other problem shares the same list of fetus options.)

Default mappings

Most map groups terminate with an unconditional rule – a rule whose predicate is “TRUE” or, equivalently, “OTHERWISE TRUE”. This rule is considered a “default” because it should be applied if nothing further is known about the patient’s condition.

I-MAGIC makes no special case for default mappings, nor for the case in which there is no default, because the procedure outlined above applies in any case. Rules are evaluated in order, and the result comes from the first rule whose predicates apply.

4. Interactive application of the Map

I-MAGIC embeds the rule evaluation module in a user interface that translates between the algorithm’s style of questions and answers and a style suitable for Web interaction. The interactive user interface does these main things:

- Consolidates “comorbidity” questions
- Maps a whole problem list
- Exchanges between “age” and “date of birth”
- Characterizes refinement as “mandatory” or “optional”

Problem refinement (comorbidity)

I-MAGIC’s Map execution module turns each IFA predicate about a subtype into a yes-or-no question asking whether the patient has the respective problem.

Some map groups involve several comorbidity choices. Consider Toxic encephalopathy (28394000):

1. IFA 51399001 | Toxic encephalopathy due to lead (disorder) |
2. IFA 55623006 | Toxic encephalopathy due to mercury (disorder) |
3. IFA 75143000 | Toxic encephalitis due to thallium (disorder) |
4. IFA 59651006 | Sedative, hypnotic AND/OR anxiolytic-induced persisting dementia (disorder) |
5. IFA 62239001 | Parkinson-dementia complex of Guam (disorder) |
6. IFA 73935008 | Toxic encephalopathy due to hydroxyquinoline (disorder) |
7. IFA 74267005 | Toxic encephalopathy due to carbon tetrachloride (disorder) |
8. IFA 230355005 | Encephalopathy due to heavy metals (disorder) |
9. IFA 425522009 | Hyperammonemic encephalopathy (disorder) |
10. OTHERWISE TRUE

Users might resent *nine* yes-or-no questions, so I-MAGIC’s web user interface combines them into a single menu. I-MAGIC sorts the menu so subtypes precede supertypes, and furthermore instructs the user to choose the most precise applicable item:

Would one of the following diagnoses apply? Choose the most specific one:

- Toxic encephalopathy due to lead
- Toxic encephalopathy due to mercury
- Toxic encephalitis due to thallium
- Sedative, hypnotic AND/OR anxiolytic-induced persisting dementia
- Parkinson-dementia complex of Guam
- Toxic encephalopathy due to hydroxyquinoline
- Toxic encephalopathy due to carbon tetrachloride
- Encephalopathy due to heavy metals
- Hyperammonemic encephalopathy
- The above choices are **not applicable***

Then, with the user's selection, the user interface re-expands the selection into a collection of yes-or-no answers to the original nine questions: the chosen problem is answered with Yes; the choices representing its SNOMED CT ancestors are also answered with Yes; and the remaining choices are answered with No.

Problem list as comorbidities

I-MAGIC's web user interface invites the user to specify multiple problems for mapping – but the Map execution module accepts only a single problem for mapping at once. How does that work?

I-MAGIC accomplishes this with sleight-of-hand: the controller submits each problem separately to the Map execution module, *along with pre-filled "yes" comorbidity facts* for the remaining problems.

I-MAGIC's web user interface flags mappings that were influenced by the problem list. It does this by running the mapping *twice* – once with comorbidity facts inferred from the problem list, and again without. If the results come out differently, the problem list must have played a role.

Mandatory vs. optional refinement

When the information on hand is already sufficient to produce a valid ICD-10-CM code, it is up to the user whether additional questions for refinement will be shown. This is called "optional refinement". However, when there is no resulting valid code (such as when the resulting code is blank or ends in "?"), the questions are automatically posed. This is called "mandatory refinement".