Formal Verification of Health Assessment Tools: a Case Study

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Motivation

- Health Assessment Tools

Motivation

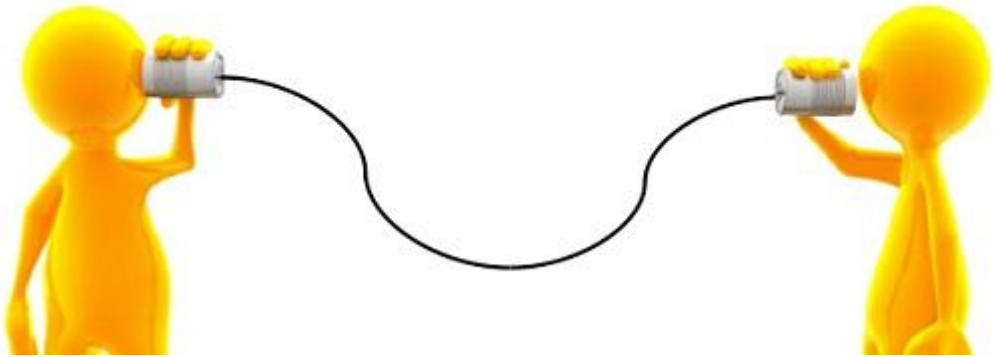
- Health Assessment Tools
- Software Specification

Motivation

- Health Assessment Tools
- Software Specification
- Specifications in Natural Language

Motivation

- Natural Language Communication Problems



Motivation

- Natural Language Communication Problems
  - Ambiguity

Motivation

- Natural Language Communication Problems
  - Ambiguity
  - Inconsistencies

Motivation

- Natural Language Communication Problems
  - Ambiguity
  - Inconsistencies
  - Omissions

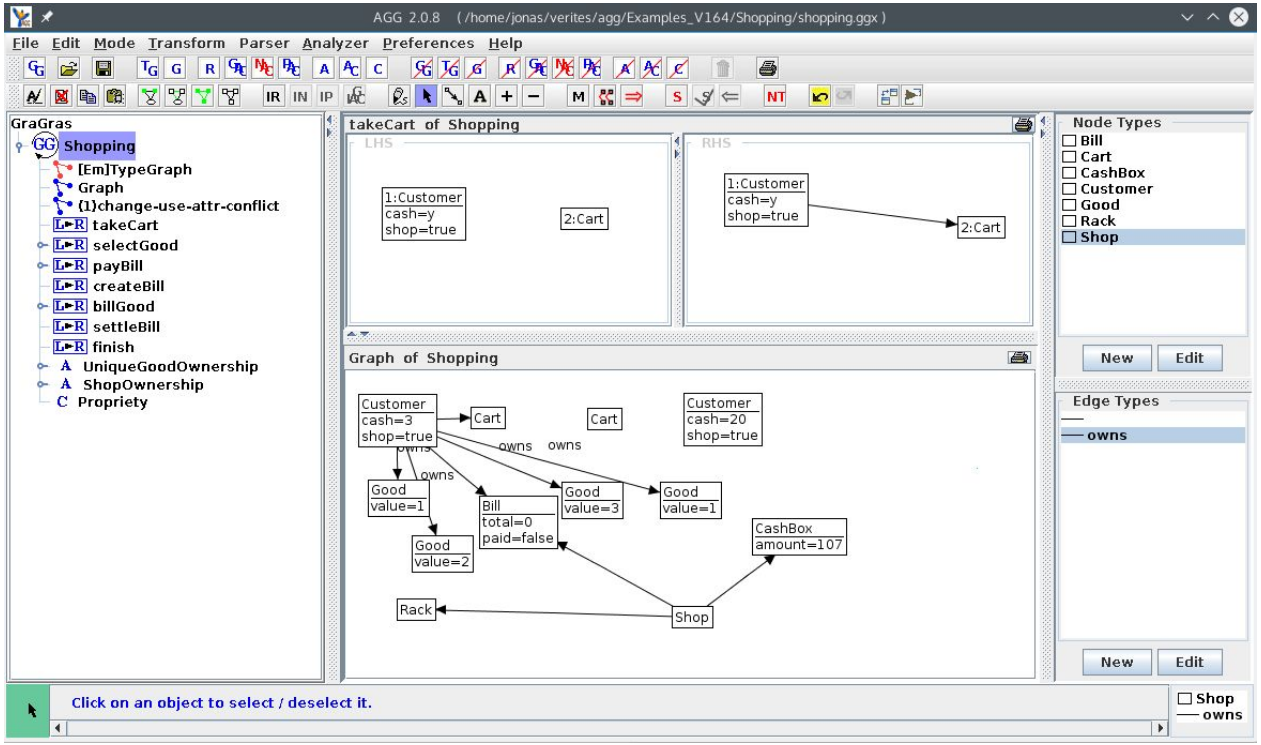
How to solve or eliminate this problems?

Formal Verification Methodology

Graph Transformations

1. Identification of entities
2. Identification of actions
3. Characterization of conditions and effects as states
4. Construction of Type Graph
5. Construction of Rules
6. Analysis

AGG: The Attributed Graph Grammar System



Case Study - Leishmaniasis treatment guideline

Applying medication

Preconditions:

1. Patient attends to criteria.
2. Lesion area is known.

Postconditions:

1. Patient under medication.

Case Study - Leishmaniasis treatment guideline

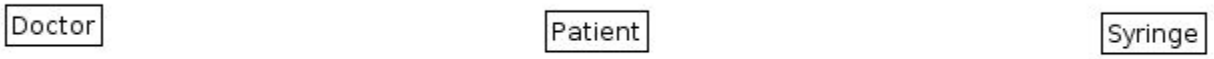
Main Scenario

1. MD calculates the total volume of medicine to be injected.
2. MD calculates 1/4 of medicine volume.
3. MD puts Lidocaine 2% in a 5ml syringe with insuline needle.
4. MD injects Lidocaine in the 4 lesion compass points until 4 3mm² anaesthetic buttons have formed.
5. MD aspirates the contents of the Glucantime ampola (5ml) using a 5ml syringe and 25x0.7G needle.
6. MD discards the needle used in the medication aspiration.
7. MD couples another 25x0.7G needle in the syringe with medication.
8. MD inserts the needle in the anaesthetic button in the direction of the center of the lesion with the bevel facing upwards.
9. MD retracts the needle towards the border of the lesion and at the same time injects 1/4 of the estimated volume of medication.
10. MD repeats steps 8 and 9 in the 3 remaining anaesthetic buttons.
11. MD observes whether edema have formed and ends the procedure.

Step 1: Identification of Entities

- Patient
- Criteria
- Area of injury
- Medication
- Medicine
- Doctor
- Medicine volume
- Estimated medicine volume
- Lidocaine 2%
- 5ml Syringe
- Insulin needle
- Cardinal Point(s) of Injury
- Anesthetics buttons
- 5ml ampoule of Glucantime
- Glucantime
- 25 x 0.7G needle
- Center of Injury
- Bevel
- Swelling/Edema
- Saturation of injury.

Step 1: Identification of Entities



Step 1: Identification of Entities

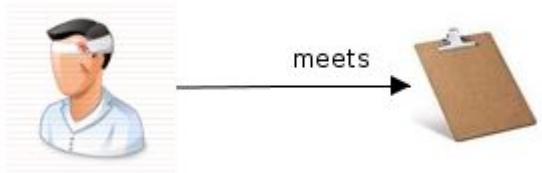
Step 2: Identification of Actions

- calculateVolume
- divideVolume
- aspireLidocaine
- injectLidocaine
- aspirateGlucantime
- discardNeedle
- coupleNewNeedle
- coupleNewNeedle
- insertNeedleInAnaestheticsButtonsadministerGlucantime
- observeSaturatedInjury
- observeNotSaturatedInjury
- administerMoreGlucantime

Step 2: Identification of Actions

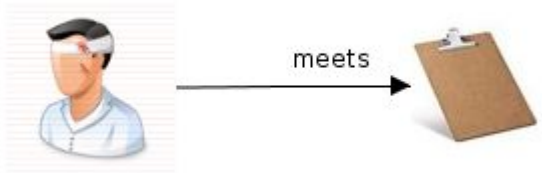
Action	Conditions	Effects
calculateVolume	1. The area of the injury is known 2. Patient meets criteria	1. MD knows the estimated volume of the medicine
...	...	...

Step 3: Characterization of conditions and effects

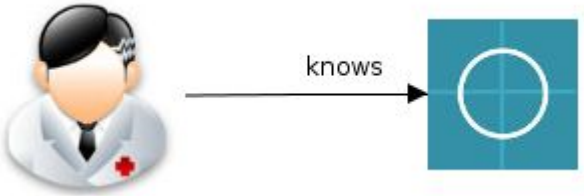


Patient meets criteria

Step 3: Characterization of conditions and effects

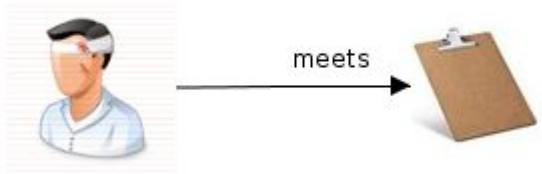


Patient meets criteria

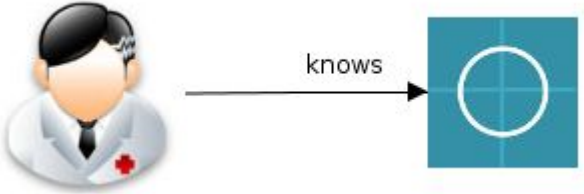


The area of the injury is known

Step 3: Characterization of conditions and effects



Patient meets criteria



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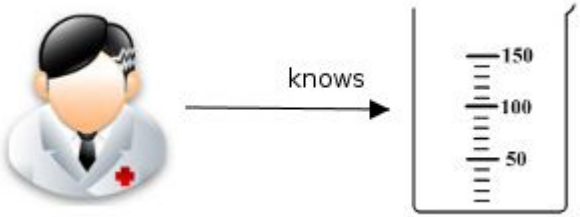
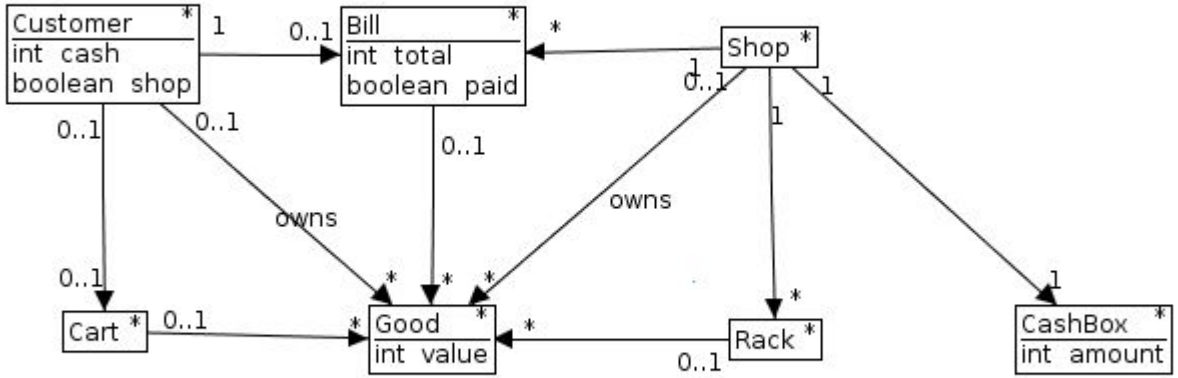


MD knows the estimated volume of the medicine

Step 4: Construction of Type Graph



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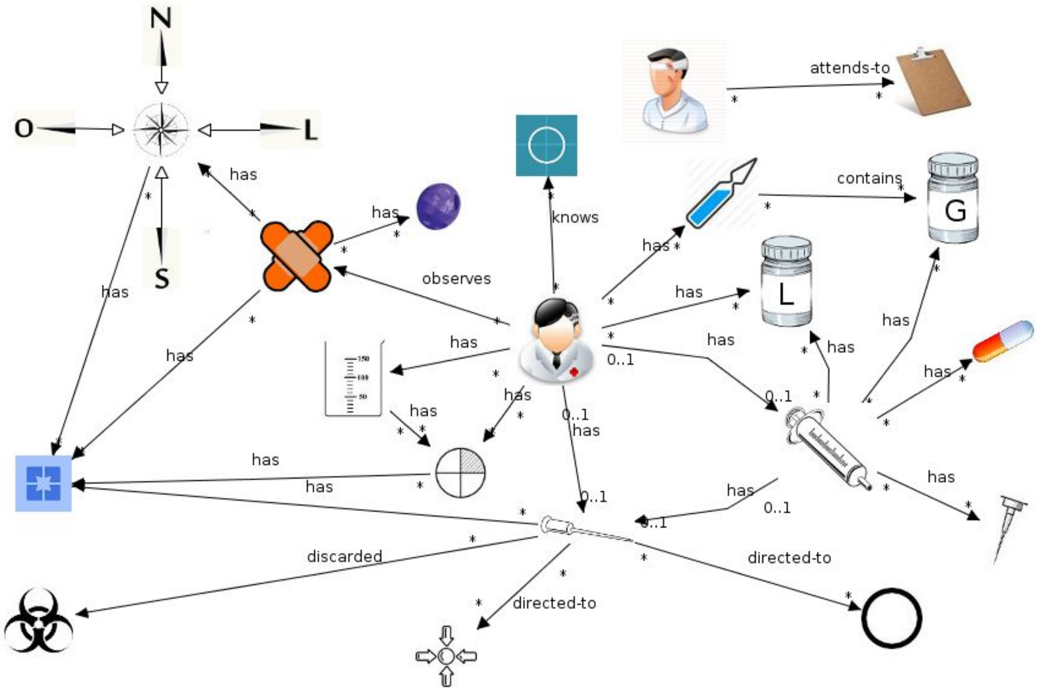

Step 5: Construction of rules

- Left Hand Side (LHS): the conditions that must be true for this action to occur.
- Right Hand Side (RHS) represents the result of the rule application.

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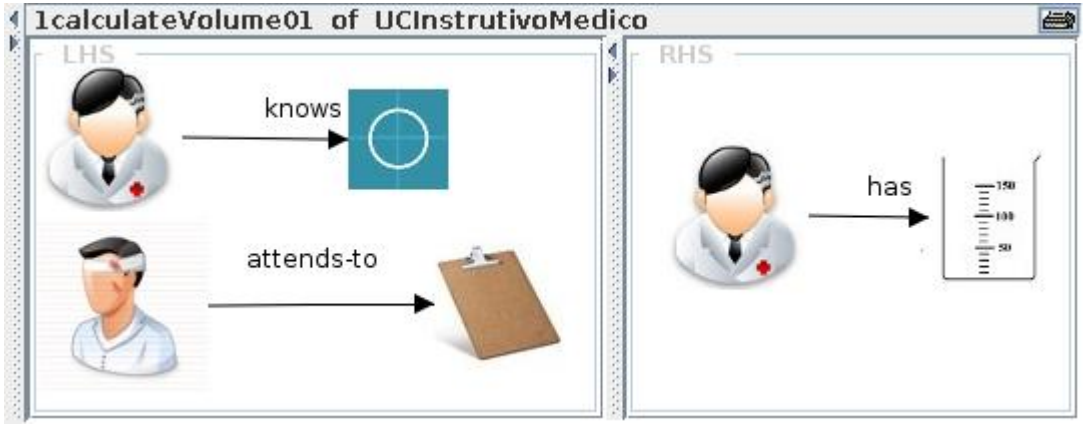
- Right Hand Side (RHS) represents the result of the rule application.

Effects of Rule Application

1. items in the LHS that do not appear in the RHS are deleted
2. items in the LHS that appear in RHS are preserved
3. items in the RHS that do not appear in the LHS are created

Step 5: Construction of rules



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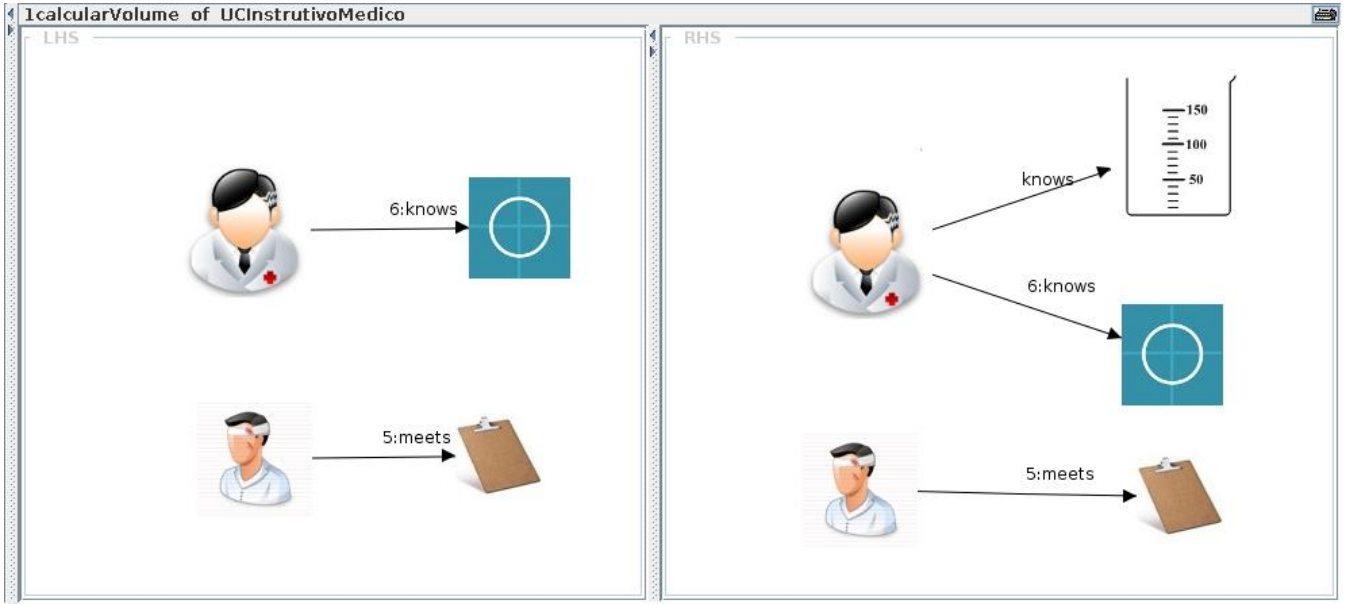
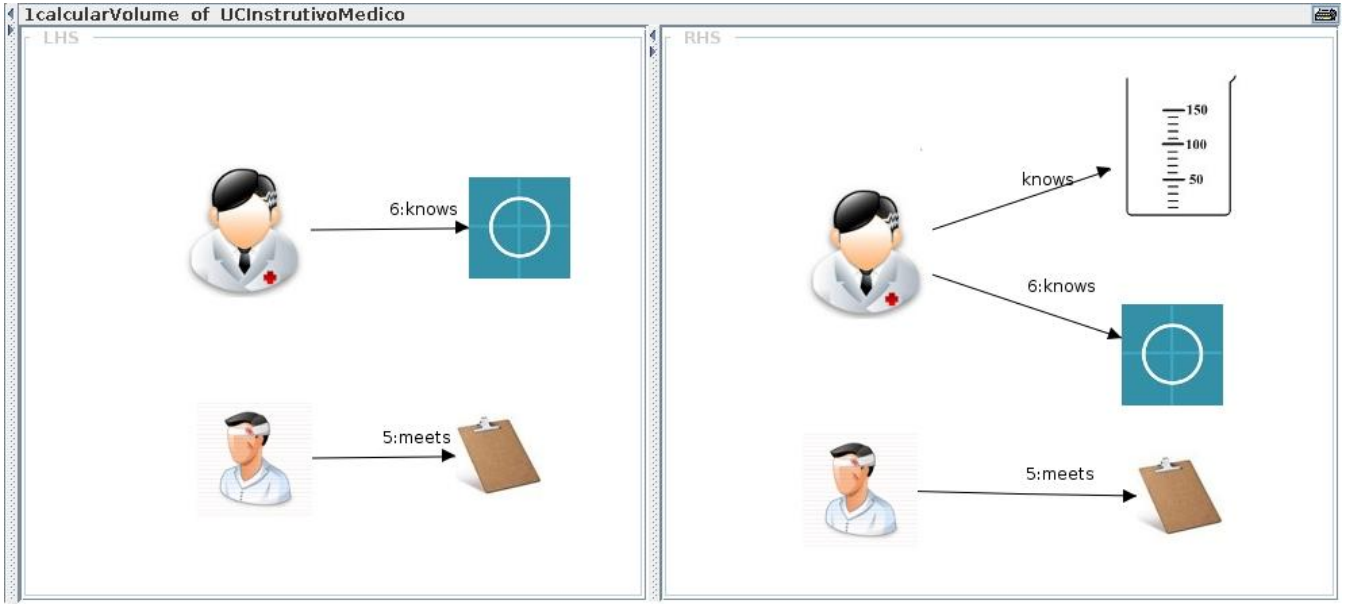


Step 5: Construction of rules

Negative Application Condition NAC

- Specify a forbidden context for rule application:
  - The LHS is copied
  - The forbidden elements are added to it.

Step 5: Construction of rules



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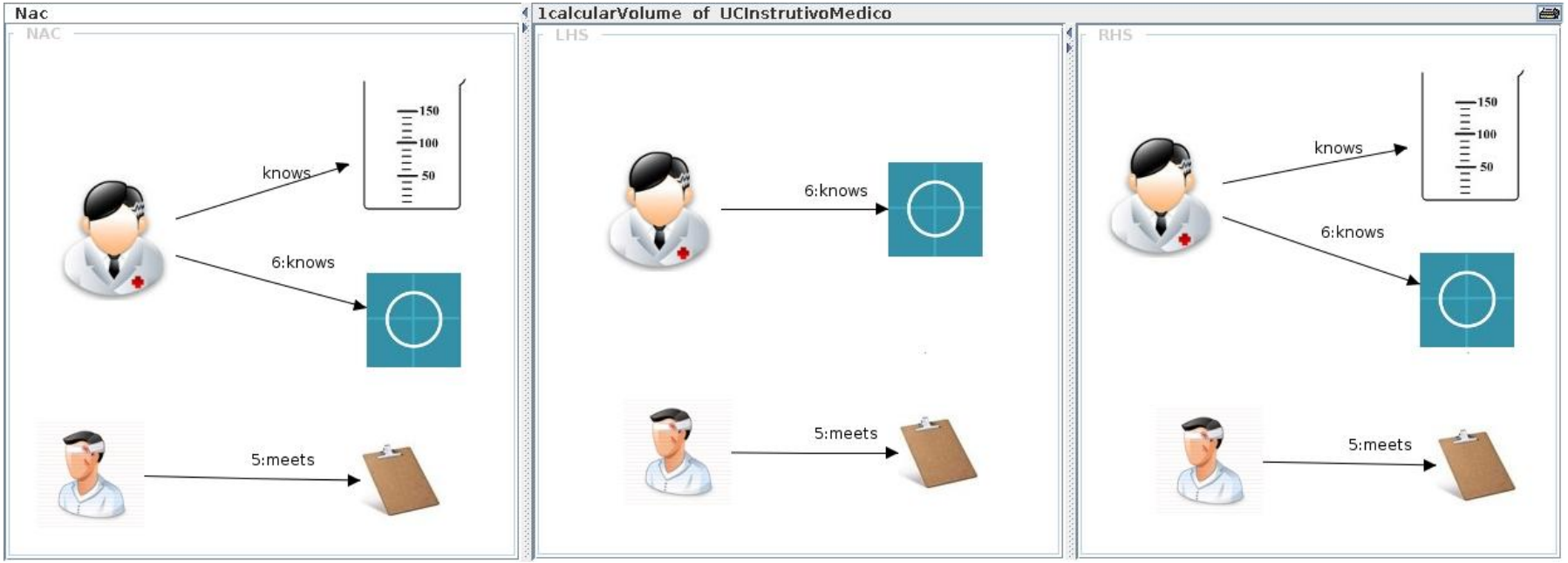

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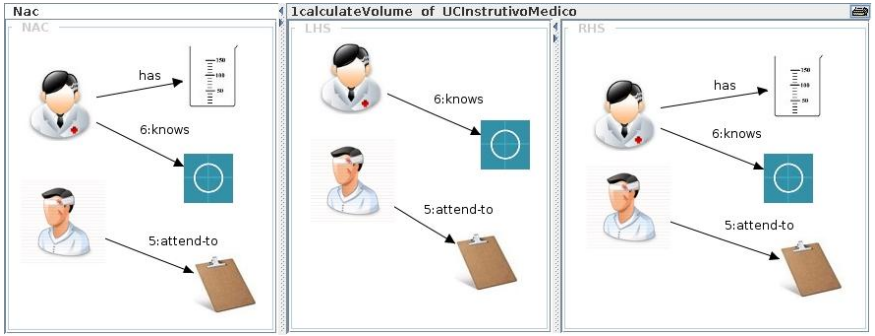

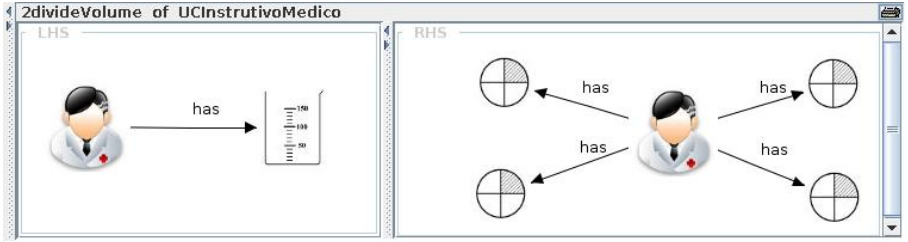

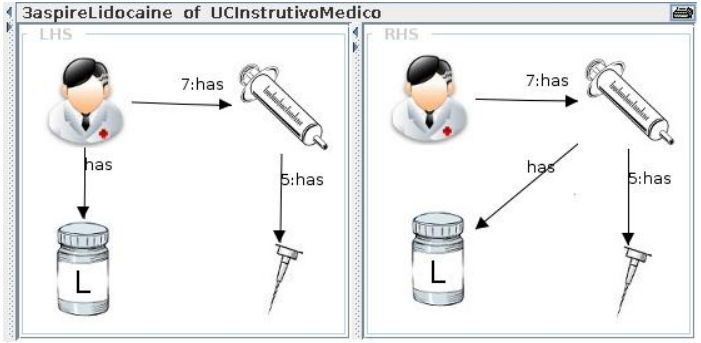

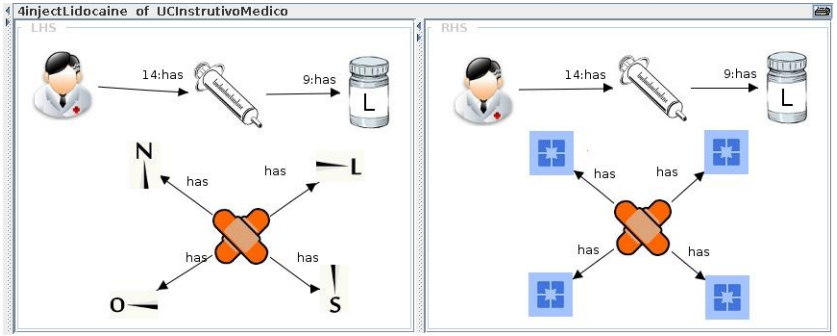

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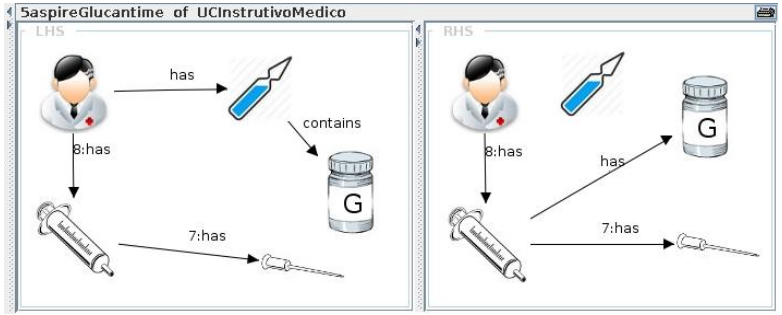

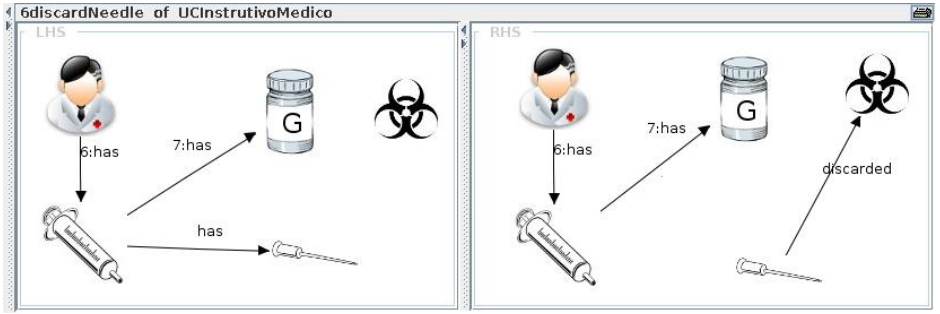

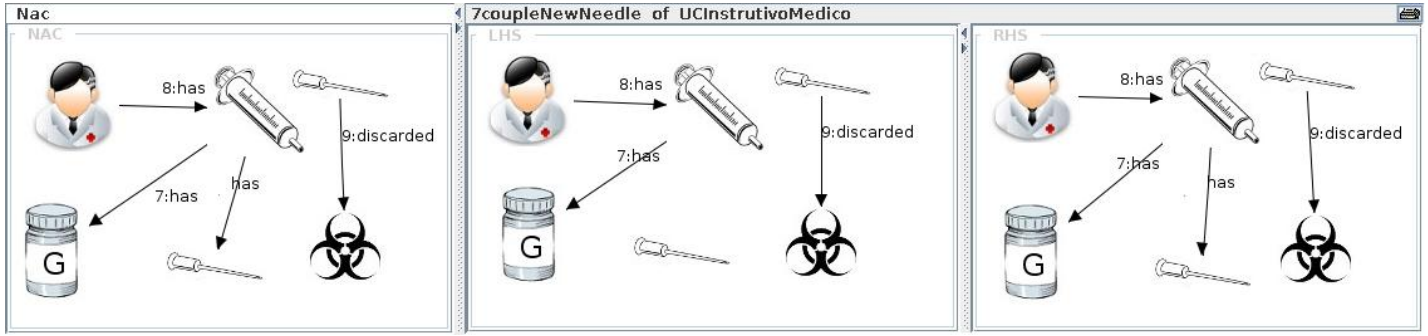

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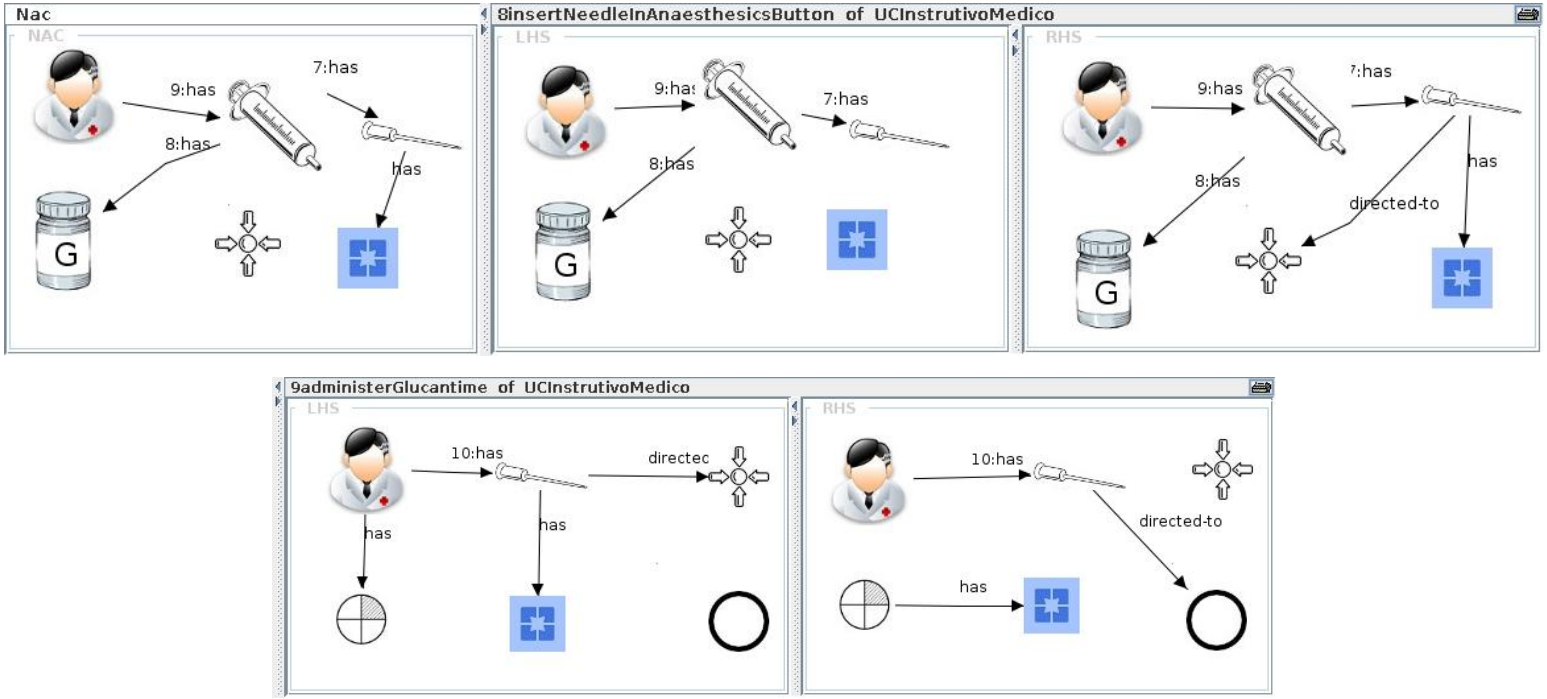

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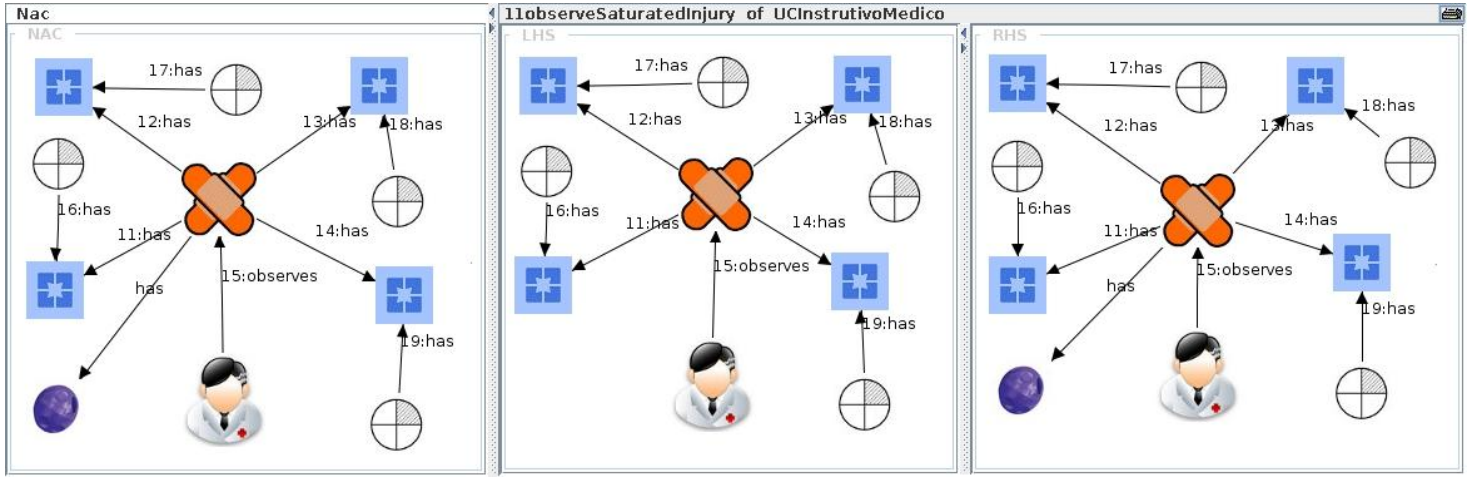

Step 6: Analysis

- Conflict Analysis
- Dependency Analysis
- Concurrent Rule

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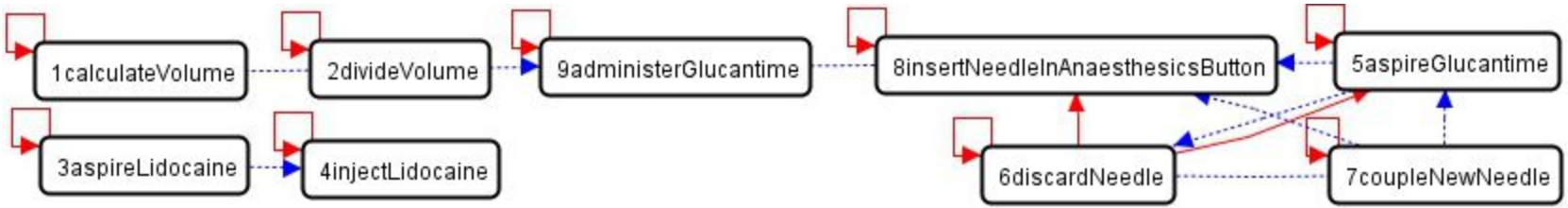

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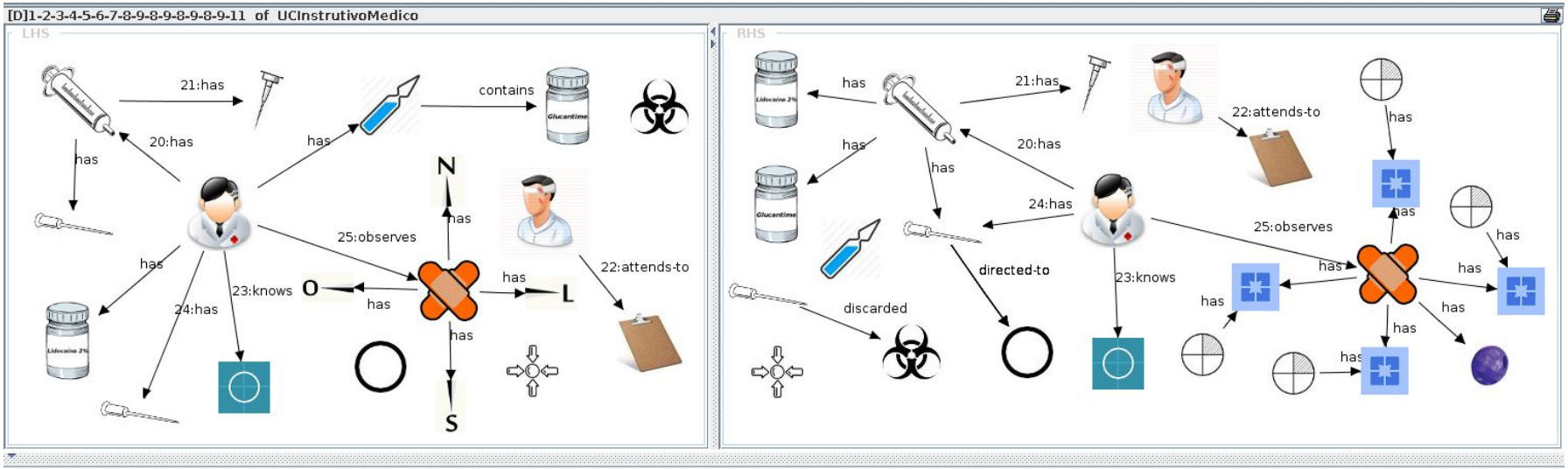

Step 6: Analysis

Open issue	Verification	Problem	Severity level	Possible action
OI.4	A concurrent rule (for any alternative path in the UC) cannot be built using all the rules in the corresponding RSs	Items generated by some rule and used by another one may be missing by omission or modeling error	Red	Review the rules
OI.5	Multiple concurrent rules are built for a single UC scenario	Multiple instances of one or more entities are possible, leading to different (possibly unexpected) ways of combining the rules of the UC	Red	Check dependencies between rules to find unexpected subpaths in the UC behavior
OI.6	UC pre-conditions are not a subgraph of the LHSs of the concurrent rules	Pre-conditions may include unnecessary items	Yellow	Remove unused pre-conditions from the UC text
OI.7	The LHS of a concurrent rule is not a subgraph of the UC pre-conditions	UC requires something that is not explicitly stated in the pre-conditions	Orange	Identify the RS in problematic concurrent rule and check whether all actions in this path were correctly modeled. If model is correct, check for missing pre-conditions.
OI.8	Post-conditions of	Some rule is not		Check the rules. If all rules

Results

- 13 open issues found:
  - 3 synonyms misuse
  - 4 weak pre-conditions
  - 2 weak post-conditions
  - 4 step rewrites

Results

Name	Intralesional Infiltration Technique
Preconditions	Pacient meets treatment criteria Lesion area is known *MD has:* *- two syringes with needles, one with insuline needle and one with a 25x0.7G needle (none of the syringes have been used)* *- a second unused 25x0.7G needle* *- a 5ml Glucantime ampola* *- Lidocaine 2%*
Postconditions	Pacient under medication *Lesion has 4 anaesthetic buttons*
Primary Actor(s)	Physician (MD)

Main Scenario	Step	Action
	1	MD calculates the total volume of medicine to be injected. ***MD estimates the total volume of Glucantime to be injected.***
	2	MD calculates 1/4 of medicine volume. ***MD calculates 1/4 of Glucantime volume.***
	3	MD puts Lidocaine 2% in a 5ml syringe with insuline needle.
	4	MD injects Lidocaine in the 4 lesion compass points until 4 3mm^2 anaesthetic buttons have formed. ***MD uses syringe with Lidocaine to inject Lidocaine in the 4 lesion compass points until 4 3mm^2 anaesthetic buttons have formed.***
	5	MD aspirates the contents from Glucantime ampoule (5 ml) using 5ml syringe and 25 x 0,7G needle ***MD aspirates the contents from Glucantime ampoule (5 ml) using 5ml syringe and 25 x 0,7G needle and discards the ampoule***
	6	MD discards the needle used for the aspiration of the medication ***MD discards the needle used in the Glucantime aspiration.***
	7	MD couples another 25 x 0,7G needle in the syringe with the medication ***MD couples another 25x0.7G needle in the syringe with Glucantime.***
	8	MD inserts the needle from an anaesthetic button towards the center of the lesion, tangent its with the bevel facing upwards ***MD inserts the 25x0.7G needle in the anaesthetic button towards the center of the lesion with the bevel facing upwards***
	9	MD retracts the needle towards the border of the lesion and at the same time injects 1/4 of the estimated volume of medication. ***MD retracts the 25x0.7G needle towards the border of the lesion and at the same time injects 1/4 of the estimated volume of Glucantime.***
	10	MD repeats steps 8 and 9 in the 3 remaining anaesthetic buttons.
	11	MD observs whether edema has formed
	12	MD ends the procedure.
		Use case ends successfully

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		Use case ends successfully

Final Remarks

- Systematic way to improvement specifications in Natural Language
- General Applicability
- Towards an Automatization

Acknowledgement

Dr. Gláucia Cota from Centro de Pesquisas René Rachou (Fiocruz-MG)

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Thank you!