

# VISPEC: A graphical tool for elicitation of MTL requirements

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# Safety Critical Systems

## Rehabilitation Robots

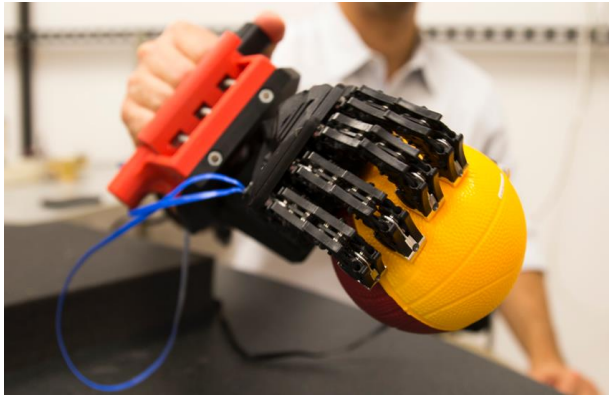


Image retrieved from:  
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## Medical Devices



Image retrieved from: [http://missionsurgical.com/wp-content/uploads/2014/07/000800\\_si\\_patient\\_cart\\_oblique\\_1000x896.jpg](http://missionsurgical.com/wp-content/uploads/2014/07/000800_si_patient_cart_oblique_1000x896.jpg)

## Autonomous Vehicles



Image retrieved from:  
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## Disaster R&R Robots



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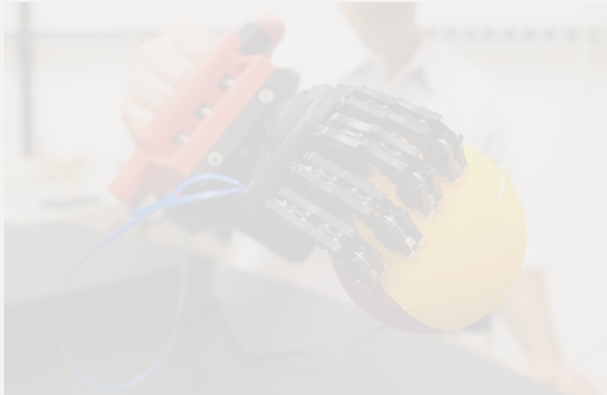


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## Safety is of Paramount Importance

## Autonomous Vehicles



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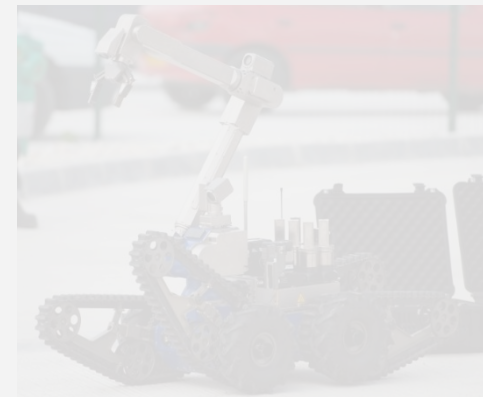


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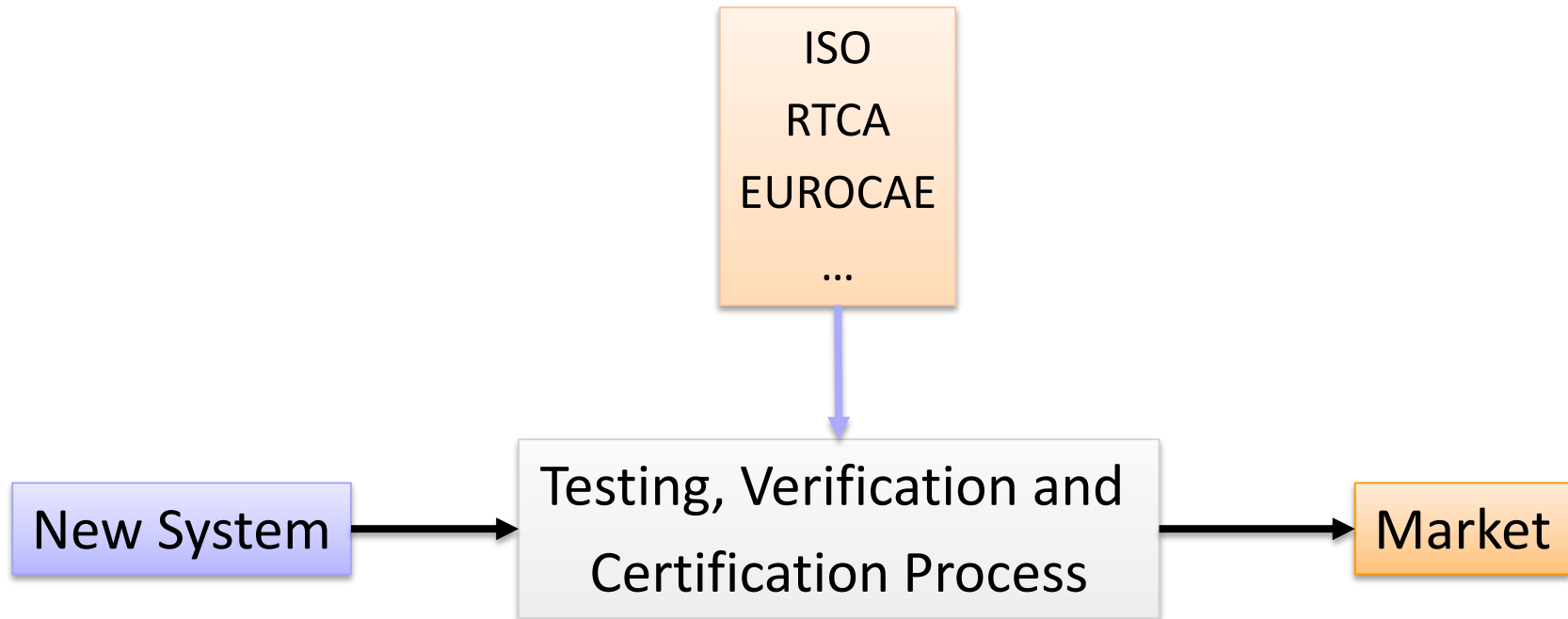
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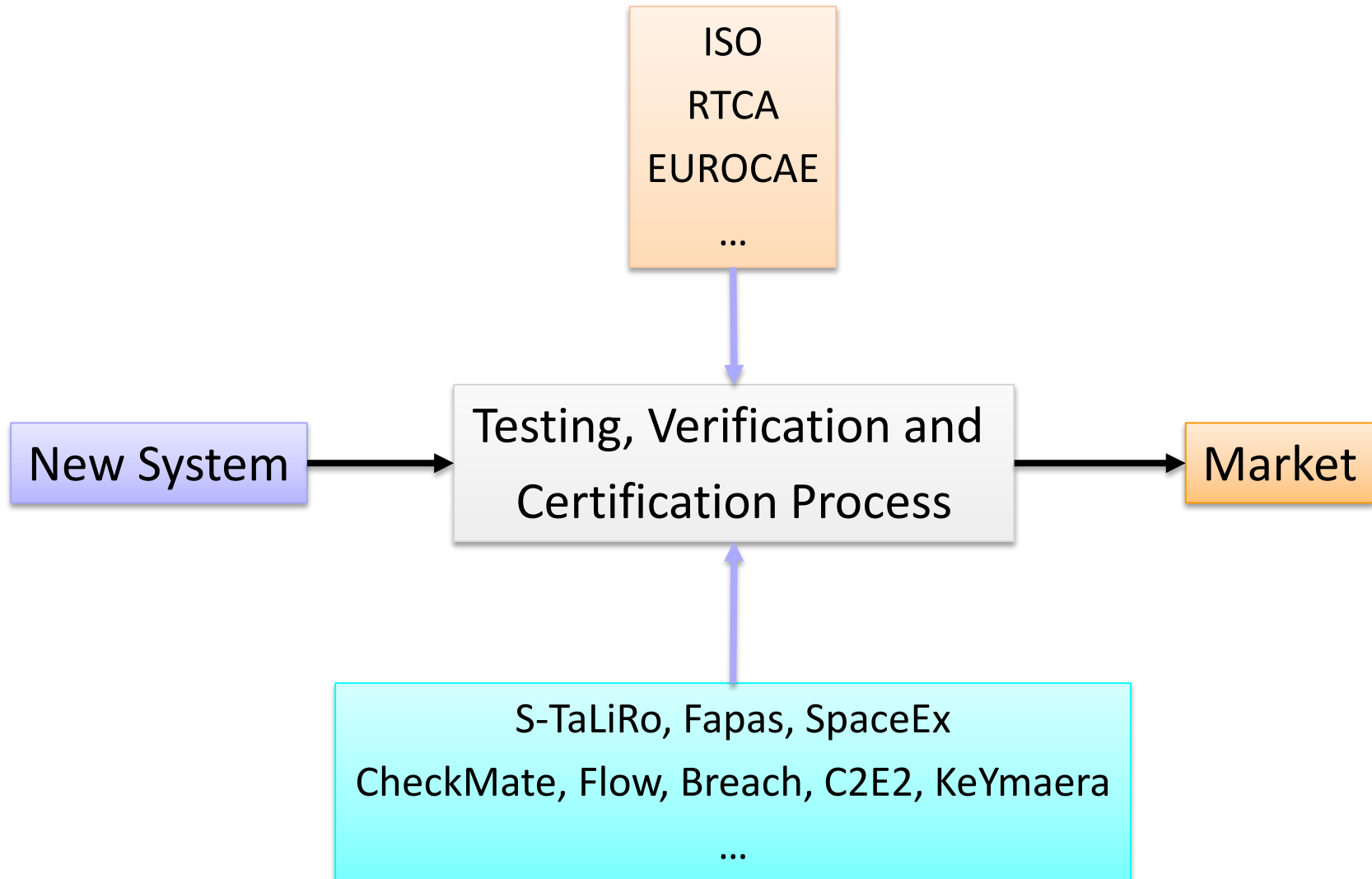
New System

Market

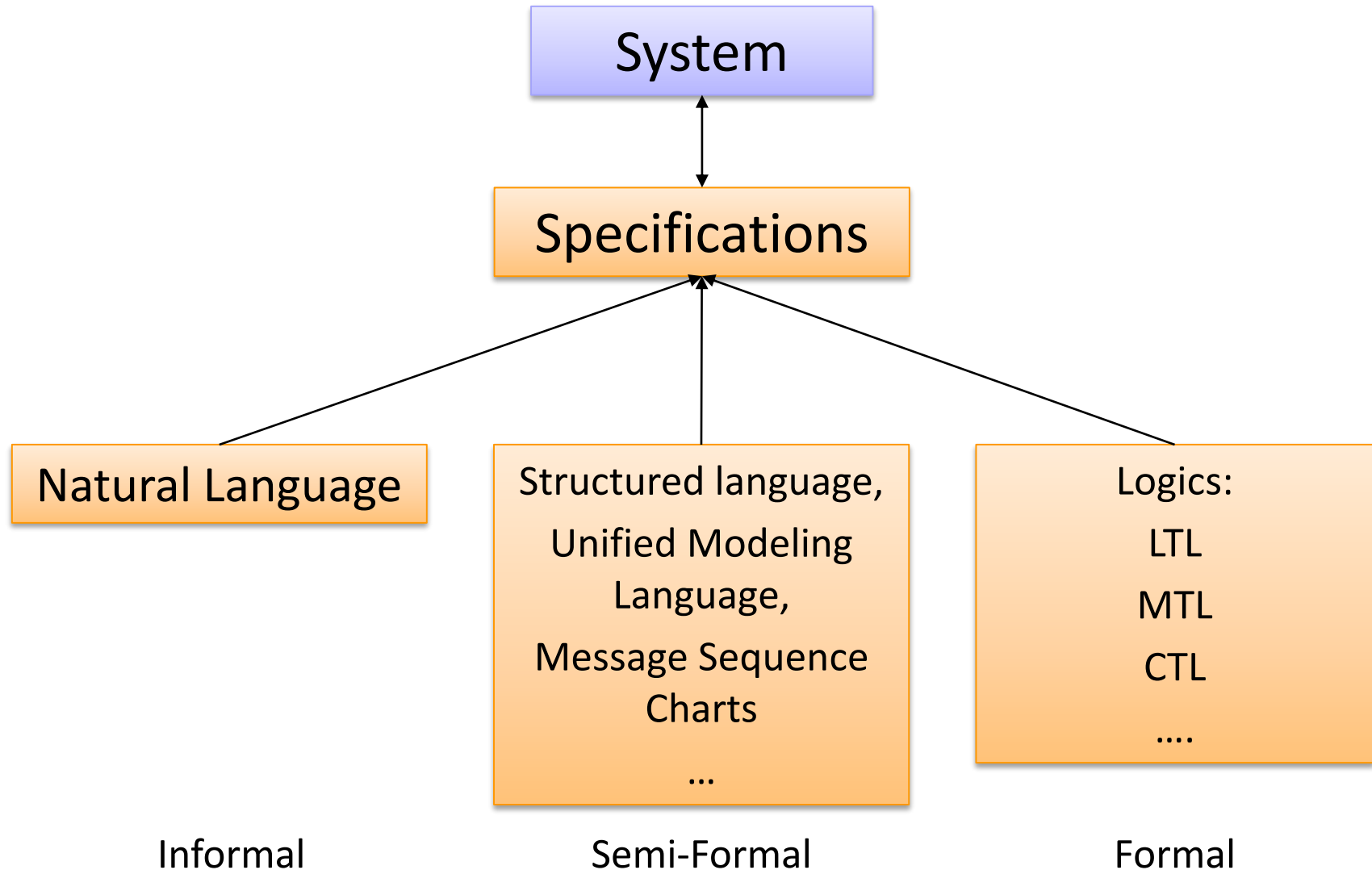
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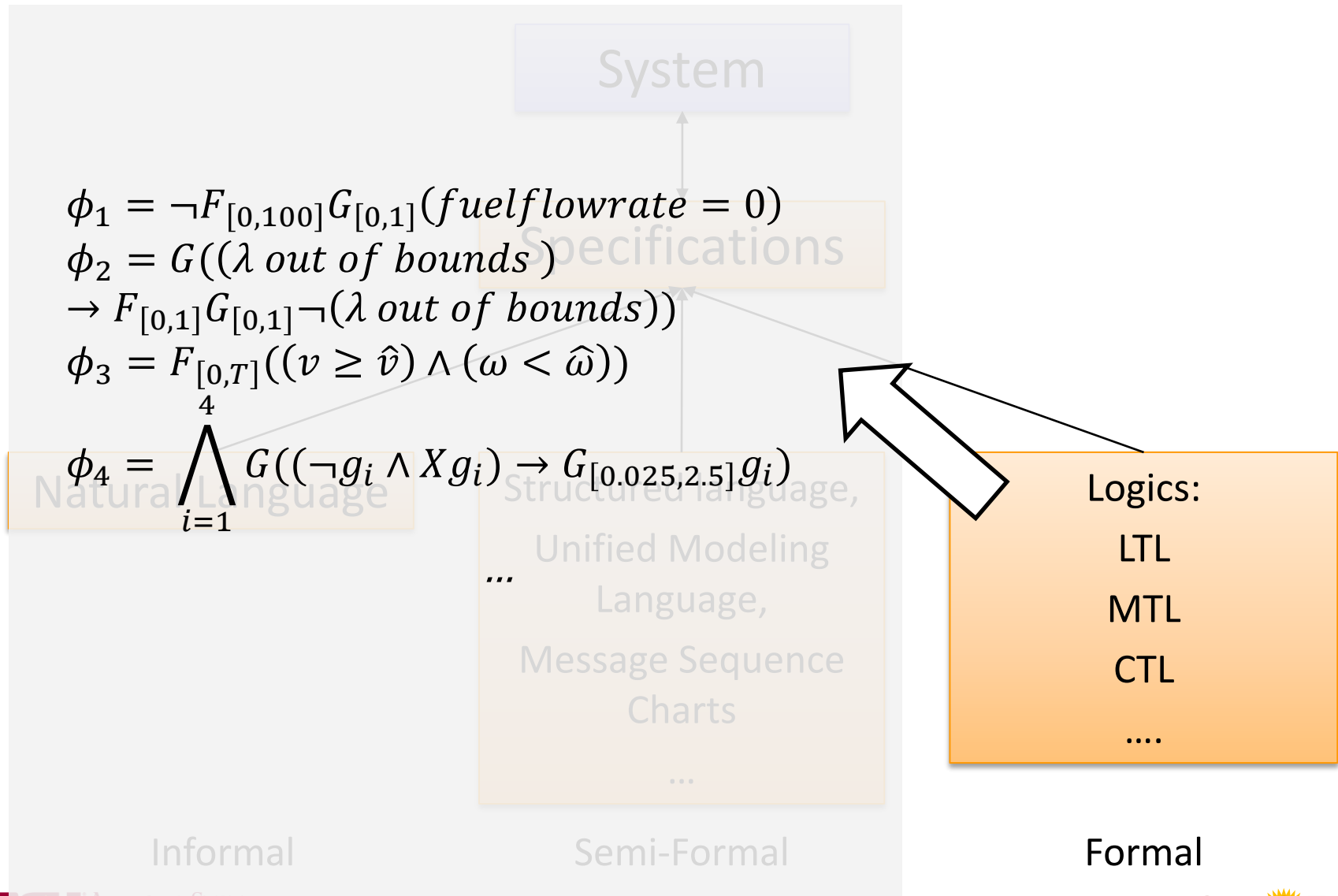


# Testing and verification

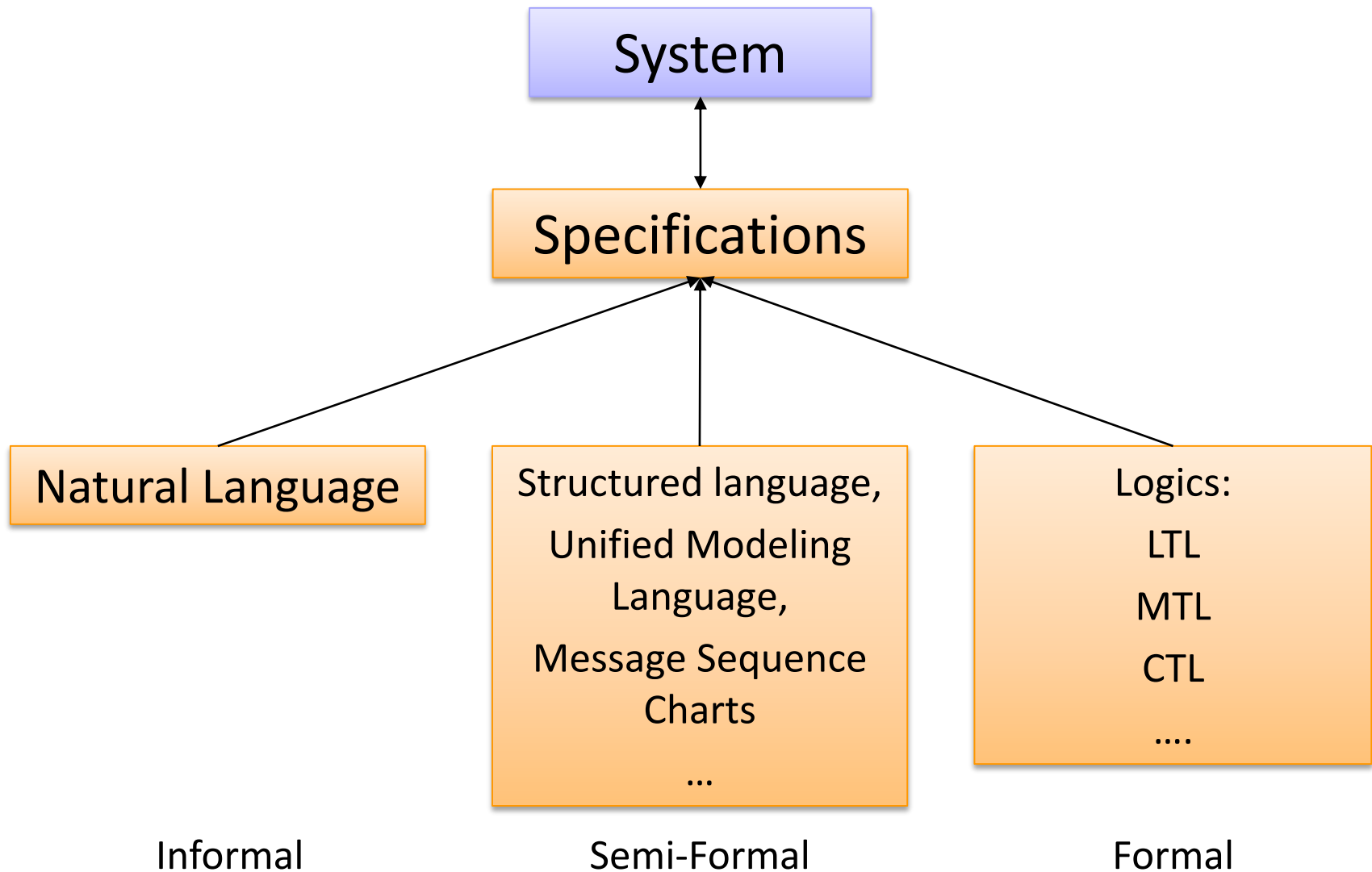




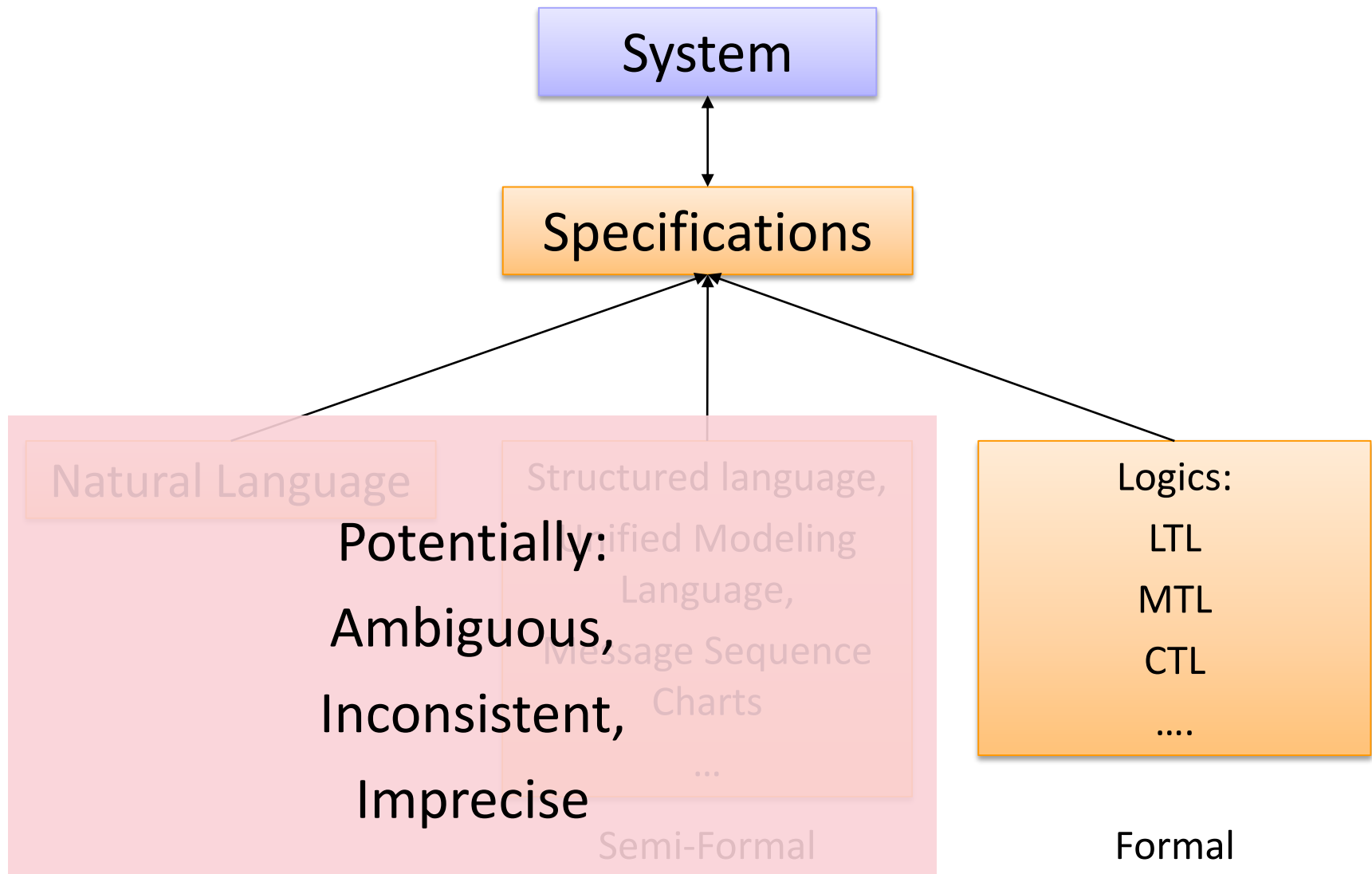
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- We conducted a usability study to evaluate the tool.
- We present applications of the tool for real-world robots

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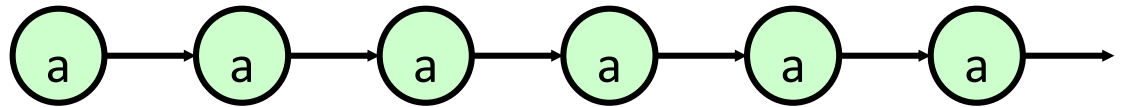
- Goals for the tool:
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  - Wide class of specifications
  - Translate the graphical formalism to a formal language (Metric Temporal Logic)
- Development challenges
  - Expressivity vs. ease of use

# Metric Temporal Logic: Semantic Intuition

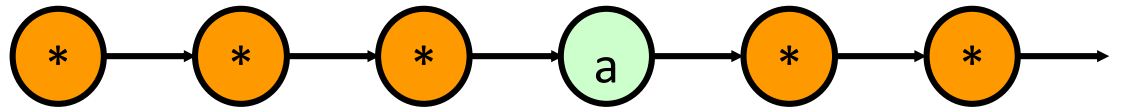
Syntax: Boolean connectives with temporal operators

$$\phi ::= \top \mid \neg\phi \mid \phi_1 \vee \phi_2 \mid G\phi \mid F\phi \mid \phi_1 U_I \phi_2$$

$G a$  - always a

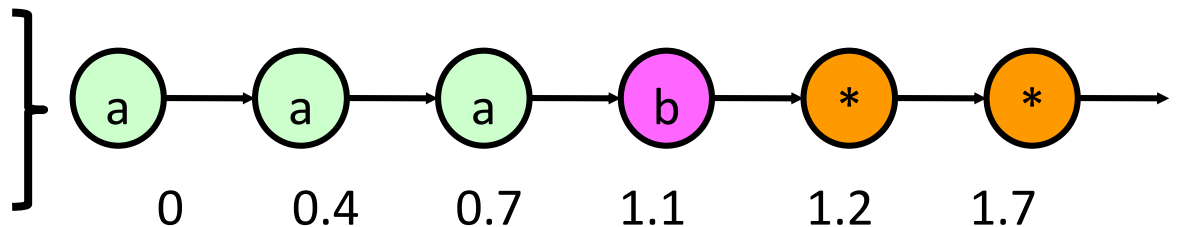


$F a$  - eventually a



$a U b$  - a until b

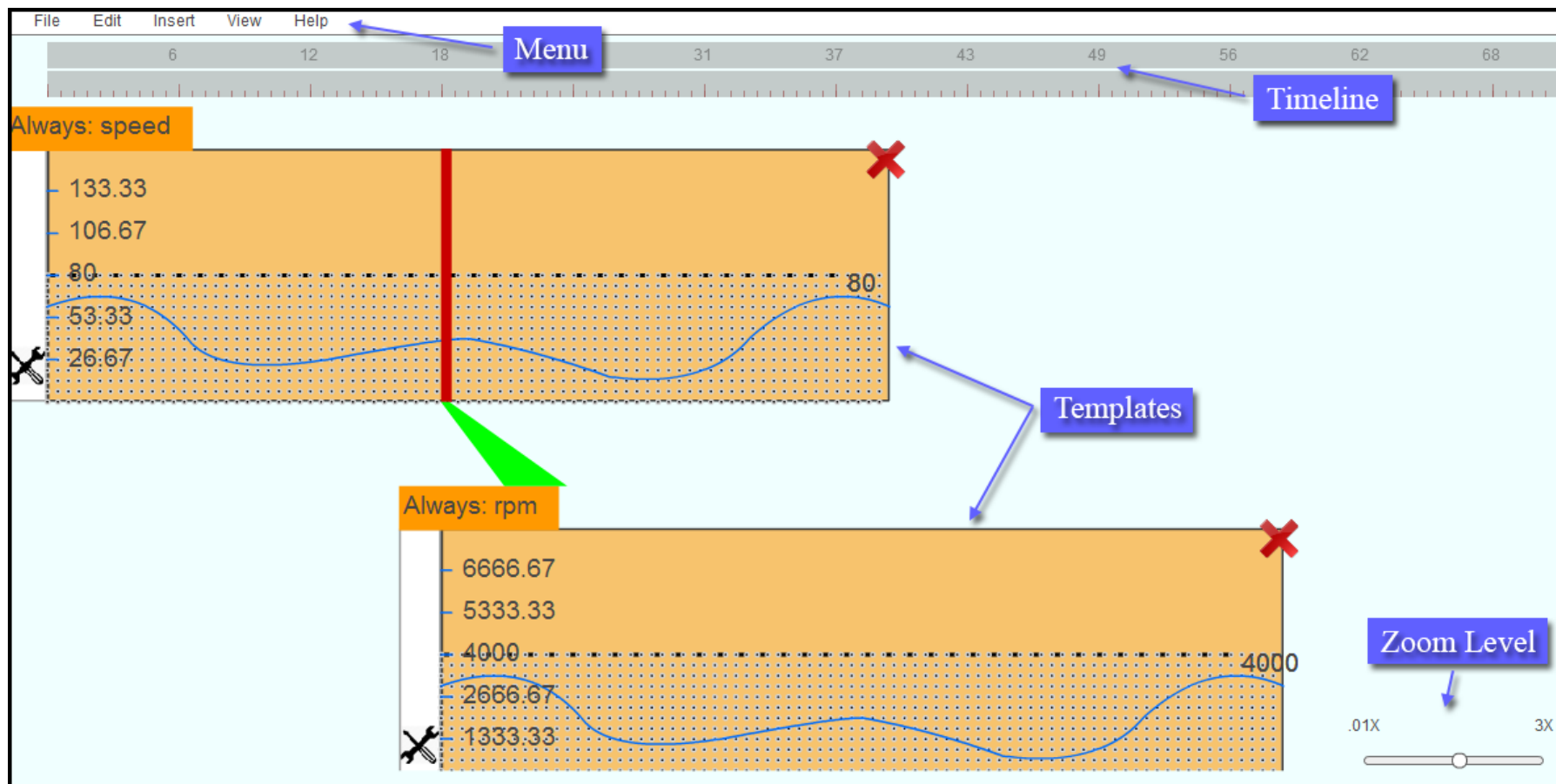
$a U_{[1,1.5]} b$  - a until b



time



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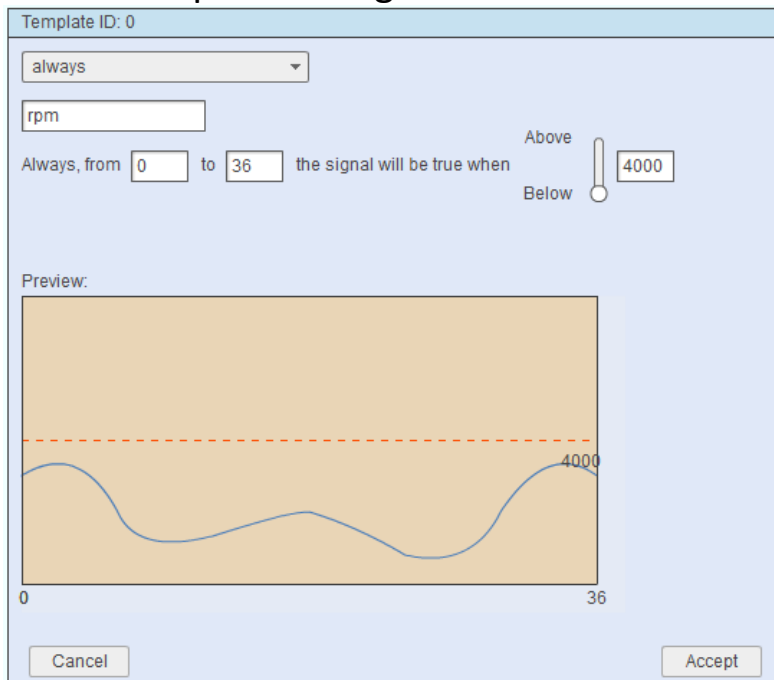
# ViSpec – Templates

Automotive example:

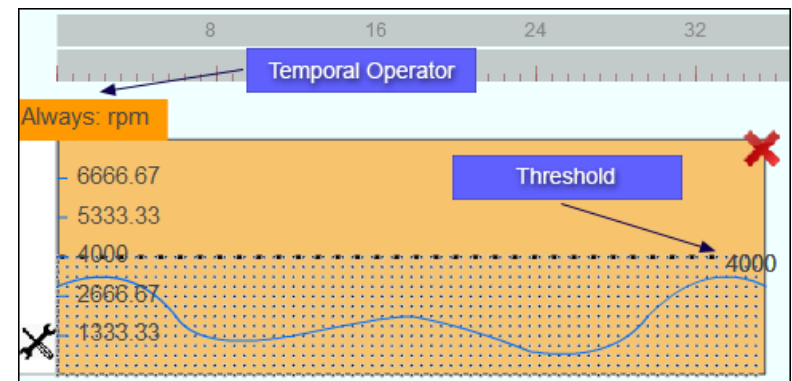
NL Requirement: In the next 36 seconds, engine speed should always be less than 4000

ViSpec:

Template configuration window



Resulting template



MTL:

$$\phi = G (rpm < 4000)$$

# ViSpec – Specification Classes

Safety:

$$G_I \phi$$

Implication:

$$\phi \rightarrow \psi$$

Reachability:

$$F_I \phi$$

Reactive Response:

$$N_I(\phi \rightarrow M_I \psi)$$

Stabilization:

$$F_I G_I \phi$$

Conjunction:

$$\phi \wedge \psi$$

Recurrence:

$$G_I F_I \phi$$

Non-strict Sequencing:

$$N_I(\phi \wedge M_I \psi)$$

$$M \in \{G, F\}, N \in \{G, F\}$$

# ViSpec – Usability Study

## Goal:

Evaluate whether ViSpec enables users to develop formal specifications

## Two Cohorts

### Cohort I: Non-expert users

No experience in working with requirements.

20 subjects from the student community at ASU

### Cohort II: Expert users

Experienced in working with requirements (not necessarily formal requirements)

10 subjects from the industry in the Phoenix area

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- How user friendly and easy-to-use ViSpec is



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## Example Task (Recurrence):

NL: At every point in time in the first 40 seconds, vehicle speed will go over 100 in the next 10 seconds.

MTL:  $G_{[0,40]}F_{[0,10]}(\text{speed} > 100)$

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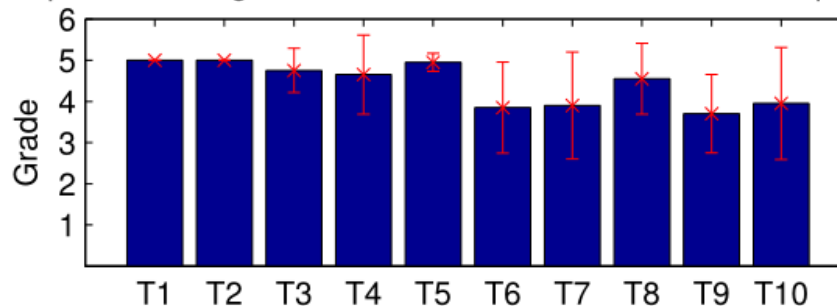
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  - How accurate the meaning of the natural language specification is captured.
  - Whether the inaccuracies in the user submitted formula can be easily debugged and corrected in the testing and verification process.

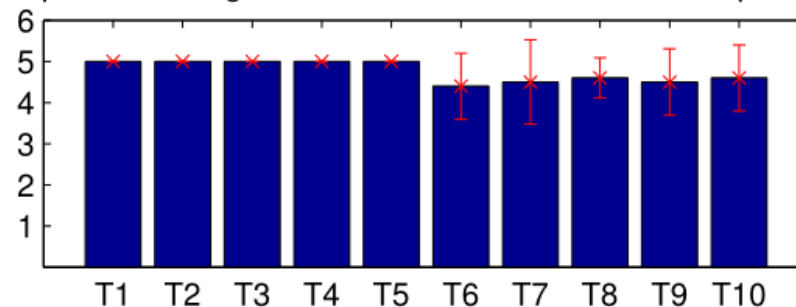
# ViSpec – Results

Average grade per task:

Bar plot of mean grade and std. dev. over tasks for non-expert users



Bar plot of mean grade and std. dev. over tasks for expert users



We test the hypothesis that:

Non-expert and Expert users can define formal requirements accurately using the Visual Specification Tool.

# ViSpec – Improvements

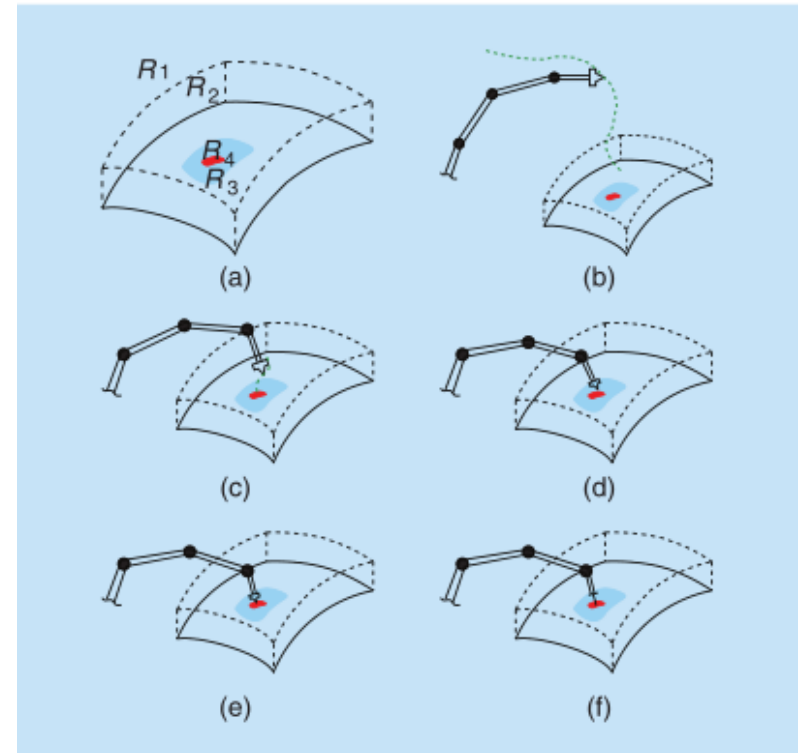
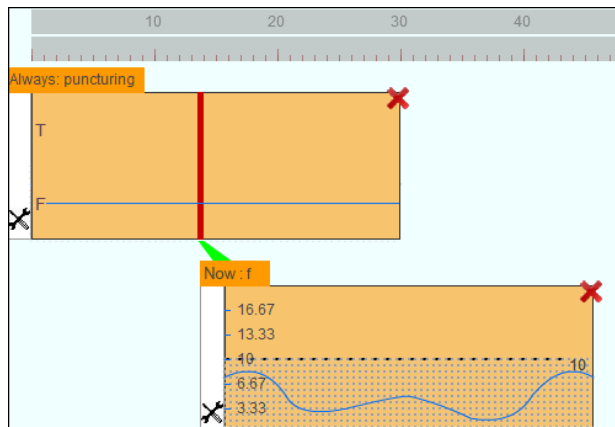
#	Improve...	Prime Indicators
1	the process of creating child templates	Misclicks. User feedback
2	the tutorial by placing more emphasis on the difference between implication and conjunction when connecting the templates	User generated specifications, User feedback, Task accuracy grade
3	the visual representation of grouped templates	User generated specifications, User feedback, Task accuracy grade
4	the Template setup assistant	User Feedback, User thought map



# ViSpec – Application

## Serial link manipulator for robotic surgery

- ◆ Puncturing action
- ◆ NL: The force applied to the patient by the end effector is always less than a given threshold, except for the puncturing subtask.
- ◆ MTL:  
 $G_{[0,30]}(\neg puncturing \rightarrow f \leq f_{max})$
- ◆ ViSpec:



Muradore, Riccardo, et al. "Robotic surgery." *Robotics & Automation Magazine*, IEEE 18.3 (2011): 24-32.

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- We presented a graphical formalism and tool that enables users to easily develop formal specifications.
- The ViSpec tool enables users who have little to no mathematical training in formal logics to develop formal specifications, as indicated by a usability study.
- The tool was utilized to formalize specifications for robotic applications.

# Future Work

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- Expand the usability study to experts in formal languages.
  - We have some preliminary results
  - We need more data! Please participate through

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*Metric Interval Temporal Logic Specification Elicitation and Debugging,  
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- Expand the set of specifications supported by the graphical formalism

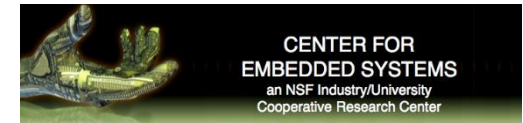
# Acknowledgements



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## Thank you!

## Survey Link:

<http://goo.gl/forms/MJtLAa6nNe>