

Analysing normative contracts

*On the semantic gap between natural
and formal languages*

John J. Camilleri

Licentiate seminar 2015-10-29

CHALMERS



UNIVERSITY OF GOTHENBURG

<http://www.biggestlie.com/>



Site Policy / GitHub Privacy Policy	
<h2>GitHub Privacy Policy</h2>	
<h3>General Information</h3> <p>We collect the e-mail addresses of those who communicate with us via e-mail, aggregate information on what pages consumers access or visit, and information volunteered by the consumer (such as survey information and/or site registrations). The information we collect is used to improve the content of our Web pages and the quality of our service, and is not shared with or sold to other organizations for commercial purposes, except to provide products or services you're requested, when we have your permission, or under the following circumstances:</p> <p>It is necessary to share information in order to investigate, prevent, or take action regarding illegal activities, suspected fraud, situations involving potential threats to the physical safety of any person, violations of Terms of Service, or as otherwise required by law.</p> <p>We transfer information about you if GitHub is acquired by or merged with another company. In this event, GitHub will notify you before information about you is transferred and becomes subject to a different privacy policy.</p>	
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<h3>Cookies</h3> <p>A cookie is a small amount of data, which often includes an anonymous unique identifier, that is sent to your browser from a web site's computers and stored on your computer's hard drive.</p> <p>Cookies are required to use the GitHub service.</p> <p>We use cookies to record current session information, but do not use permanent cookies. You are required to re-login to your GitHub account after a period of time has elapsed to protect you against others accidentally accessing your account contents.</p>	
<h3>Data Storage</h3> <p>GitHub uses third-party vendors and hosting partners to provide the necessary hardware, software, networking, storage, and related technical infrastructure to run GitHub. Although GitHub owns the code, infrastructure and all rights to the GitHub application, you retain all rights to your data.</p>	
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<p>relevant to you and your of it. After all, GitHub's code is not a vulnerability.</p> <p>GitHub is for information about our to submit a vulnerability.</p> <p>GitHub is a center technicians and data center access data center location real protection against!</p> <p>GitHub has low profile independent firm.</p> <p>GitHub, patched OS cases to help block.</p> <p>GitHub mitigation services store.</p> <p>GitHub are regularly audited by ISO 9001 T1 Type 2.</p> <p>GitHub used for auditing purposes cases for all services.</p> <p>GitHub general procedures.</p> <p>GitHub or specialists at GitHub to close up to date eliminating every a wide range of and eliminating attacks to the.</p> <p>GitHub is always transmitted and is served over HTTPS, of private data to share over HTTPS using your GitHub.</p> <p>GitHub and pull can not be used if users are virtual (meaning access), open source and access.</p> <p>GitHub an identical copy ready and</p>	
<p>yes), or any services of to be bound by the of Services), IF YOU ENT ON BEHALF OF A YOU REPRESENT G BIND SUCH ENTITY, TO ACCESS OUR NOT TO THESE TERMS THE TERMS "YOU" OR ITY, ITS AFFILIATES IF YOU DO NOT HAVE TO AGREE WITH US MUST NOT ACCEPT THE SERVICES.</p> <p>GitHub Service in your are special terms that I, I, below, for more</p> <p>GitHub Terms, we will notify our site before the a that augment or the release of new tools terms of Service. such changes shall. You can review the price at any time at.</p> <p>GitHub the termination of act conduct and Content we that GitHub cannot be Service and you forfeits. You agree to</p> <p>GitHub an email address, and order to complete the</p> <p>GitHub a single login session. You may create it as your plan allows.</p> <p>GitHub the security of your not and will not be liable liable to comply with this</p> <p>GitHub posted and activity</p>	



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ToS;DR – Terms of Service; Didn't Read

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Please note that if you are accessing any GitHub service in your capacity as a government entity, there are special terms that may apply to you. Please see Section G.17, below, for more details.

If GitHub makes material changes to these Terms, we will notify you by email or by posting a notice on our site before the changes are effective. Any new features that augment or enhance the current Service, including the release of new tools and resources, shall be subject to the Terms of Service.

Continued use of the Service after any such changes shall constitute your consent to such changes. You can review the most current version of the Terms of Service at any time at: <https://github.com/terms>

Violation of any of the terms below will result in the termination of your Account. While GitHub prohibits such conduct and Content on the Service, you understand and agree that GitHub cannot be responsible for the Content posted on the Service and you nonetheless may be exposed to such materials. You agree to use the Service at your own risk.

A. Account Terms

1. You must be 13 years or older to use this Service.
2. You must be a human. Accounts registered by "bots" or other automated methods are not permitted.
3. You must provide your name, a valid email address, and other information requested in order to complete the sign-up process.
4. Your login may only be used by one person - a single login shared by multiple people is not permitted. You may create separate logins for as many people as your plan allows.
5. You are responsible for maintaining the security of your account and password. GitHub cannot and will not be liable for any loss or damage from your failure to comply with this security obligation.
6. You are responsible for all Content posted and activity that occurs under your account (even when Content is posted by others who have accounts under your account).
7. One person or legal entity may not maintain more than one free account.
8. You may not use the Service for any illegal or unauthorized purpose. You must not, in the use of the Service, violate any laws in your jurisdiction (including but not limited to copyright or trademark laws).

B. API Terms

Customers may access their GitHub account data via an API (Application Program Interface). Any use of the API, including use of the API through a third-party product that accesses GitHub, is bound by these Terms of Service plus the following specific terms:

1. You expressly understand and agree that GitHub shall not be liable for any direct, indirect, incidental, special,



GitHub

Class B



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Changes can happen any time, sometimes without notice



You shall defend and indemnify GitHub



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Expected use

Does this website's privacy policy disclose whether data it collects about you is used in ways other than you would reasonably expect given the site's service?

Yes, without opt-out. Or undisclosed.

Yes, with choice to opt-out.

No.

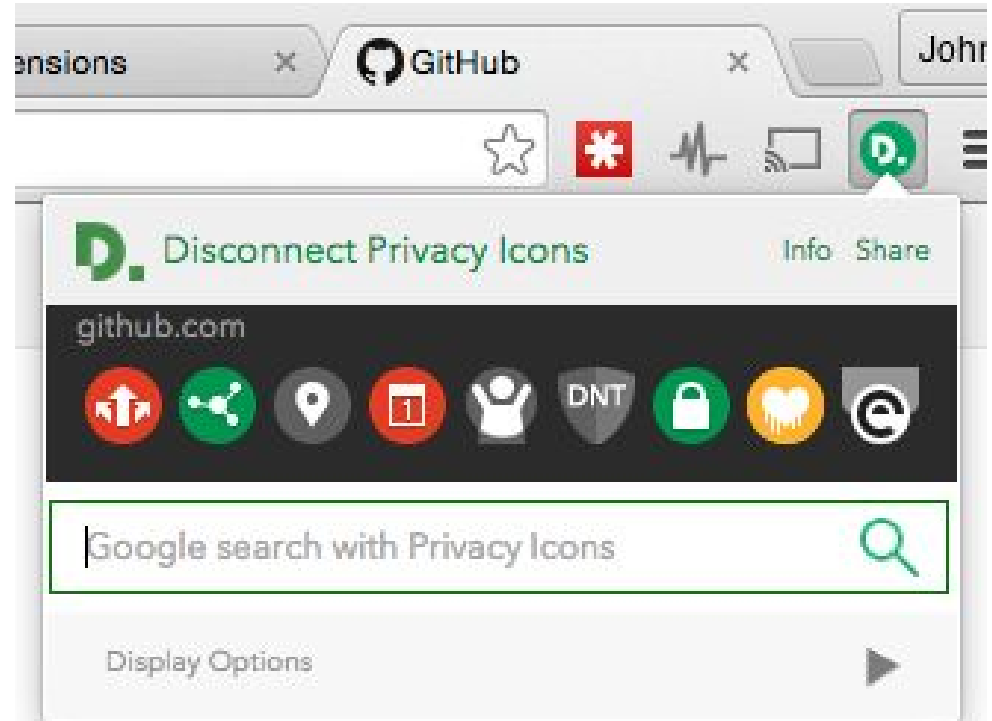
Info unavailable.



Expected collection



Precise location



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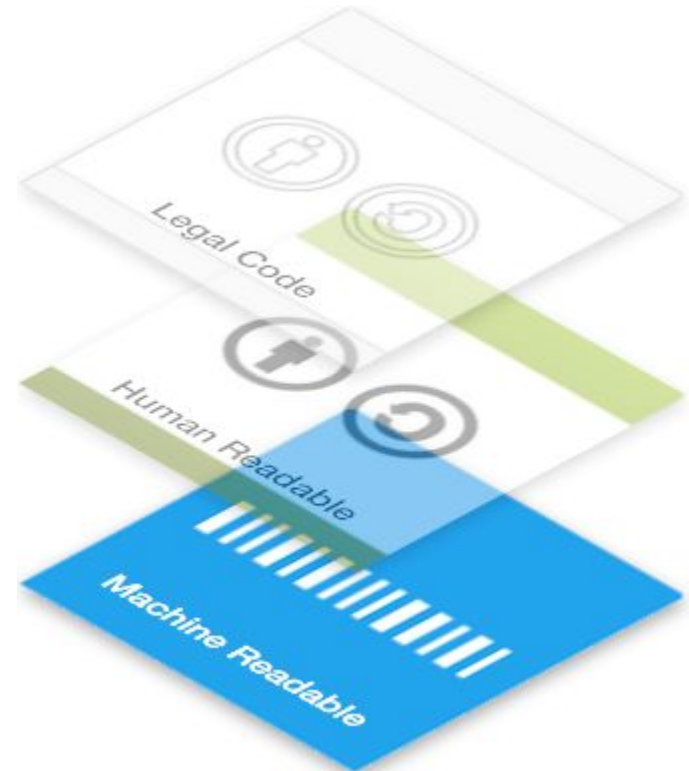


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Machine Readable

```
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  xmlns:owl="http://www.w3.org/2002/07/owl#"
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  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
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  </rdf:Description>
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  </rdf:Property>
  <rdf:Description rdf:about="http://web.resource.org/cc/permits">
    <owl:equivalentProperty rdf:resource="http://creativecommons.org/ns#permits"/>
  </rdf:Description>
  ...
</rdf:RDF>
```



Automated analysis

Classification

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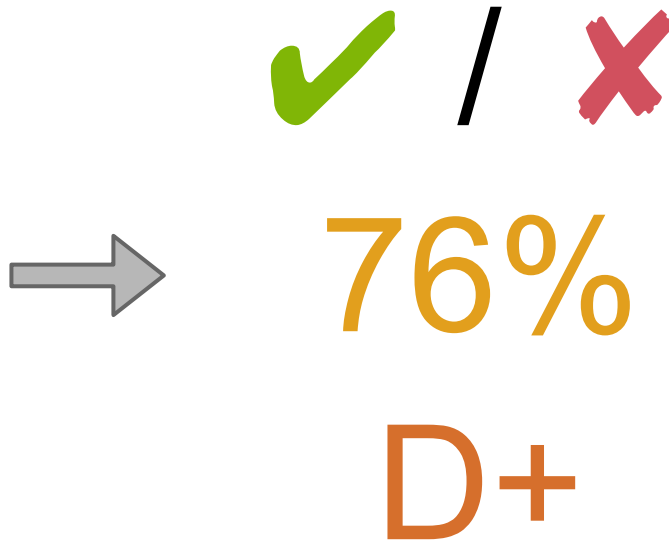
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- 4 Your login may only be used by one person - a single login shared by multiple people is not permitted. You may create separate logins for as many people as you plan allow.
- 5 You are responsible for maintaining the security of your account and password. GitHub cannot and will not be liable for any loss or damage from your failure to comply with this security obligation.
- 6 You are responsible for all Content posted and activity that occurs under your account (even when Content is posted by others who have accounts under your account).
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File system and backups

Every piece of hardware we use has an identical copy ready and waiting for an immediate hot-swap in case of hardware or software failure. Every line of code we store is saved on a minimum of three different servers, including an off-site backup. We do not retroactively remove repositories from backups when deleted by the user, as we may need to restore the repository for the user if it was removed accidentally.

We do not encrypt repositories on disk because it would not be any more secure. The website and git back-end would need to decrypt the repositories on demand, slowing down response times. Any user with shell access to the file system would have access to the encryption routine, thus negating any security it provides. Therefore, we focus on making our machines and network as secure as possible.

Site Policy / GitHub Terms of Service

GitHub Terms of Service

By using the GitHub.com web site ("Service"), or any services of GitHub, Inc. ("GHN&P"), you are agreeing to be bound by the following terms and conditions ("Terms of Service"). IF YOU ARE ENTERING INTO THIS AGREEMENT ON BEHALF OF A COMPANY OR OTHER LEGAL ENTITY, YOU REPRESENT THAT YOU HAVE THE AUTHORITY TO BIND SUCH ENTITY, ITS AFFILIATES AND ALL USERS WHO ACCESS OUR SERVICES THROUGH YOUR ACCOUNT TO THESE TERMS AND CONDITIONS. IN WHICH CASE THE TERM "YOU" OR "YOUR" SHALL REFER TO SUCH ENTITY, ITS AFFILIATES AND USERS ASSOCIATED WITH IT. IF YOU DO NOT HAVE SUCH AUTHORITY, OR IF YOU DO NOT AGREE WITH THESE TERMS AND CONDITIONS, YOU MUST NOT ACCEPT THIS AGREEMENT AND MAY NOT USE THE SERVICES.

Please note that if you are accessing any GitHub service in your capacity as a government entity, there are special terms that may apply to you. Please see Section G.17, below, for more details.

If GitHub makes material changes to these Terms, we will notify you by email or by posting a notice on our site before the changes are effective. Any new features that augment or enhance the current Service, including the release of new tools and resources, shall be subject to the Terms of Service.

Continued use of the Service after any such changes shall constitute your consent to such changes. You can review the most current version of the Terms of Service at any time at: <https://github.com/terms>

Violation of any of the terms below will result in the termination of your Account. While GitHub prohibits such conduct and Content on the Service, you understand and agree that GitHub cannot be responsible for the Content posted on the Service and you nevertheless may be exposed to such materials. You agree to use the Service at your own risk.

A. Account Terms

1. You must be 13 years or older to use this Service.
2. You must be a human. Accounts registered by "bots" or other automated methods are not permitted.
3. You must provide your name, a valid email address, and any other information requested in order to complete the sign-up process.
4. Your login may only be used by one person - a single login shared by multiple people is not permitted. You may create separate logins for as many people as you plan allow.
5. You are responsible for maintaining the security of your account and password. GitHub cannot and will not be liable for any loss or damage from your failure to comply with this security obligation.
6. You are responsible for all Content posted and activity that occurs under your account (even when Content is posted by others who have accounts under your account).
7. One person or legal entity may not maintain more than one free account.
8. You may not use the Service for any illegal or unauthorized purpose. You must not, in the use of the Service, violate any laws in your jurisdiction (including but not limited to copyright or trademark laws).

B. API Terms

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1. You expressly understand and agree that GitHub shall not be liable for any direct, indirect, incidental, special,

- You don't grant any copyright license to GitHub
- Changes can happen any time, sometimes without notice
- You shall defend and indemnify GitHub
- Your personal information is used for limited purposes
- Your account can be suspended and your data deleted any time for any reason



Comparison

A. Account Terms

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Compatibility

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Cookies

- › A cookie is a small amount of data, which often includes an anonymous unique identifier, that is sent to your browser from a web site's computers and stored on your computer's hard drive.
- › Cookies are required to use the GitHub service.
- › We use cookies to record current session information, but do not use permanent cookies. You are required to re-login to your GitHub account after a certain period of time has elapsed to protect you against others accidentally accessing your account contents.

Data Storage

GitHub uses third-party vendors and hosting partners to provide the necessary hardware, software, networking, storage, and related technology required to run GitHub. Although GitHub owns the code, databases, and all rights to the GitHub application, you retain all rights to your data.

Disclosure

GitHub may disclose personally identifiable information under special circumstances, such as to comply with subpoenas or when your actions violate the [Terms of Service](#).

EU and Swiss Safe Harbor

If you choose to provide GitHub with your information, you consent to the transfer and storage of that information on our servers located in the United States.

GitHub adheres to the US-EU and US-Swiss Safe Harbor Privacy Principles of Notice, Choice, Onward Transfer, Security, Data Integrity, Access and Enforcement, and is registered with the U.S. Department of Commerce's Safe Harbor Program <http://www.export.gov/safeharbor/>.

For European Union and Swiss residents, any questions or concerns regarding the use or disclosure of your information should be directed to GitHub by sending an email to privacy@github.com. We will investigate and attempt to resolve complaints and disputes regarding use and disclosure of your information in accordance with this Privacy Policy. For complaints that cannot be resolved, and consistent with the Safe Harbor Enforcement Principle, we have committed to cooperate with data protection authorities located within Switzerland or the European Union (or their authorized representatives).

Translation

A. Account Terms

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English



A. Términos Cuenta

- 1 Usted debe tener 13 años o más para poder utilizar este servicio.
- 2 Usted debe ser un ser humano. No se permiten Cuentas registradas por "bots" u otros métodos automatizados.
- 3 Usted debe proporcionar su nombre, una dirección de correo electrónico válida, y cualquier otra información solicitada con el fin de completar el proceso de registro.
- 4 Su nombre de usuario sólo puede ser utilizado por una sola persona - no se permite un solo inicio de sesión compartido por varias personas. Puede crear accesos separados para tantas personas como su plan permite.
- 5 Usted es responsable de mantener la seguridad de su cuenta y contraseña. GitHub no puede y no será responsable por cualquier pérdida o daño de su incumplimiento de esta obligación de seguridad.
- 6 Usted es responsable de todo el contenido publicado y la actividad que ocurra bajo su cuenta (incluso cuando está contenido publicado por otros que tienen cuentas en su cuenta).
- 7 Una persona física o jurídica no pueden mantener más de una cuenta gratuita.
- 8 Usted no puede usar el Servicio para ningún propósito ilegal o no autorizado. No debe, en el uso del Servicio, violar cualquier ley en su jurisdicción (incluyendo pero no limitado a las leyes de derechos de autor o de marca).

español

Simulation

A. Account Terms

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sequence of events

2015-10-20

13:45 Register account

14:00 Create repository

2015-10-22

11:05 Upgrade to pro

2015-10-29

19:25 Request refund

A. Account Terms

- 1 You must be 13 years or older to use this Service.
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B. API Terms

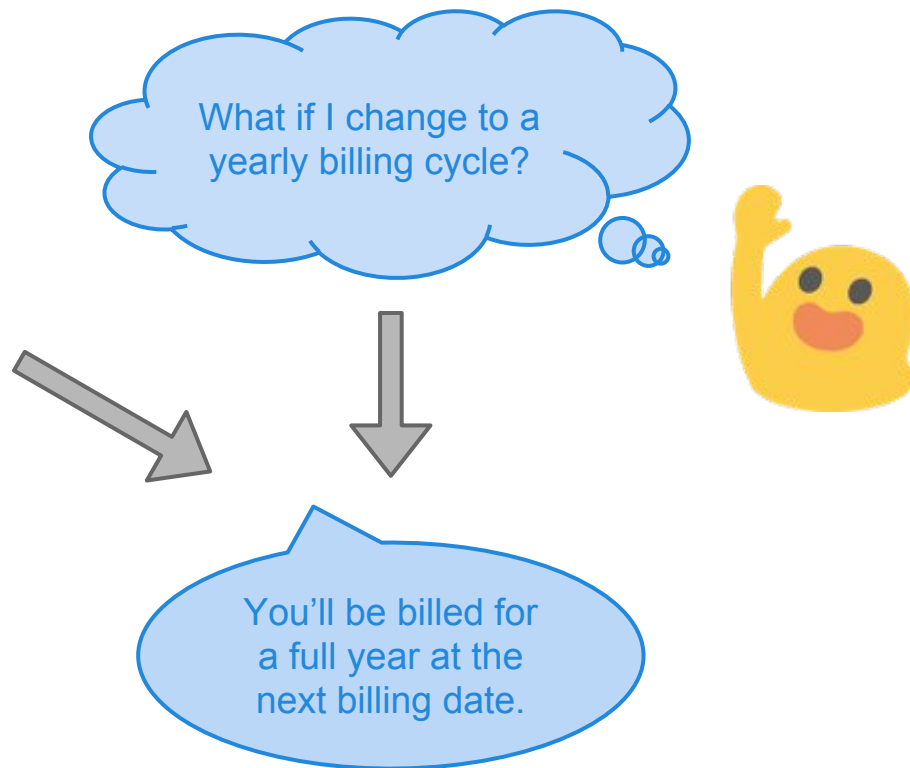
Customers may access their GitHub account data via an API (Application Program Interface). Any use of the API, including use of the API through a third-party product that accesses GitHub, is bound by these Terms of Service plus the following specific terms:

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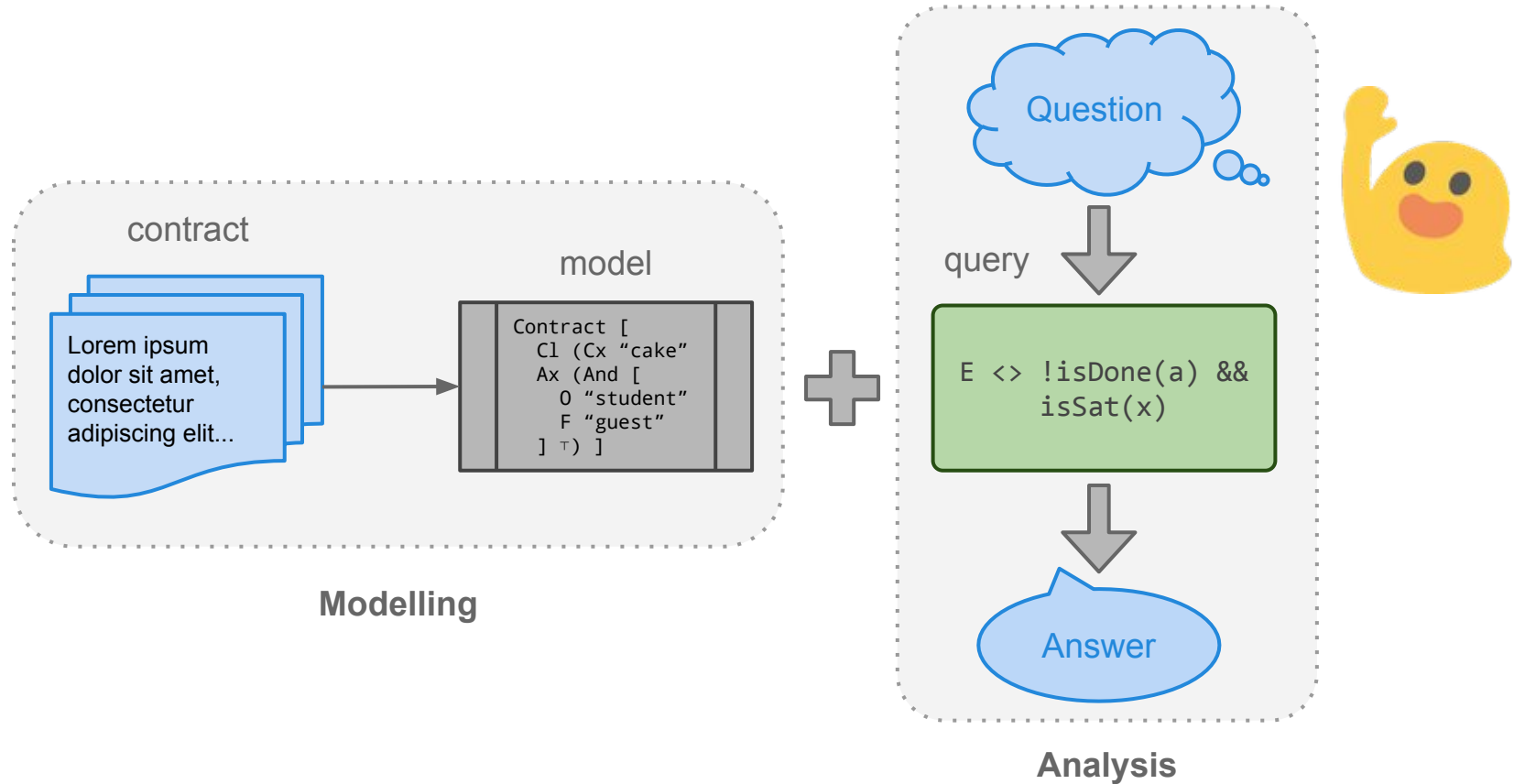
Query answering

C. Payment, Refunds, Upgrading and Downgrading Terms

- 1 All paid plans must enter a valid payment account. Free accounts are not required to provide payment account information.
- 2 **An upgrade from the free plan to any paying plan will immediately bill you.**
- 3 For monthly payment plans, **the Service is billed in advance on a monthly basis and is non-refundable. There will be no refunds or credits for partial months of service, upgrade/downgrade refunds, or refunds for months unused with an open account. In order to treat everyone equally, no exceptions will be made.**
- 4 **When changing from a monthly billing cycle to a yearly billing cycle, GitHub will bill for a full year at the next monthly billing date.**
- 5 All fees are exclusive of all taxes, levies, or duties imposed by taxing authorities, and you shall be responsible for payment of all such taxes, levies, or duties, excluding only United States (federal or state) taxes.
- 6 For any upgrade or downgrade in plan level while on a monthly billing cycle, the credit card that you provided will automatically be charged the new rate on your next billing cycle. For upgrades or downgrades while on a yearly plan, GitHub will immediately charge or refund the difference in plan cost, prorated for the remaining time in your yearly billing cycle.
- 7 Downgrading your Service may cause the loss of Content, features, or capacity of your Account. GitHub does not accept any liability for such loss.



Method overview



Modelling

Formalism: syntax

Agents: you, the student

Actions: sending an email, giving speech

Modalities: obligation, permission, prohibition

```
Clause = O Agent Action  
        | P Agent Action  
        | F Agent Action
```

Formalism: syntax

A **clause** can be built from other clauses

Refinement: conjunction, sequence, choice

```
Clause = ...  
        | And Clause Clause  
        | Seq Clause Clause  
        | Or  Clause Clause
```


Formalism: syntax

Guards say when a clause is applicable

```
Clause = O [Guard] Agent Action  
       | P [Guard] Agent Action  
       | F [Guard] Agent Action  
       | ...
```

```
Guard = GV Var Op Int  
       | GC Clock Op Int   where Op  $\in \{<, =, >\}$ 
```

Formalism: syntax

Reparations apply when a clause is violated

```
Clause = O [Guard] Agent Action Rep
        | P [Guard] Agent Action
        | F [Guard] Agent Action Rep
        | ...
Rep =  $\top$  |  $\perp$  | R Clause
```

Formalism: syntax

```
Contract = [Clause]
Clause = O [Guard] Agent Action Rep
      | P [Guard] Agent Action
      | F [Guard] Agent Action Rep
      | And [Guard] Clause Clause Rep
      | Seq [Guard] Clause Clause Rep
      | Or [Guard] Clause Clause Rep
Guard = GV Var Op Int
      | GC Clock Op Int  where Op ∈ {<,=,>}
Rep =  $\top$  |  $\perp$  | R Clause
```

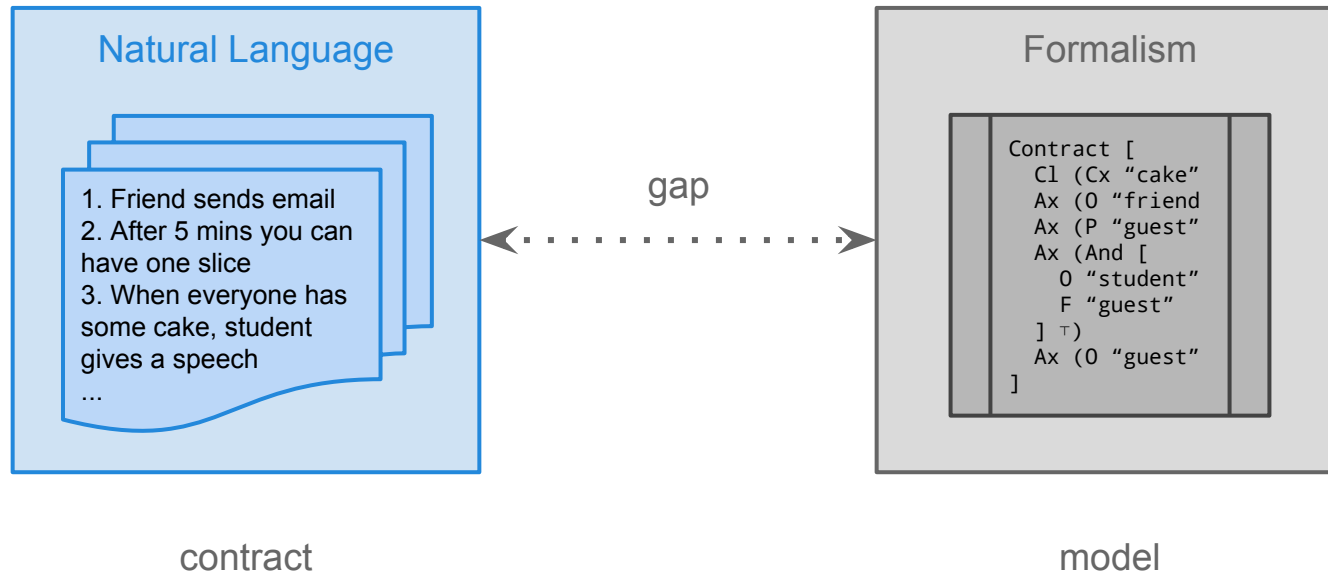
Example



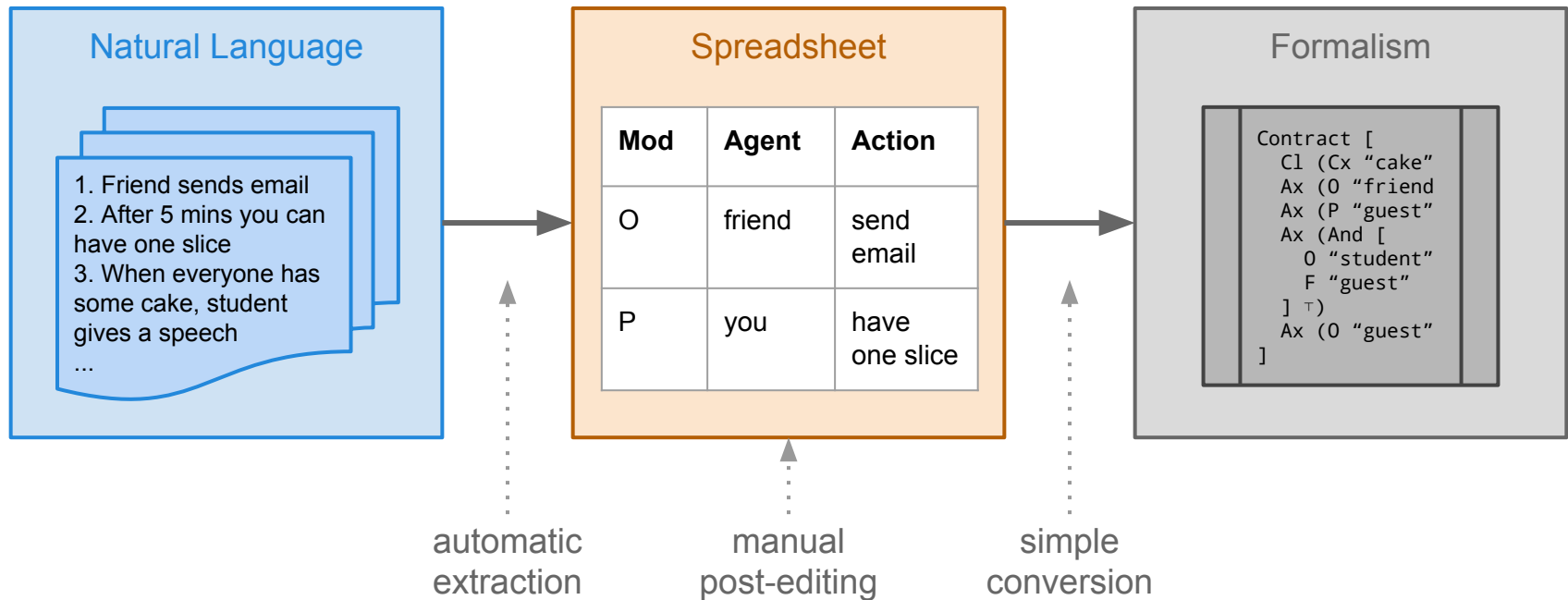
Licentiate cake rules

1. Friend sends email announcing cake
2. After 5 mins you can take one slice
3. When everyone has some cake,
the student gives a speech
 - a. You shouldn't take any cake at this time
 - b. ...but if you must, at least don't interrupt the speech
4. If there's cake left,
 - a. Student must say "*please, have more cake*"
 - b. Then you can take another slice

The semantic gap



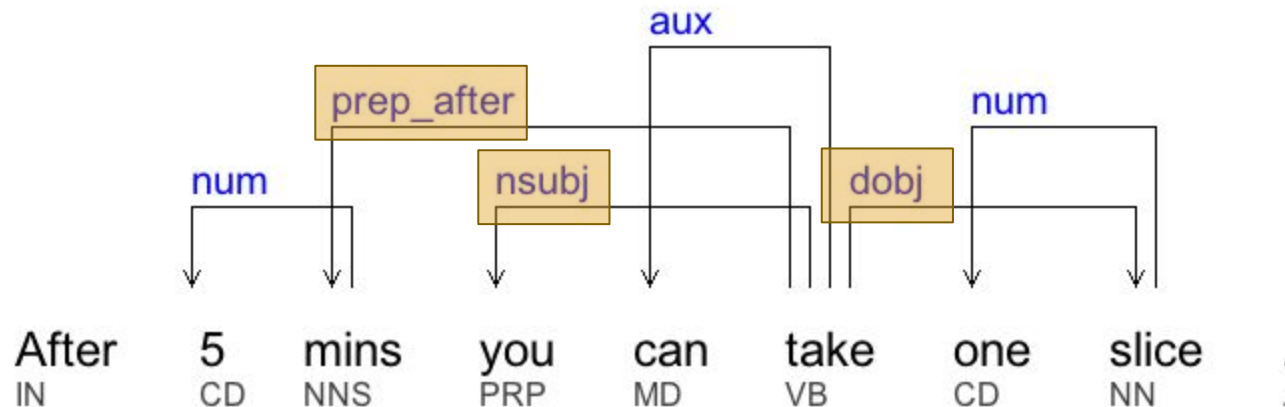
Extraction of partial model



Extraction of partial model

ConPar

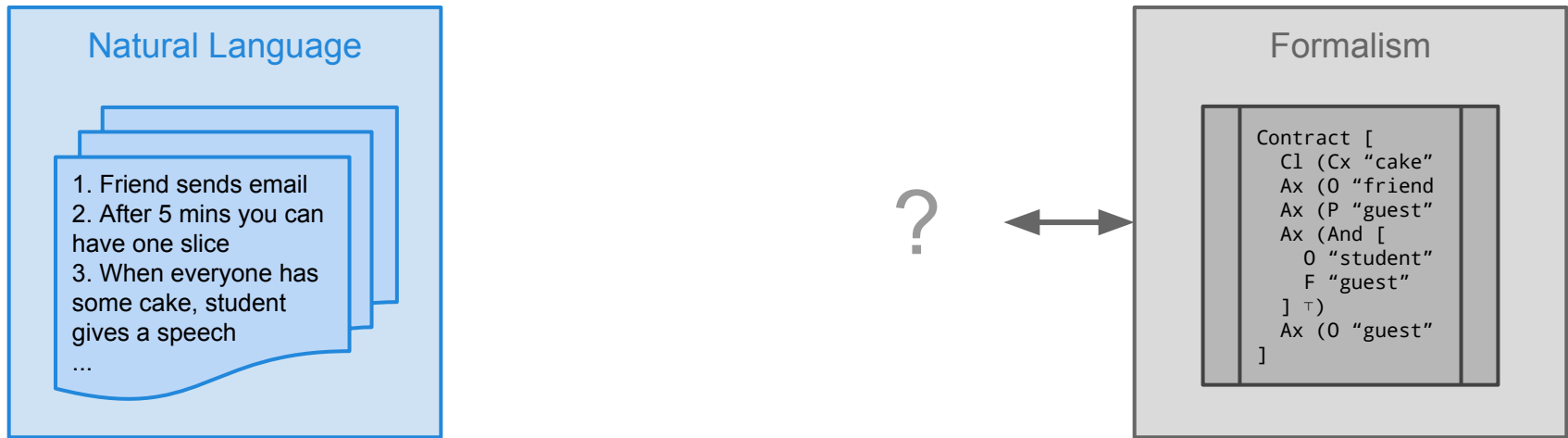
- Use Stanford dependency parser
- Post-process trees to extract bits of info



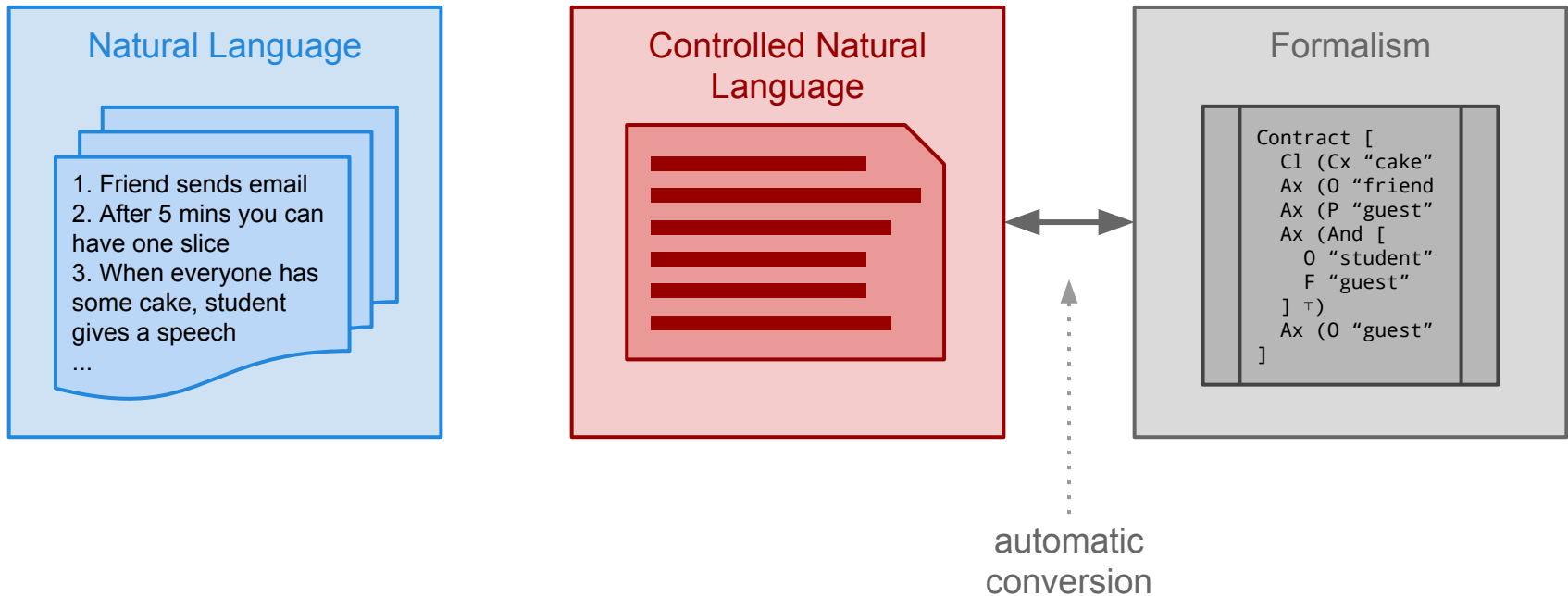
Extraction of partial model

No	Subject	Verb	Object	Mod.	Time	Adverbials	Conditions
1	friend	send	email	D			
2	you	take	slice	P	after 5 mins		SLICE: one
3	student	give	speech	D		when everyone has cake	
4	student	say	[to] please more cake	O			SAY: if there's cake left
AND	you	take	slice	P			

Intermediate representation



A natural language representation



Controlled Natural Language (CNL)

- Restricted subset of natural language (NL)
 - Restricted syntax and lexicon
 - Defined as a formal grammar
 - Unambiguous parsing
 - Easily human-readable
- English-like linearisation for contract models
- Directly parsable back into model

CNL: simple example

0

[]

(Agent "the friend")

(Action "send an email")

T

the friend **is required to** send
an email

CNL: modal variants (O)

0

[]

(Agent "the friend")

(Action "send an email")

T

the friend **is obliged to** send
an email

the friend **is required to** send
an email

the friend **must** send an email

CNL: modal variants (P)

P

[]

(Agent "the friend")

(Action "send an email")

the friend **is allowed to** send
an email

the friend **is permitted to** send
an email

the friend **may** send an email

CNL: modal variants (F)

F

[]

(Agent "the friend")

(Action "send an email")

T

the friend **is not allowed to**
send an email

the friend **may not** send an
email

the friend **must not** send an
email

CNL: agreement

0

[]

(Agent "friends")

(Action "send an email")

T

friends **are** obliged to send an email

friends **are** required to send an email

friends must send an email

CNL: one guard

P

```
[ t_announce > 5 ]  
(Agent "guests")  
(Action "take some cake")
```

when `t_announce` is greater than 5 guests may take some cake

CNL: two guards

```
P
  [ t_announce > 5,
    isDone(lay_table) ]
  (Agent "guests")
  (Action "take some cake")
```

```
when
  - t_announce is greater than 5 , and
  - lay_table is done
guests may take some cake
```

```
when t_announce is greater than 5 and lay_table is done guests may
take some cake
```

CNL: refinement

And

```
[ all_cake == 1 ]  
(O [] (Agent "student") (Action "give a speech")  $\top$ )  
(F [] (Agent "guests") (Action "take some cake")  $\top$ )  
 $\top$ 
```

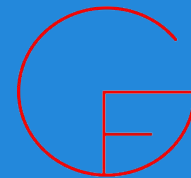
when all_cake is equal to 1 each of

- student must give a speech
- guests may not take some cake

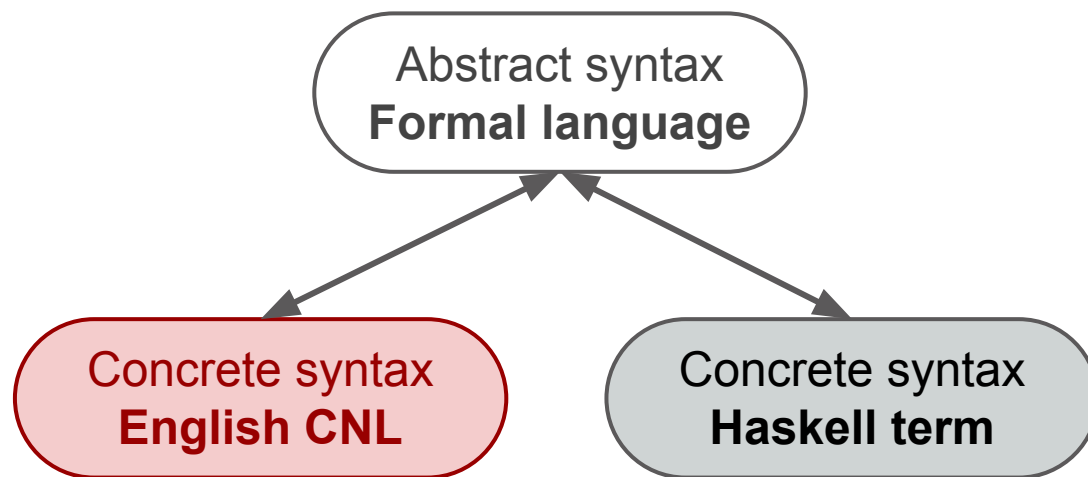
when all_cake is equal to 1 student must give a speech and guests may not take some cake

Grammatical Framework (GF)

<http://www.grammaticalframework.org/>

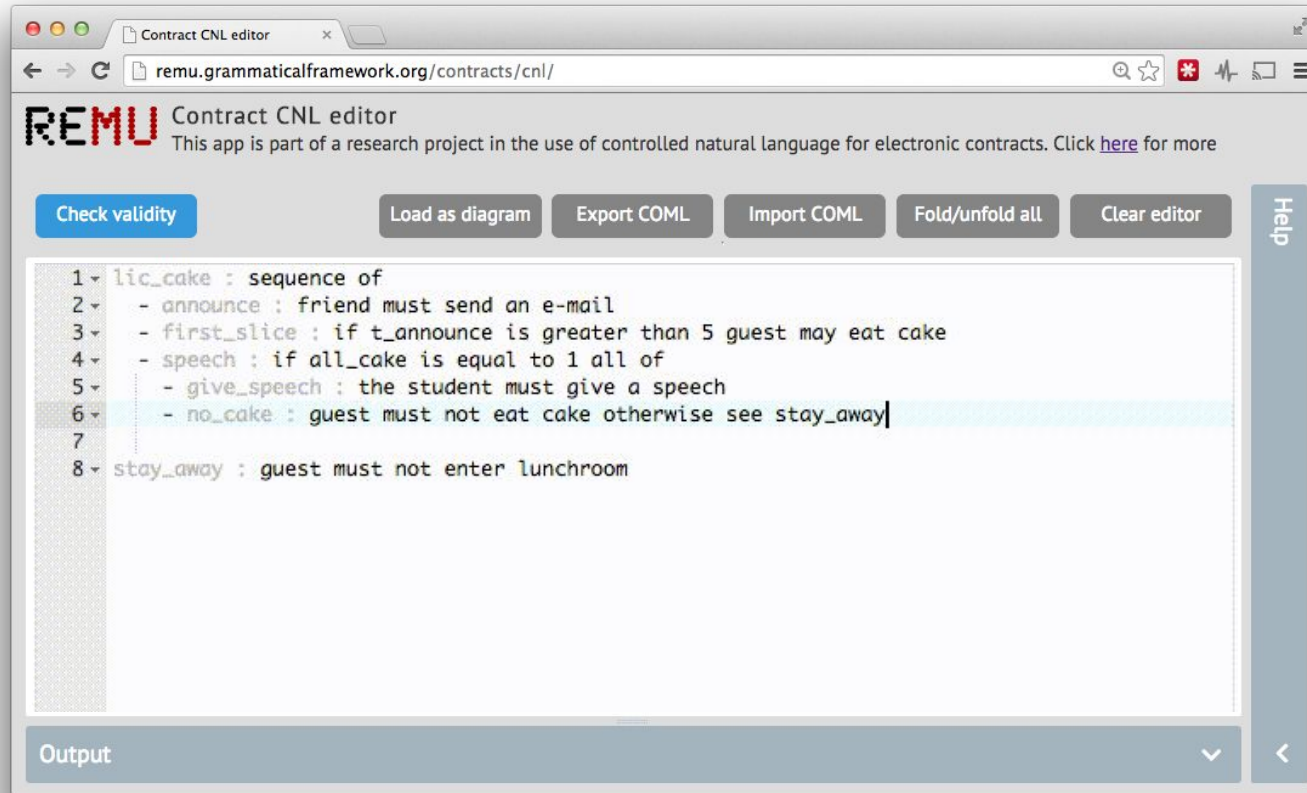


- Framework for multilingual grammars
- Language-independent semantic interlingua
- Generation and parsing from single grammar

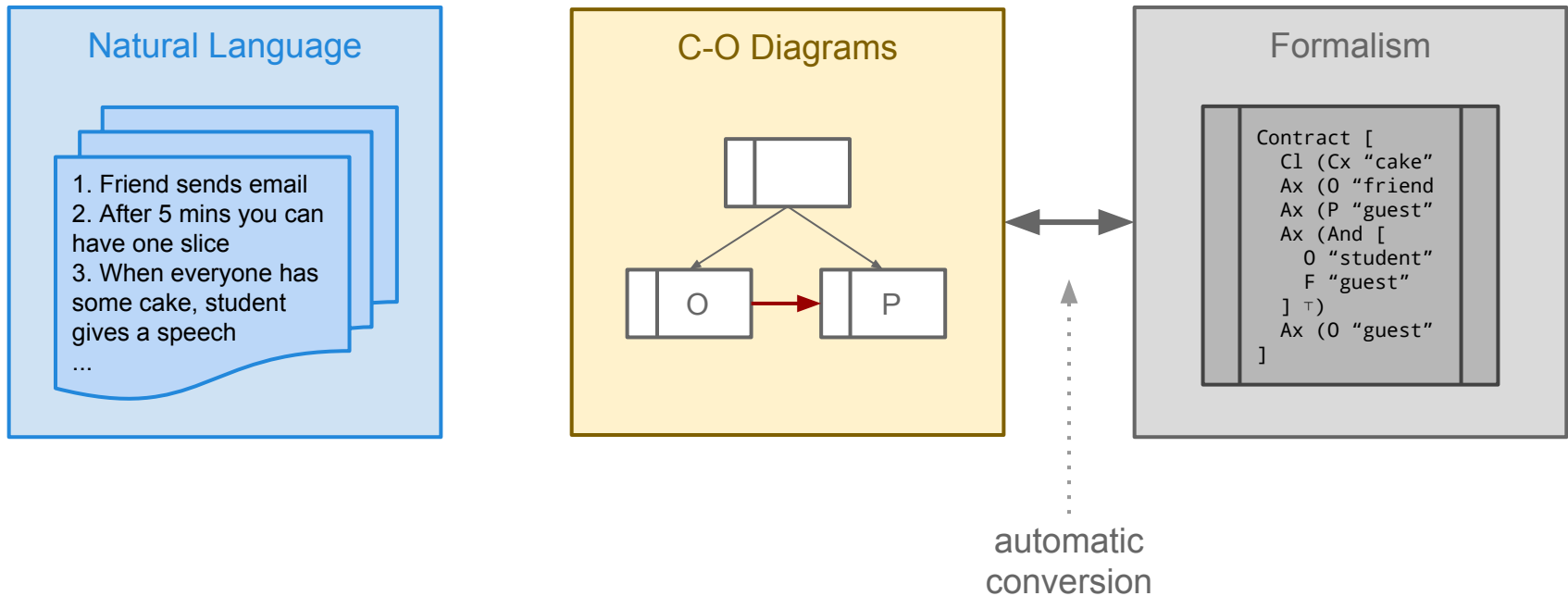


Tool: CNL editor

<http://remu.grammaticalframework.org/contracts/cnl/>



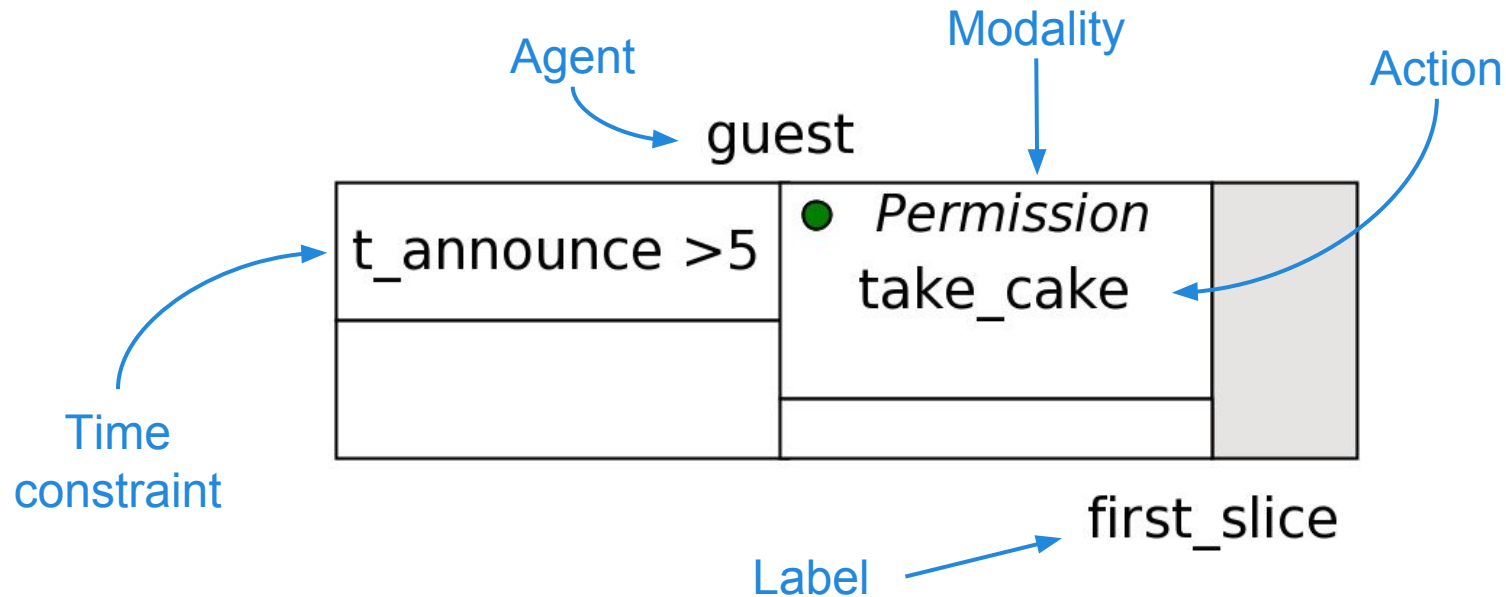
A visual representation



Contract-Oriented Diagrams

Martínez et al. 2010; Díaz et al. 2014

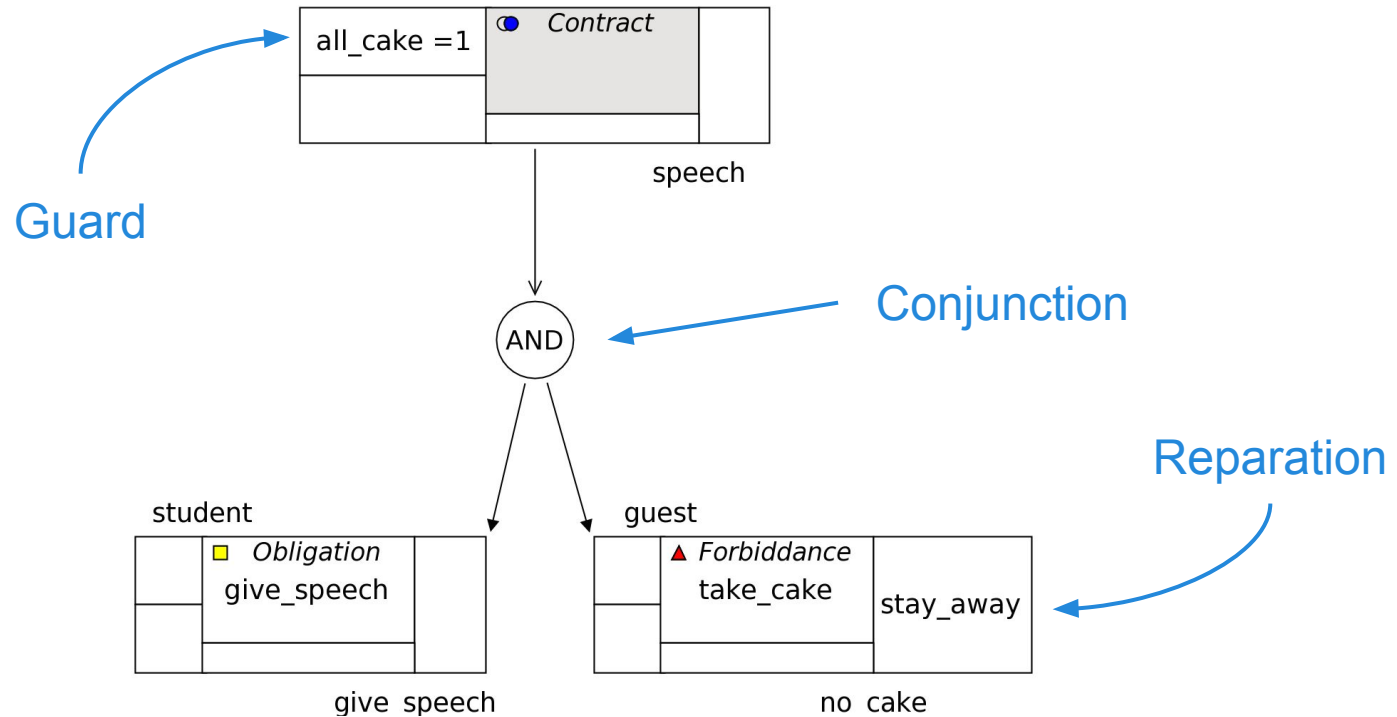
- A visual formalism for normative contracts
- Boxes as clauses:



Contract-Oriented Diagrams

Martínez et al. 2010; Díaz et al. 2014

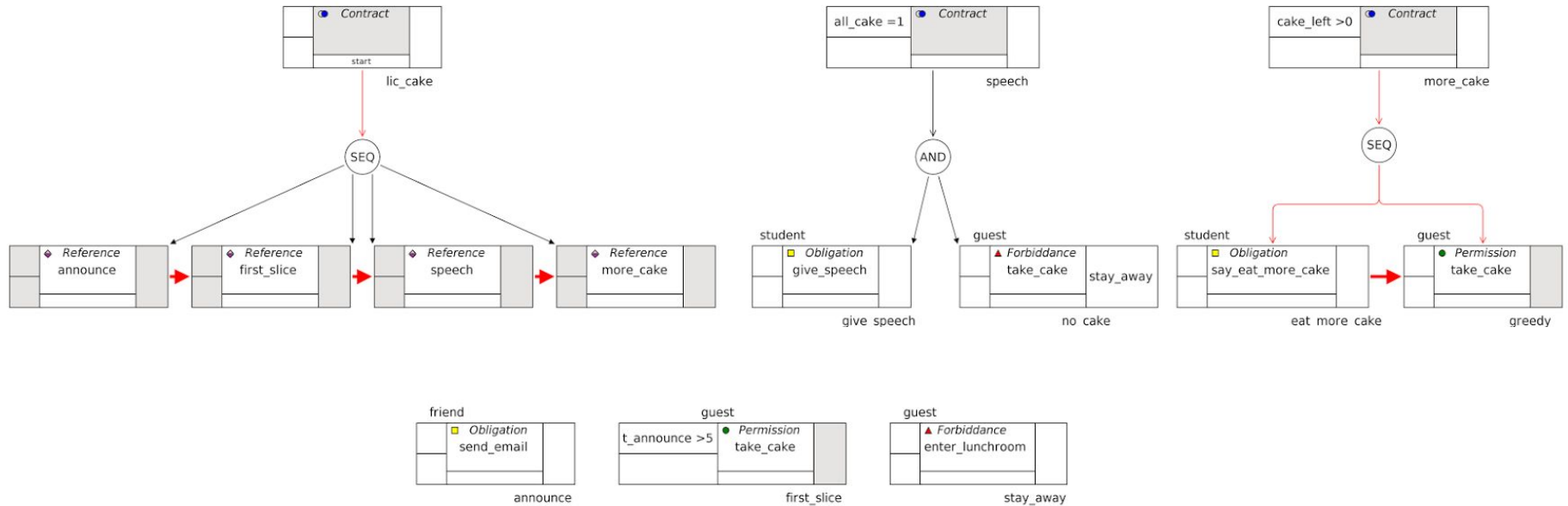
- Edges show refinement



Contract-Oriented Diagrams

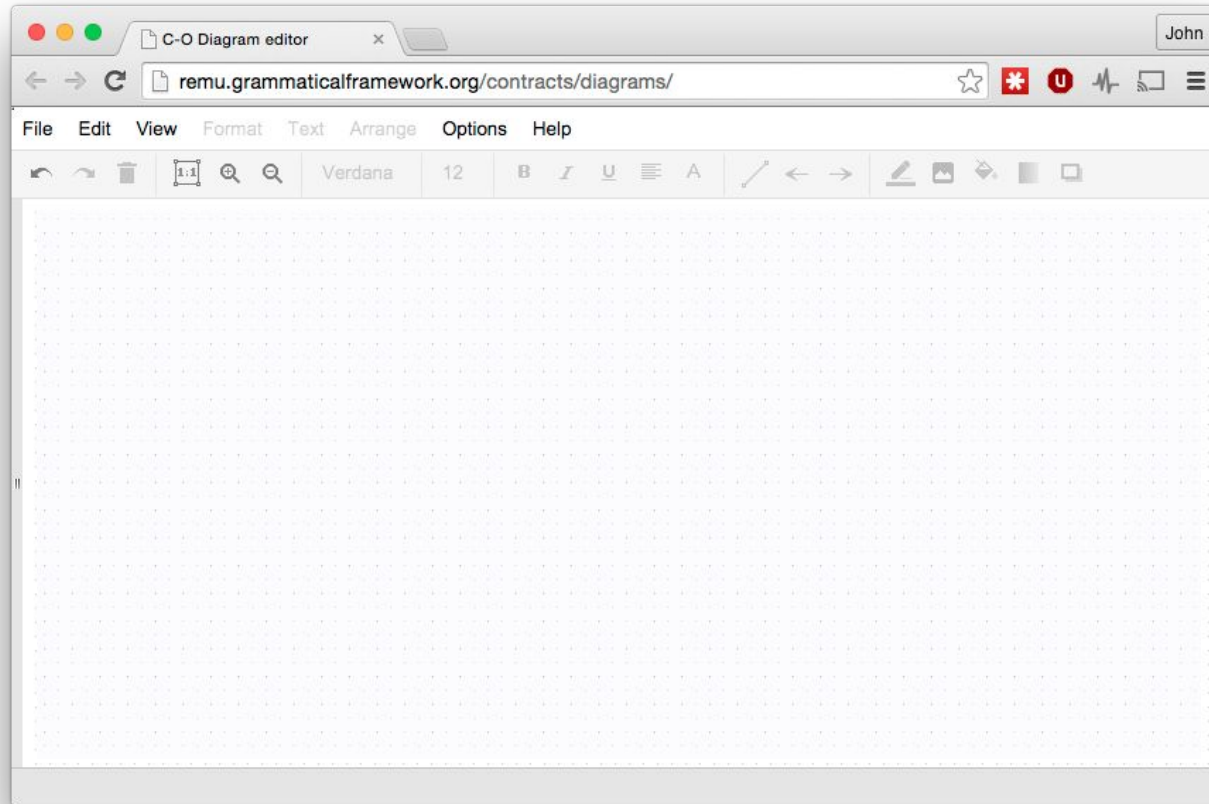
Martínez et al. 2010; Díaz et al. 2014

- Contract is a forest of trees

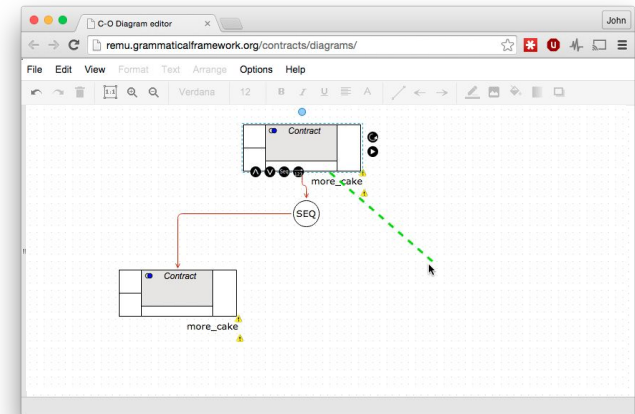
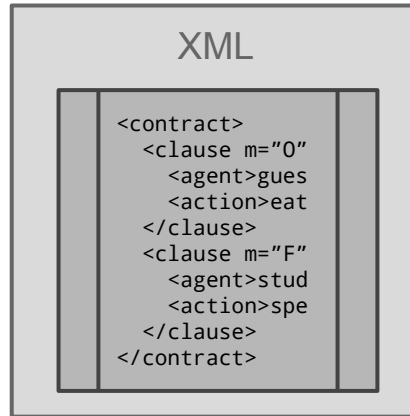
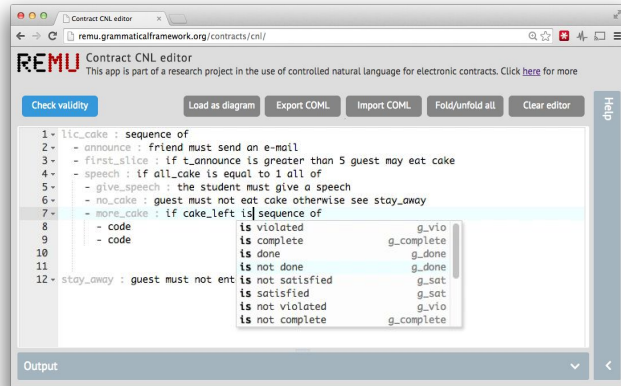


Tool: C-O Diagram editor

<http://remu.grammaticalframework.org/contracts/diagrams/>



Tool communication



Analysis

Simulation



Formalism: semantics

- Given:
 - Sequence of observed events (trace)
 - Contract model
- We want to know:
 - Does a trace respect a model?
- More generally:
 - After following the trace, what is the resulting contract?

Formalism: semantics

An **event** is an action observed at a time

A **trace** is a sequence of events

```
Event = (Agent, Action, TimeStamp)
```

```
Trace = [Event]
```

Formalism: semantics

An **environment** is a context of variables and clocks, which vary over time

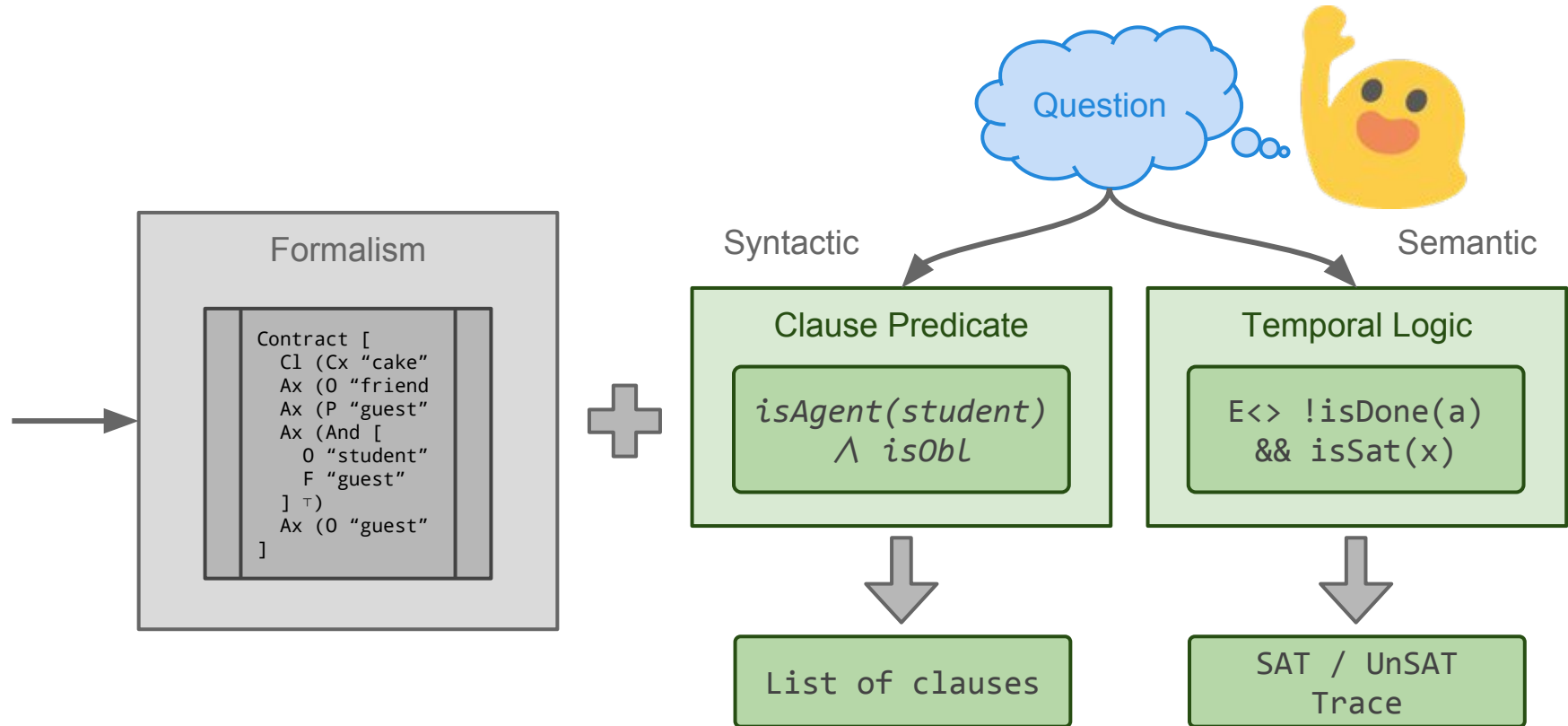
```
Context = ( Map Var    Int
            , Map Clock Int )
Env = TimeStamp -> Context
```

Formalism: semantics

Given a contract, trace, and environment, what is the resulting contract? (could be \top or \perp)

```
respects :: Contract  
         -> Trace  
         -> Env  
         -> Contract
```

Query-based analysis



Syntactic queries

- Predicates over single clauses
e.g. `isObl`, `hasRep`, `ofAgent(a)`
- Combine into complex queries
- Applied over structure of model
- Return list of matching clauses

Syntactic queries

All obligations for student

$\text{isObl} \wedge \text{ofAgent}(\text{"student"})$

$\{ \text{give_speech}, \text{eat_more_cake} \}$

Syntactic queries

Prohibitions without reparations

`isFor \wedge \neg hasRep`

`{ stay_away }`

Semantic analysis

- Syntactic filtering is limited
- We want to test properties involving:
 - **Reachability** — could ... possibly be the case?
 - **Invariance** — is it always the case that ...?
- Timing constraints and guards
- Clauses depend on others
- Changes in environment

Model checking using UPPAAL

<http://www.uppaal.org/>

1. Translate contract model into Network of Timed Automata (NTA)
2. Encode query as a property in real-time logic
3. Apply UPPAAL model checking tool
4. Response:
 - Sat (property holds)
 - Unsat (property doesn't hold)
 - Symbolic trace

Translation to NTA

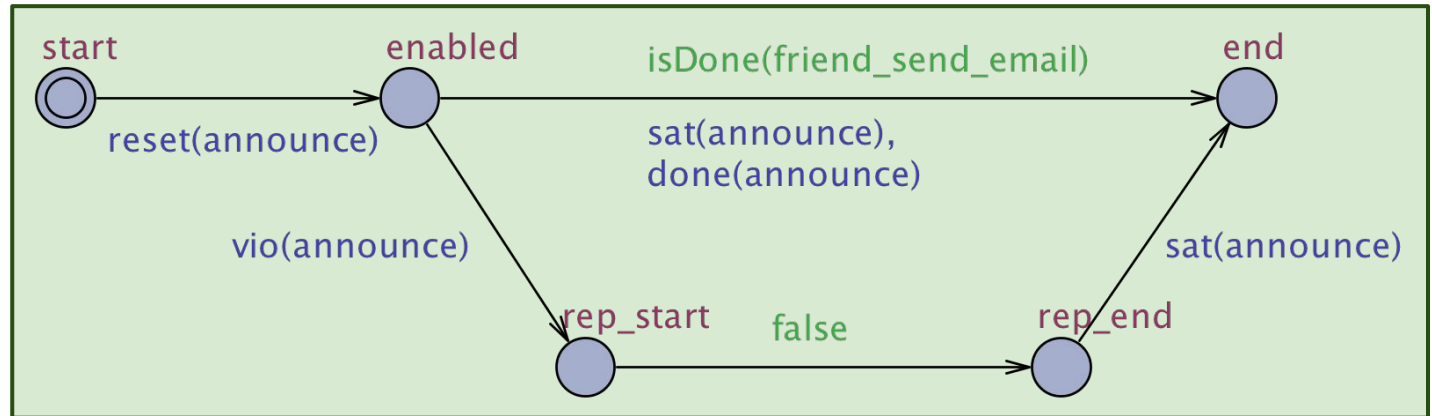
0

[]

(Agent "the friend")

(Action "send an email")

⊥



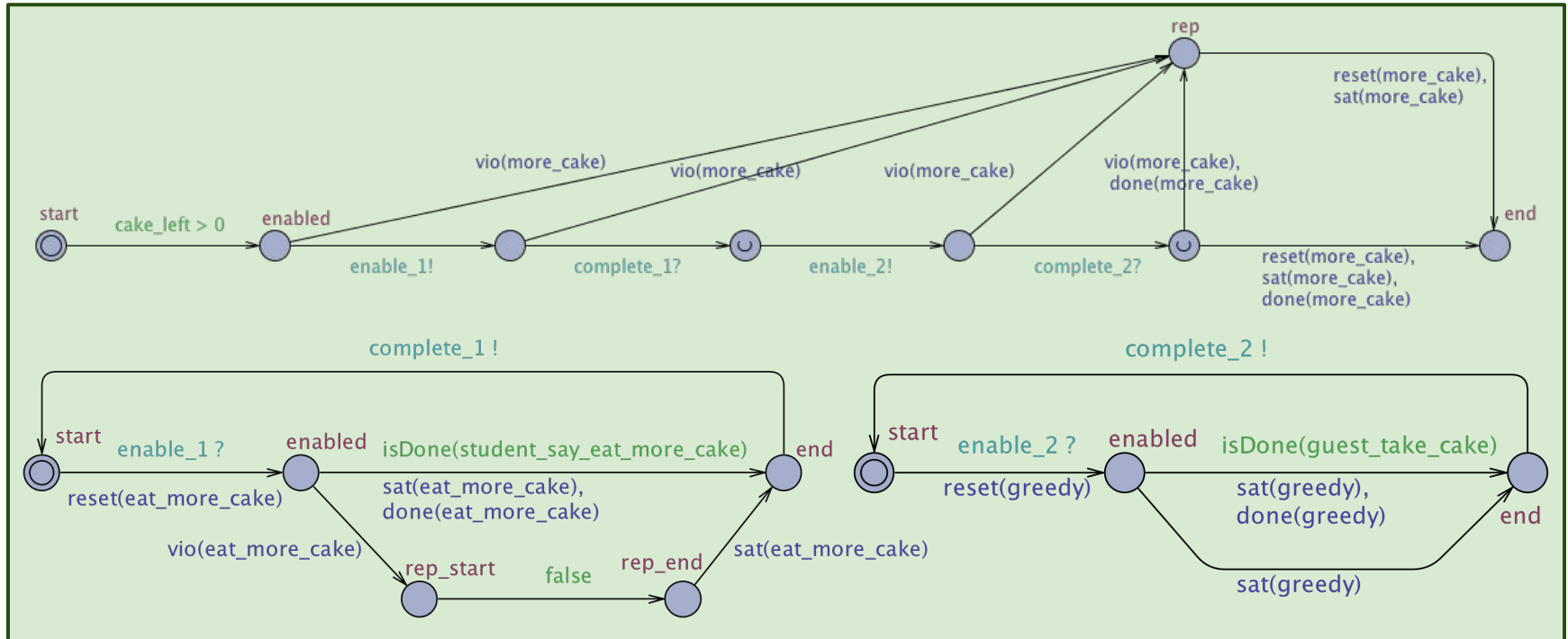
Seq

[cake_left > 0]

(O [] (Agent "student") (Action "say eat more cake") \perp)

(P [] (Agent "guests") (Action "take some cake"))

T



Property testing

Can a guest eat cake before the announcement?

```
E<> !isDone(announce) &&  
    isDone(first_slice)
```

Not satisfied

Property testing

A guest cannot eat cake before the announcement.

```
A[] !isDone(announce) imply  
    !isDone(first_slice)
```

Satisfied

Property testing

A guest never enters the lunchroom during the speech.

```
A[] !isDone(give_speech) imply  
    !isVio(stay_away)
```

Not satisfied — but why?

Counter example trace

The screenshot displays a software interface with a title bar indicating the file path: `/Users/john/repositories/REMU/projects/contracts/Examples/licentiate/cake.xml`. The interface includes a toolbar with icons for file operations and simulation controls, and a tabbed menu with options: `Editor`, `Simulator` (selected), `ConcreteSimulator`, `Verifier`, and `Yggdrasil`.

The main window is titled **Simulation Trace** and contains a list of simulation events. The events are as follows:

- `changed: do_guest_enter_cake`
- `(lic_cake_mid, lic_cake_Seq_enabled_3, announce_13_disabled, first_slice_16_disabled, speech_mid, speech_And_collect, give_speech_enabled, no_cake_enabled, no_cake_32`
- `(lic_cake_mid, lic_cake_Seq_enabled_3, announce_13_disabled, first_slice_16_disabled, speech_mid, speech_And_collect, give_speech_enabled, stay_away_start, mor`
- `no_cake_32`
- `(lic_cake_mid, lic_cake_Seq_enabled_3, announce_13_disabled, first_slice_16_disabled, speech_mid, speech_And_collect, give_speech_enabled, stay_away_check, mc`
- `checked: checker → no_cake_32`
- `(lic_cake_mid, lic_cake_Seq_enabled_3, announce_13_disabled, first_slice_16_disabled, speech_mid, speech_And_collect, give_speech_enabled, stay_away_enabled,`
- `changed: do_guest_enter_lunchroom →`
- `(lic_cake_mid, lic_cake_Seq_enabled_3, announce_13_disabled, first_slice_16_disabled, speech_mid, speech_And_collect, give_speech_enabled, stay_away_enabled,`
- `no_cake_32`
- `(lic_cake_mid, lic_cake_Seq_enabled_3, announce_13_disabled, first_slice_16_disabled, speech_mid, speech_And_collect, give_speech_enabled, null_rep_init, more_c`

The last line of the trace is highlighted in blue. Below the trace, there is a control panel with buttons for `Open`, `Save`, and `Random`, and a speed slider ranging from `Slow` to `Fast`.

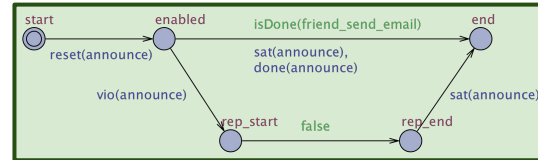
To the right of the control panel, a state transition diagram is visible. It shows a sequence of states connected by arrows, with labels such as `enabled`, `more_cake_Seq_enabled_1`, `more_cake_Seq_complete_1`, `more_cake_Seq_enabled_2`, `more_cake_Seq_complete_2`, `more_cake_Seq_done`, `changed`, `resetmore_cake`, `satimore_cake`, and `done(more_cake)`. The diagram is partially obscured by the simulation trace window.

Where is the problem?

query?

```
A[] !isDone(give_speech) imply
    !isVio(stay_away)
```

translated automata?



contract model?

```
0 []
  (Agent "the friend")
  (Action "send an email")
  T
```

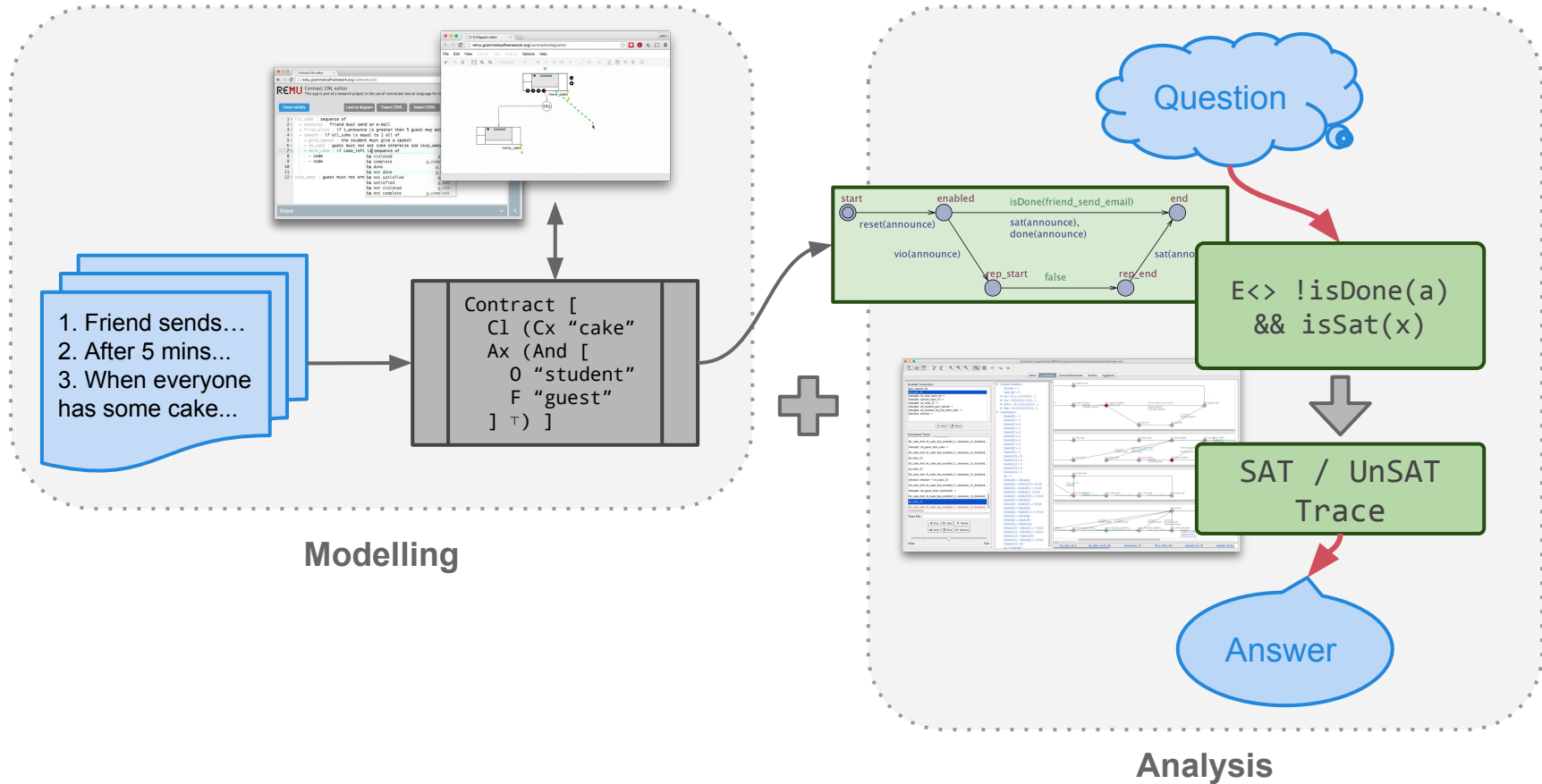
normative document?

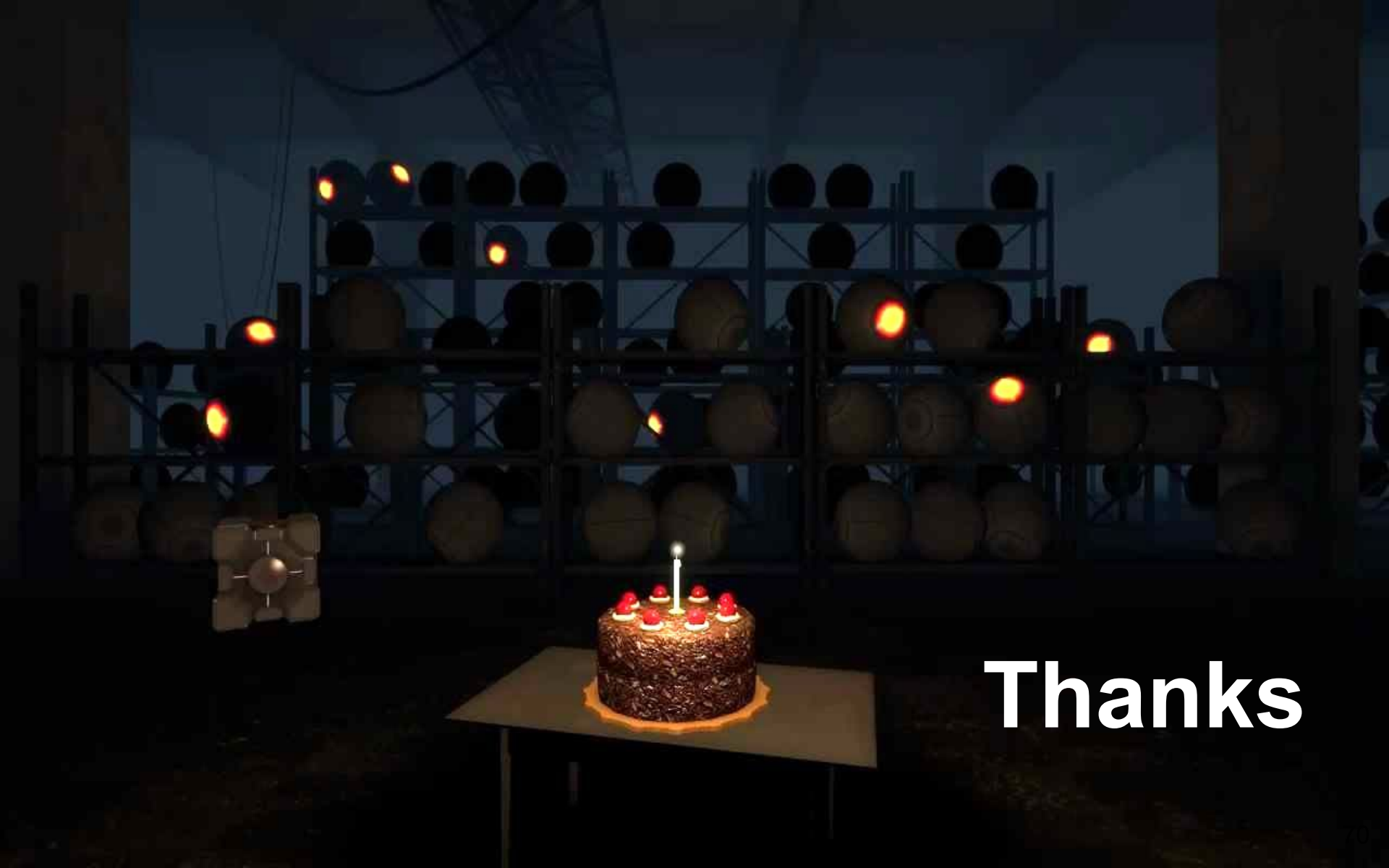
1. Friend sends email
2. After 5 mins you can have one...
3. When everyone...

Current & future work

1. Redeveloping formalism to simplify:
 - Trace semantics
 - Translation to NTA
 - Correctness argument
2. Common tool for modelling and analysis
3. Query language
 - Construct properties at a higher level of abstraction
4. Processing of counter examples
 - Using info from translation

Summary





Thanks

Summary

1. Formal language for norm-based contracts
2. Tool for automatic [partial] extraction
3. CNL interface + tool
4. Tool for visual manipulation as C-O Diagrams
5. Syntactic analysis
6. Conversion into timed automata
7. Semantic analysis as model checking

Term in Haskell

```
CODiag [  
  Clause (Complex (N "lic_cake") Nothing Nothing (C_Seq [Ref (N "announce"),Ref (N "  
  AuxCl (O (Agent "friend") (N "announce") Nothing Nothing (A_Action (Action "send_e  
  AuxCl (P (Agent "guest") (N "first_slice") (Just (GL [GTR (TR (Ck "t_announce") No  
  AuxCl (Complex (N "speech") (Just (GL [GVar (Var "all_cake") Nothing C_EQ 1])) Not  
    C_And [  
      O (Agent "student") (N "give_speech") Nothing Nothing (A_Action (Action "give_  
      F (Agent "guest") (N "no_cake") Nothing Nothing (A_Action (Action "take_cake")  
    ]) R_Top),  
  AuxCl (O (Agent "guest") (N "stay_away") Nothing Nothing (A_Action (Action "dont_e  
  AuxCl (Complex (N "more_cake") (Just (GL [GVar (Var "cake_left") Nothing C_EQ 1]))  
    C_Seq [  
      O (Agent "student") (N "eat_more_cake") Nothing Nothing (A_Action (Action "say  
      P (Agent "guest") (N "greedy") Nothing Nothing (A_Action (Action "take_cake")  
    ]) R_Top)  
]
```


Shorthand

```
lic_cake:SEQ{ #announce ; #first_slice ; #speech ; #more_cake }  
// announce:0(friend.send_email)⊤  
// first_slice:[t_announce>5]P(guest.take_cake)  
// speech:[all_cake=1]AND{give_speech:0(student.give_speech)⊤ /  
// stay_away:0(guest.dont_enter_lunchroom)⊤  
// more_cake:[cake_left=1]SEQ{ eat_more_cake:0(student.say_eat
```

CNL: labels

- All clauses must include a label
- Needed for guards, cross-refs, reparations
- Easily hidden with tools

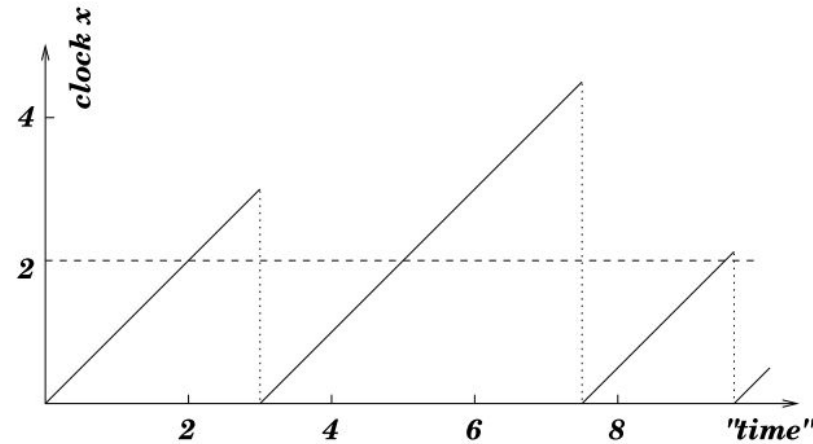
speech: when `all_cake` is equal to 1 each of

- **give_speech:** student must give a speech
- **no_cake:** guests may not take some cake

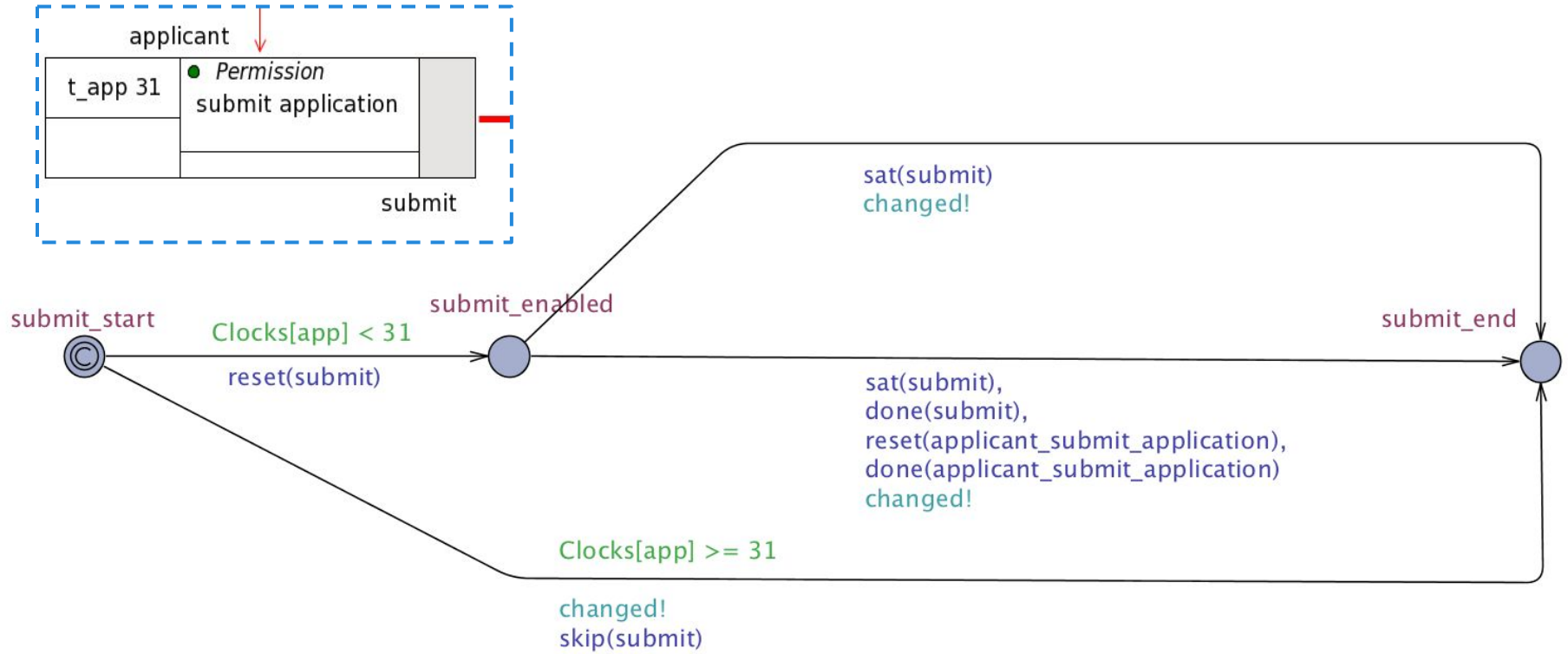
Timed Automata (TA)

Finite state automata, with:

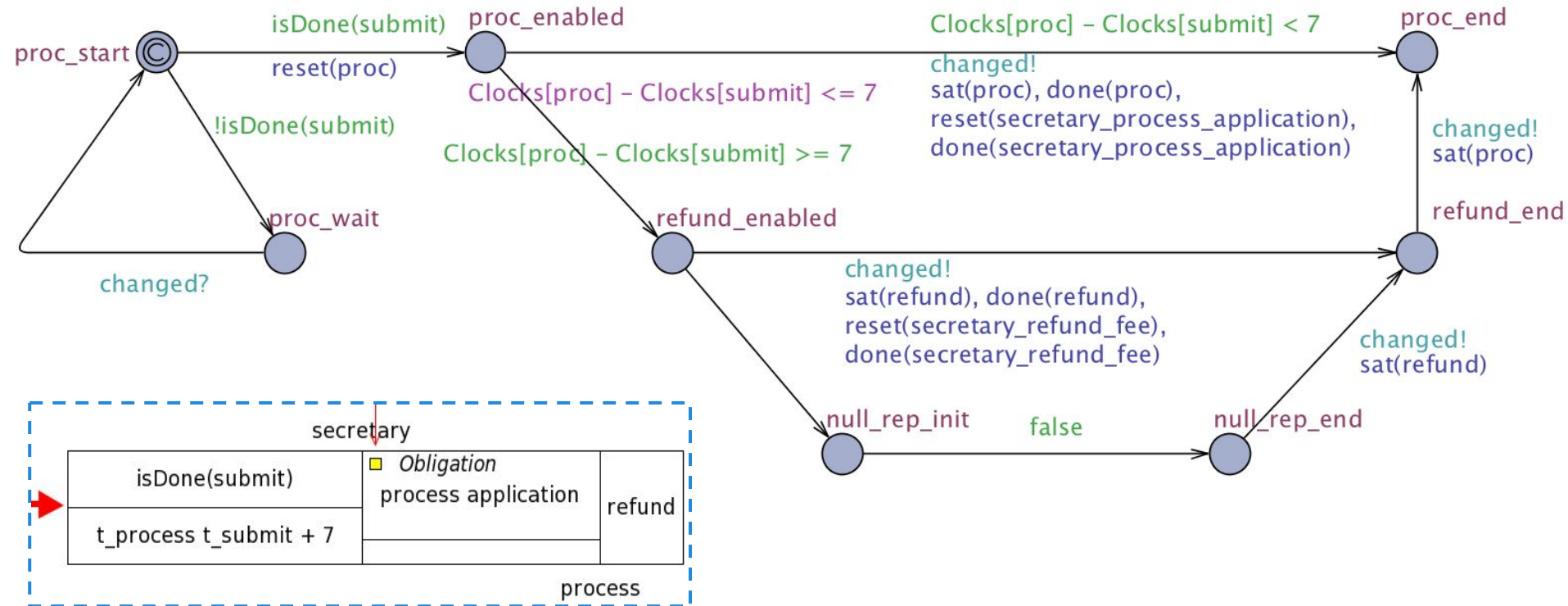
- Real-valued clocks
 - progress together
 - can be reset (to zero)
- Guards on transitions (over clocks, vars)
- Node invariants (over clocks, vars)



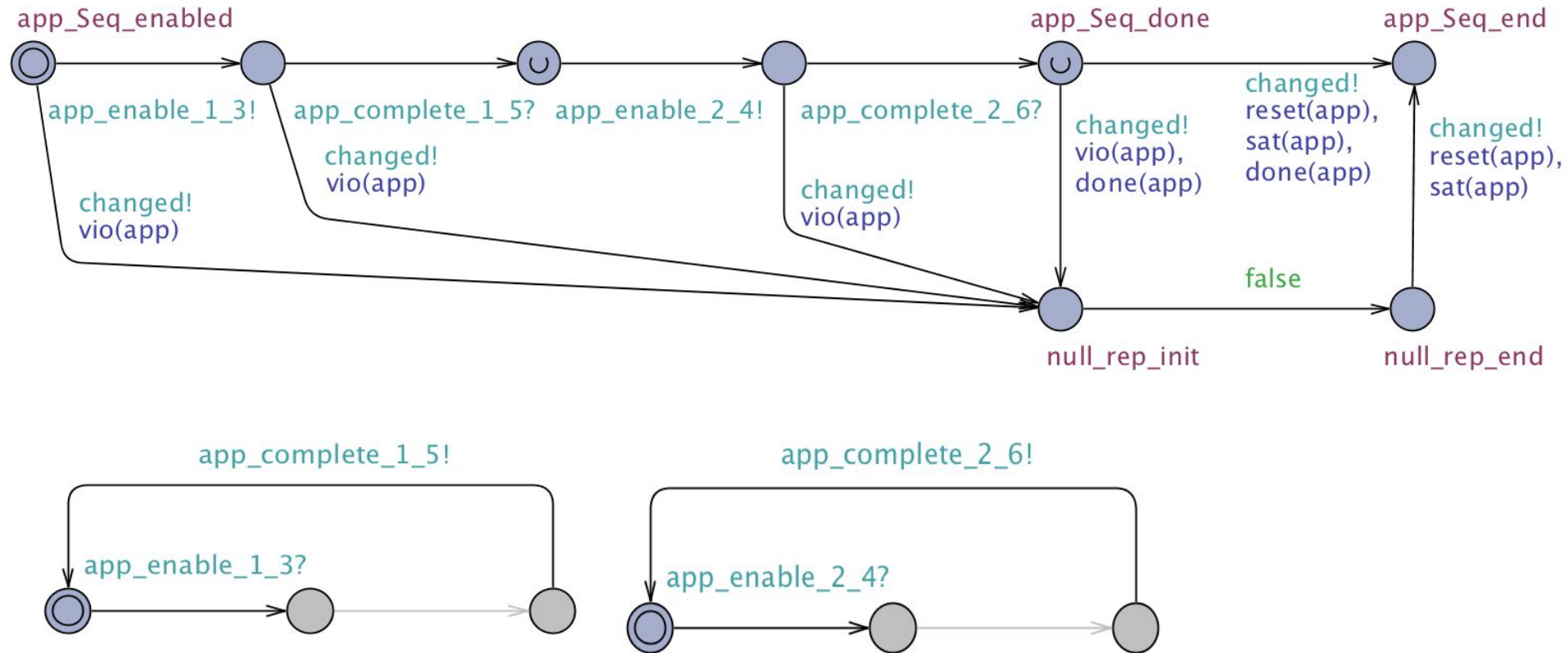
Translation to NTA: P



Translation to NTA: O



Translation to NTA: SEQ



Translation to NTA: plumbing

- Enable/complete channels per box
- Clock per box, action
- Boolean arrays: Done, Sat, Vio, Skip
- Related helper functions
- Use names as array indices

Property testing

UPPAAL requirement specification language

Name	Property	Equivalent to
Possibly	$E<> \varphi$	
Invariantly	$A[] \varphi$	$\text{not } E<> \text{ not } \varphi$
Potentially always	$E[] \varphi$	
Eventually	$A<> \varphi$	$\text{not } E[] \text{ not } \varphi$
Leads to	$\varphi \dashrightarrow \psi$	$A[] (\varphi \text{ imply } A<> \psi)$

where φ, ψ are boolean expressions over locations, variables, clocks