Analysing normative contracts

CHALMERS

On the semantic gap between natural and formal languages

John J. Camilleri Licentiate seminar 2015-10-29



The "biggest lie on the web"

http://www.biggestlie.com/





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Data integrity, Access and Enforcement, and is registered with the U.S. Department of Commerce's Sale Harbor Program



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The "biggest lie on the web"

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- We do this all the time
- No one wants to read legal agreements
- We trust that it's probably ok



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

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GitHub Privacy Policy

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We know your code is extremely important to you and your business, and we're very protective of it. After all, GitHub's code is hosted on GitHub, too!

Need to report a security vulnerability

responsible disclosure process and to submit a vulnerability

- Data center access limited to data center technicians and approved GitHub staff
- Biometric scarring for controlled data center access Security current monitoring at all data center locations. 24x7 onsite staff provides additional protection against
- unauthorized entry Urmarked facilities to help maintain low profile
- Physical security audited by an independent firm

- System iretallation using hardened, patched OS Dedicated finewall and VPN services to help block powered by industry-leading solutions
- Distributed Denial of Service (DDoS) mitigation services

Operational Security

- Our primary data center operations are regularly audited by independent firms against an ISAE 3000/AT 101 Type 2 Examination standard
- Systems access logged and tracked for auditing purposes Secure document-destruction policies for all sensitive
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controlled through the peer reviewed, open source git-shell.

The SSH login credentials used to push and pull can not be used to access a shell or the filesystem. All users are virtual (meaning) they have no user account on our machines) and are access

File system and backups

Every piece of hardware we use has an identical copy ready and 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 netwove repositories from backups whe 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 oil 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 decryption routine, thus negating any security it provides. Therefore, we focus on making our machines and network as secure as possible

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- 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 tailure to comply with this security obligation
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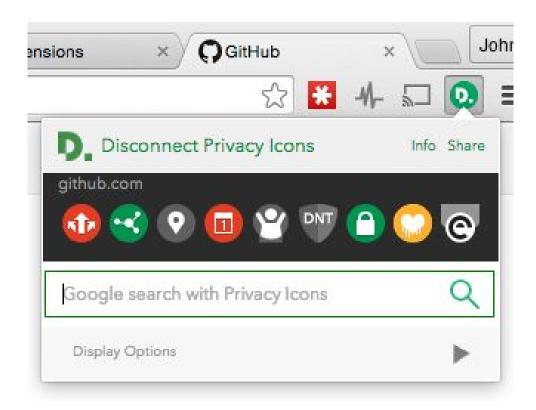
Info unavailable.



Expected collection



Precise location



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```
<?xml version="1.0" encoding="utf-8"?>
<rdf:RDF
 xmlns:cc='http://creativecommons.org/ns#'
 xmlns:owl='http://www.w3.org/2002/07/owl#'
 xmlns:rdf='http://www.w3.org/1999/02/22-rdf-syntax-ns#'
 xmlns:rdfs='http://www.w3.org/2000/01/rdf-schema#'
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    <owl:equivalentClass rdf:resource="http://creativecommons.org/ns#License"/>
 </rdf:Description>
  <rdf:Property rdf:about="http://creativecommons.org/ns#legalcode">
    <rdfs:domain rdf:resource="http://creativecommons.org/ns#License"/>
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 <rdf:Description rdf:about="http://web.resource.org/cc/prohibits">
    <owl:equivalentProperty rdf:resource="http://creativecommons.org/ns#prohibits"/>
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    <owl:equivalentClass rdf:resource="http://creativecommons.org/ns#CommercialUse"/>
  </rdf:Description>
  <rdf:Property rdf:about="http://creativecommons.org/ns#useGuidelines">
    <rdfs:range rdf:resource="http://www.w3.org/2000/01/rdf-schema#Resource"/>
    <rdfs:subPropertyOf rdf:resource="http://purl.org/dc/terms/relation"/>
    <rdfs:domain rdf:resource="http://creativecommons.org/ns#Work"/>
  </rdf:Property>
  <rdf:Description rdf:about="http://web.resource.org/cc/permits">
    <owl:equivalentProperty rdf:resource="http://creativecommons.org/ns#permits"/>
  </rdf:Description>
```



Automated analysis

Classification

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Communicatio

All private data exchanged with GRHub is always transmitted over SSL (which is why your dashboard is served over HTTPS, for instance), All pushing and pulling of private data is done over SSH auther/scaled with loys, or over HTTPS using your GRHub instance, and our security.

The SSH login credentals used to push and pull can not be used to access a shell or the flesystem. All users are virtual (meaning they have no user account on our machines) and are access controlled through the peer reviewed, open source glu-shell.

File system and backups

Every piece of hardware we use has an identical copy ready and walking for an intresidable in bi-lossiph in case of hardware or software falser. Every line of code we after its saved on a key, intrinsimal of times different servers, including an of size backput when one of windskilly removes repositories from backput swhen deleted by the user, as we may read to realize the repository for the user if it was removed accidentally.

We do not encrypt repositories on disk backsass it would not be any more secure: the websits and gif back-and record need to decrypt the repositories on diament, alsowing down response times. Any user with shell access to the like system would have access to the decryption outline, thus negating any security it provides. Therefore, we locus on making our machines and network as secure as cossible.

Site Policy / GitHub Terms of Service

Bittle th Terms of Service

Please note that if you are accessing any dithlub 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 GRHA's makes material changes to these Terms, we sell rolls you be yeared or to positive, and one on our able between the changes are officially. Any one features that augment or sehmence the current Emerica, reliable file reliases of new books and resources, shall be subject to the Terms of Service, and resources, shall be subject to the Terms of Service, and resources, shall be subject to the Terms of Service and resources, shall be subject to the Terms of Service considerable your creater to such changes, You can remove the most current version of the Terms of Service of surprise of the Service of Service of Service of the Service of Service o

Violation of any of the terms below will result in the termination of your Account. While Gilf-tub prohibits such conduct and Centeria on the Service, you understand and sayes that Gilf-tub 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

- You must be 13 years or older to use this Service.
- You must be a human. Accounts registered by "bobs" or other automated methods are not permitted.
- You must provide your name, a valid email address, and any other information requested in order to complete the signup process.
- 4 Your login may crity 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 takened to comply with this security obtaintor.
- 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.
- You may not use the Service for any illegal or unaufforized purpose. You must not, in the use of the Service, violate any taxes in your jurisdiction (including but not limited to copyright or trademark laws).

B. API Terms

Customers may access their Giff-tub account data via an API (Application Program Interface). Any use of the API, including use of the API including use of the API including a String party process Giff-tub, is bound by these Terms of Service plus the following search's terms.

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



- 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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- You expressly understand and agree that GilHub shall not be liable for any direct, indirect, incidental, special, consequential or exemplary damages, including but not limited to, damages for loss of profits, goodwill, use, data or other intangible losses (even if GilHub has been advised of the possibility of such damages), resulting from your use of the API or third-party products that access data via the API.
- 2 Abuse or excessively frequent requests to GitHub via the API may result in the temporary or permanent suspension of your account's access to the API. GitHub, in its sole discretion, will determine abuse or excessive usage of the API. GitHub will make a reasonable attempt via email to warn the account owner prior to suspension.
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Compatibility

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- 3 GitHub reserves the right at any time to modify or discontinue, temporarily or permanently, your access to the API (or any part thereof) with or without notice.

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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A. Términos Cuenta

- Usted debe tener 13 años o más para poder utilizar este servicio.
- 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.
 - Su nombre de usuario sólo puede ser utilizado por una sola persona no se permite un solo inicio de sesión compartico por varias personas. Puede crear accesos separados para tantas personas como su plan permite.
 - 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.
- 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).

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

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B. API Terms

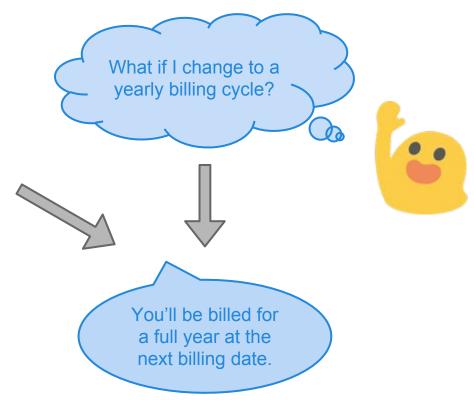
Customers may access their GitHub account data via an API (Application Program Interface). Any use of the API, including use of the API through a third-party product that accesses GitHub, is bound by these Terms of Service plus the following specific terms:

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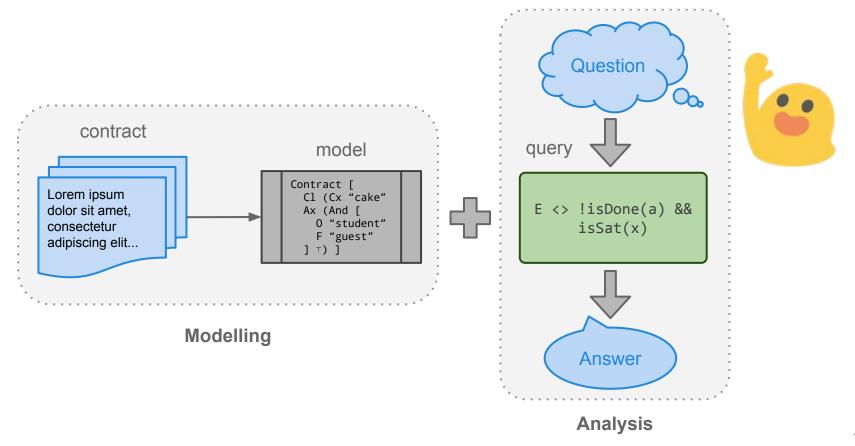
Query answering

C. Payment, Refunds, Upgrading and Downgrading Terms

- 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.
- 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.
- 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.
- 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

Agents: you, the student

Actions: sending an email, giving speech

Modalities: obligation, permission, prohibition

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

A clause can be built from other clauses Refinement: conjunction, sequence, choice

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

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 \{\langle,=,\rangle\}
```

Reparations apply when a clause is violated

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

```
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 \in \{\langle,=,\rangle\}
Rep = \top | \bot | R Clause
```

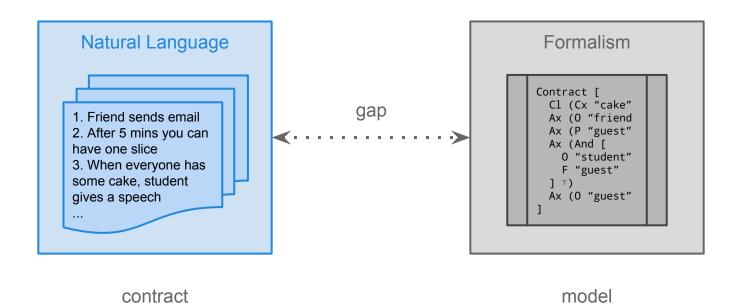
Example



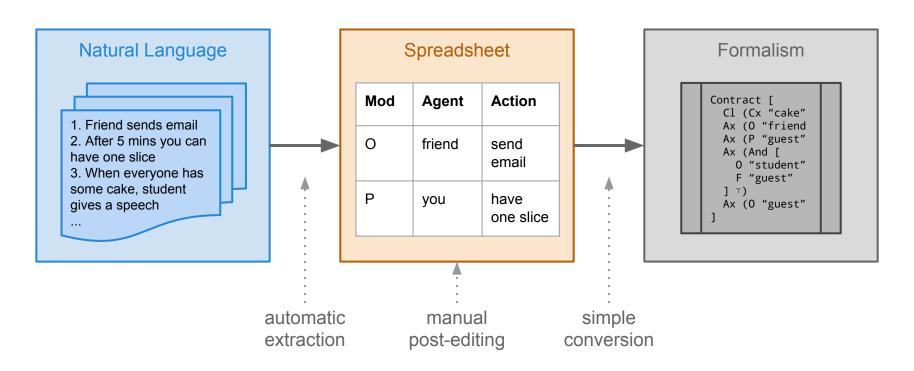
Licentiate cake rules

- 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



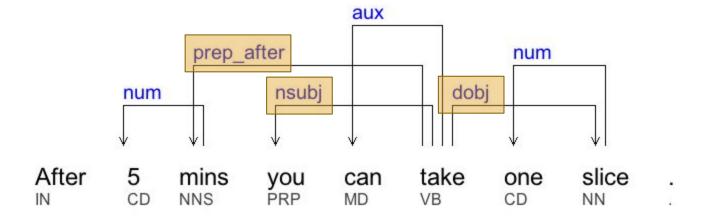
Extraction of partial model



Extraction of partial model

ConPar

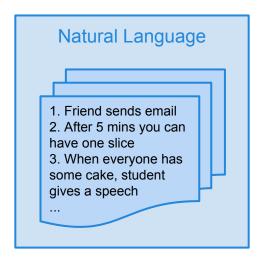
- Use Stanford dependency parser
- Post-process trees to extract bits of info

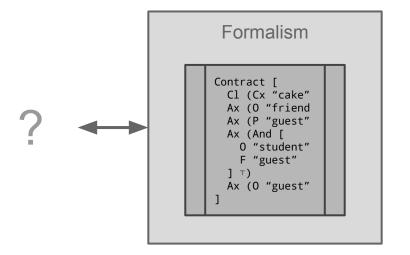


Extraction of partial model

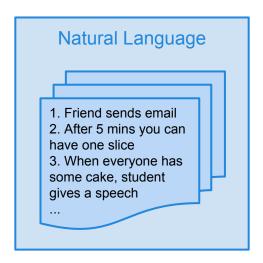
No	Subject	Verb	Object	Mod.	Time	Adverbials	Conditions
1	friend	send	email	D			
2	you	take	slice	P	after 5 mins		SLICE: one
3	student	give	speech	D		when everyone has cake	
4	student	say	[to] please more cake	0			SAY: if there's cake left
AND	you	take	slice	Р			29

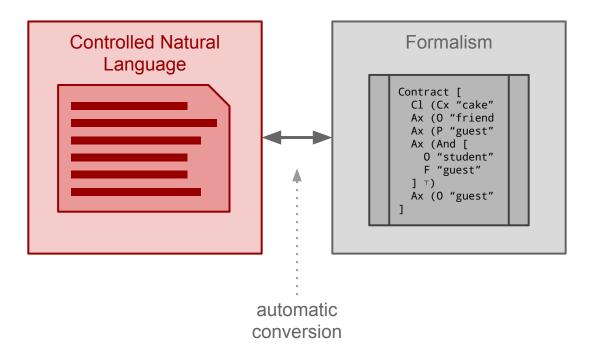
Intermediate representation





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

```
(Agent "the friend")
(Action "send an email")
```

the friend is required to send an email

CNL: modal variants (O)

```
(Agent "the friend")
(Action "send an email")
```

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)

```
(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)

```
(Agent "the friend")
(Action "send an email")
```

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

```
(Agent "friends")
(Action "send an email")
```

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") ¬)
(F [] (Agent "guests") (Action "take some cake") ¬)

⊤
```

```
when all_cake is equal to 1 each of
   - student must give a speech
   - guests may not take some cake
```

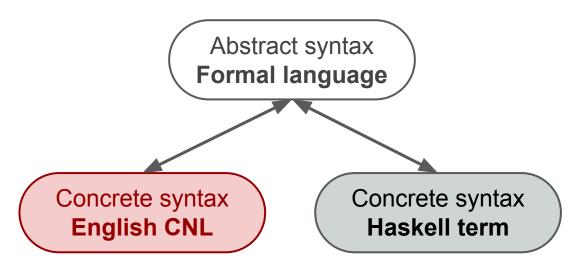
when all_cake is equal to 1 student must give a speech and guests may not take some cake

Grammatical Framework (GF)



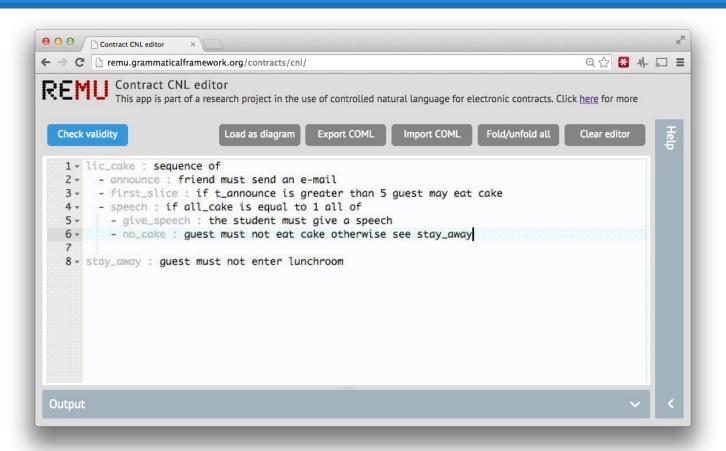
http://www.grammaticalframework.org/

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

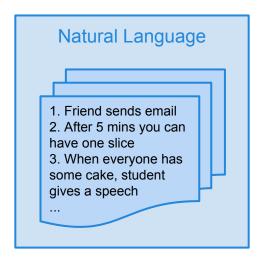


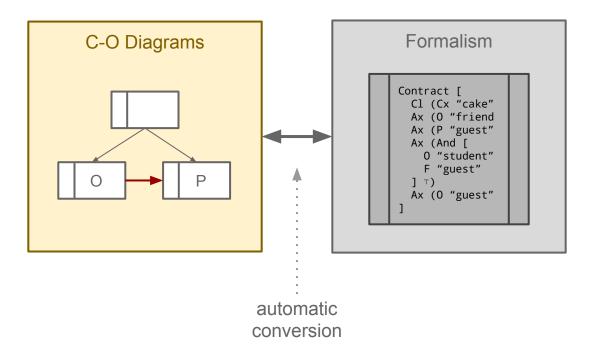
Tool: CNL editor

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



A visual representation

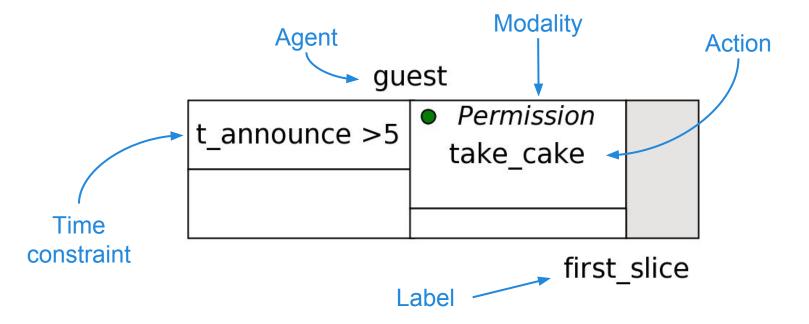




Contract-Oriented Diagrams

Martínez et al. 2010; Díaz et al. 2014

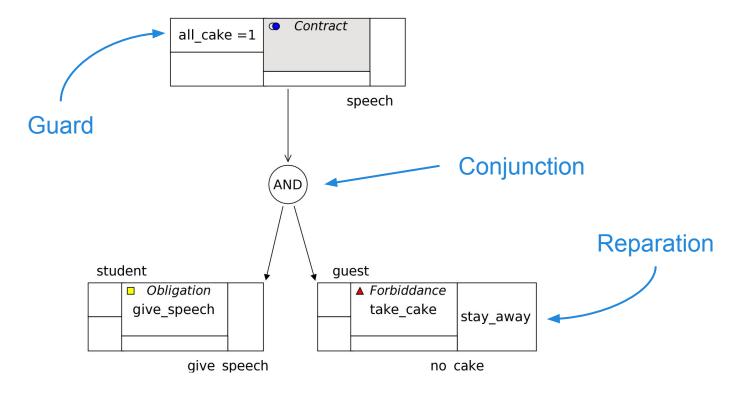
- A visual formalism for normative contracts
- Boxes as clauses:



Contract-Oriented Diagrams

Martínez et al. 2010; Díaz et al. 2014

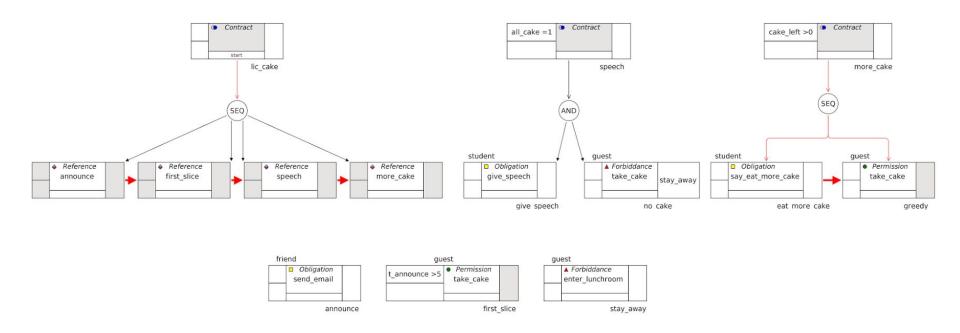
Edges show refinement



Contract-Oriented Diagrams

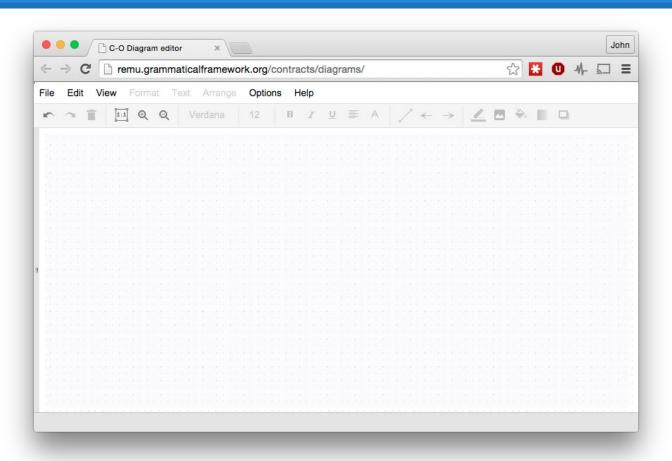
Martínez et al. 2010; Díaz et al. 2014

Contract is a forest of trees

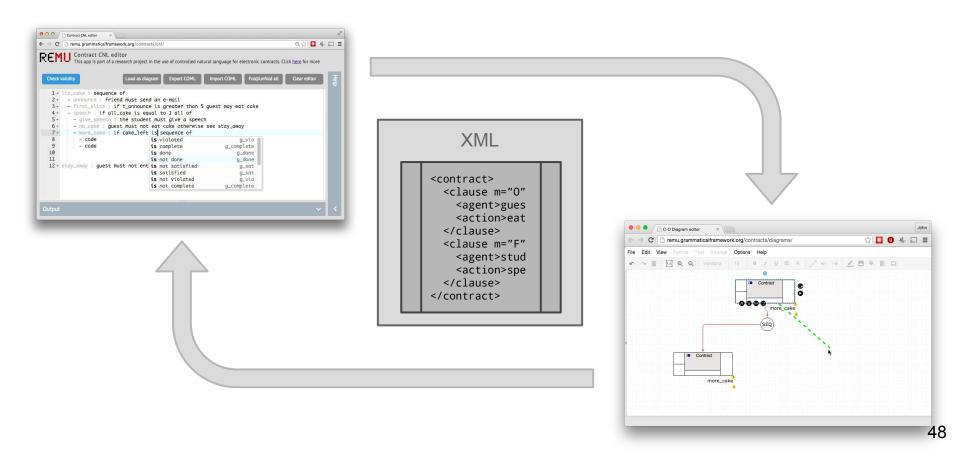


Tool: C-O Diagram editor

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

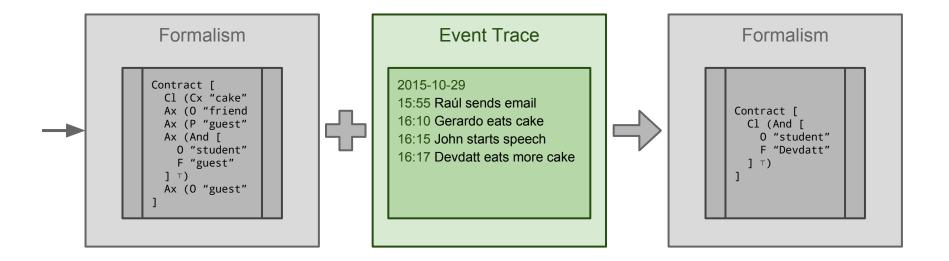


Tool communication



Analysis

Simulation



- 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?

An **event** is an action observed at a time A **trace** is a sequence of events

```
Event = (Agent, Action, TimeStamp)
Trace = [Event]
```

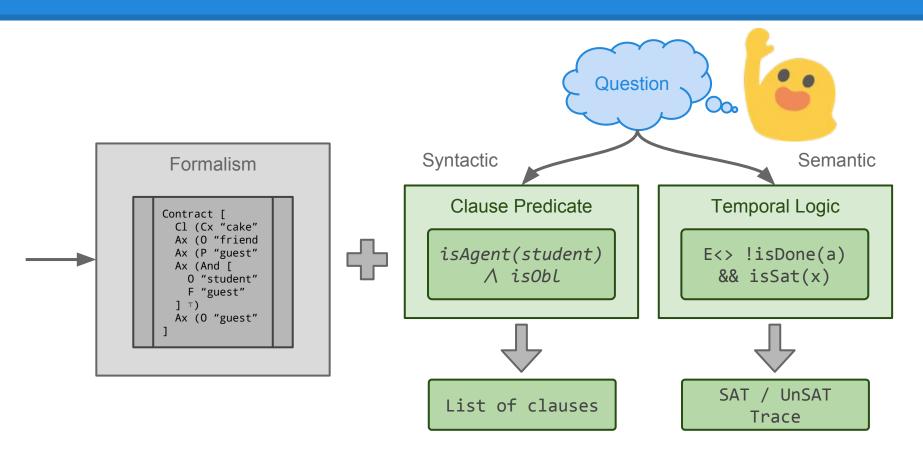
An **environment** is a context of variables and clocks, which vary over time

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

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

```
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

isObl ∧ ofAgent("student")

```
{ give_speech, eat_more_cake }
```

Syntactic queries

Prohibitions without reparations

isFor ∧ ¬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

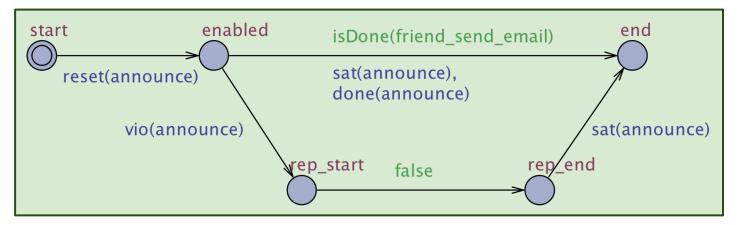
Model checking using UPPAAL

http://www.uppaal.org/

- 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")
上
```

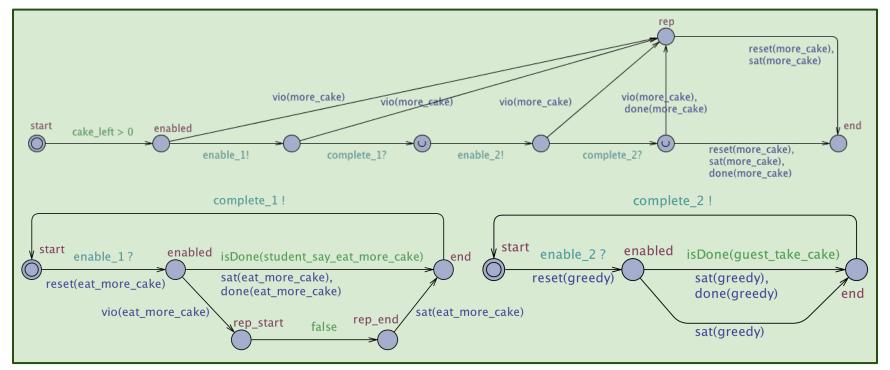


```
Seq

[ cake_left > 0 ]

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

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



Can a guest eat cake before the announcement?

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

Not satisfied

A guest cannot eat cake before the announcement.

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

Satisfied

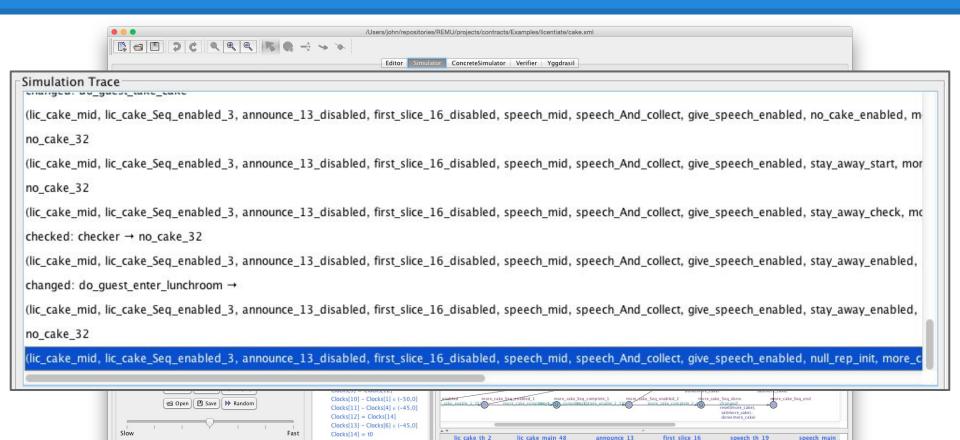
A guest never enters the lunchroom during the speech.

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

Not satisfied — but why?

Counter example trace

t0 = Clocks[0]



Where is the problem?

query?

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

translated automata?

start enabled isDone(friend_send_email) end
reset(announce) sat(announce),
done(announce)
vio(announce) sat(announce)
rep_start false rep_end

contract model?

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

T
```

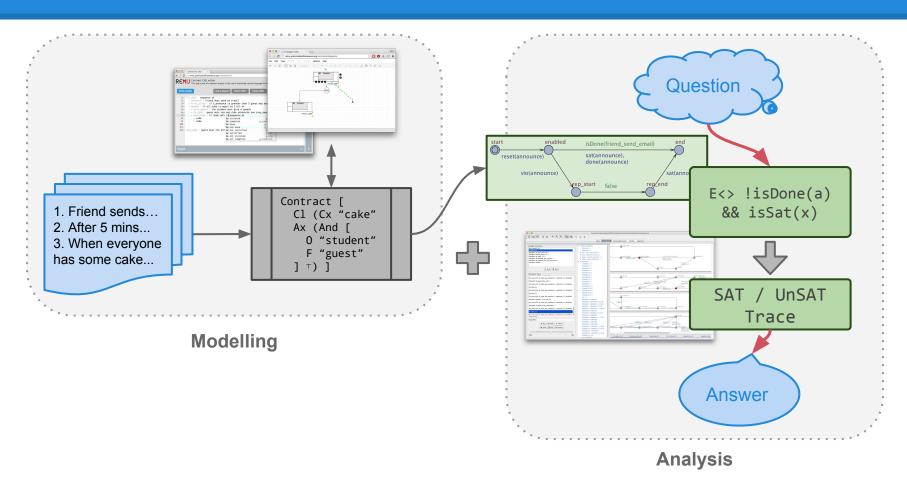
normative document?

- 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





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:O(friend.send_email)
// first_slice:[t_announce>5]P(guest.take_cake)
// speech:[all_cake=1]AND{give_speech:O(student.give_speech)
// stay_away:O(guest.dont_enter_lunchroom)
// more_cake:[cake_left=1]SEQ{ eat_more_cake:O(student.say_eat_
```

CNL: labels

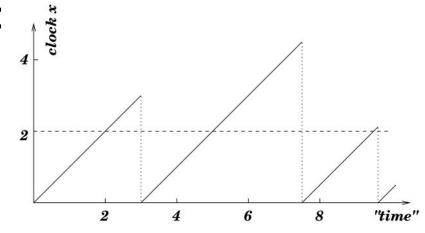
- All clauses must include a label
- Needed for guards, cross-refs, reparations
- Easily hidden with tools

```
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)

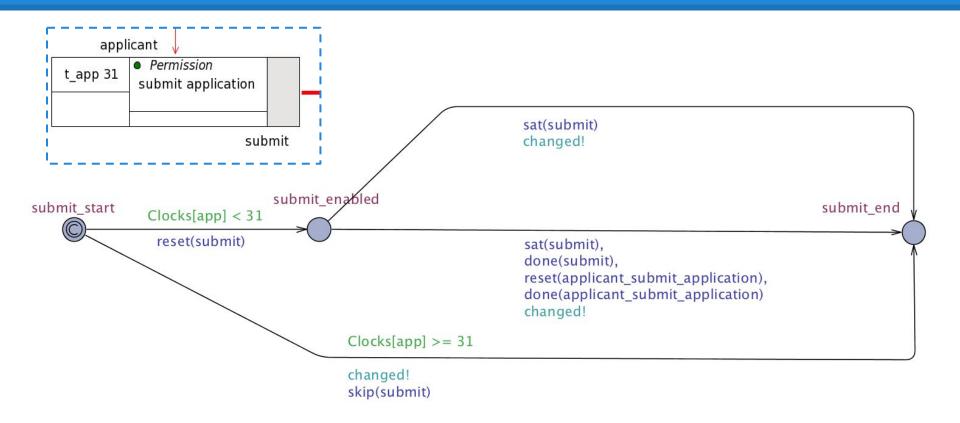
Finite state automata, with:

- Real-valued clocks
 - progress together
 - can be reset (to zero)

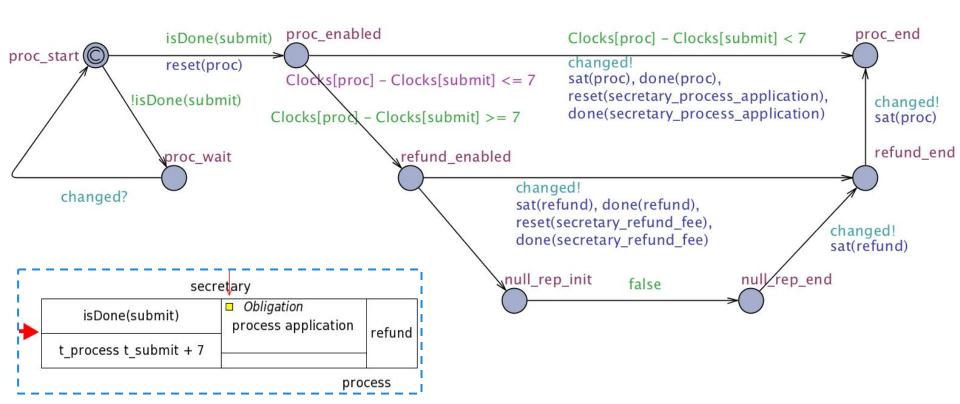


- Guards on transitions (over clocks, vars)
- Node invariants (over clocks, vars)

Translation to NTA: P

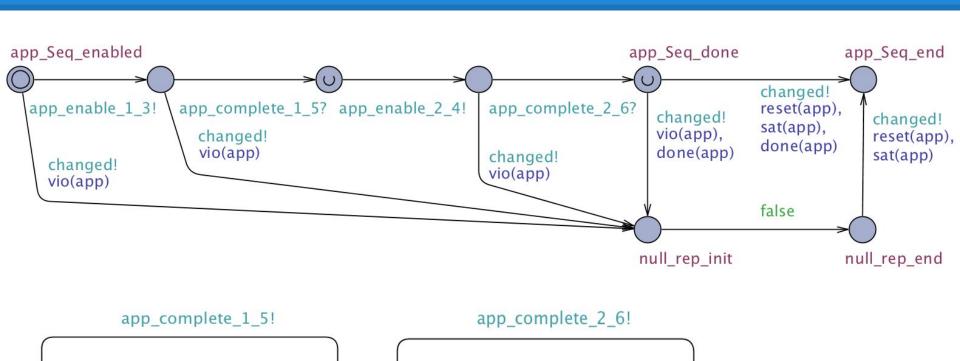


Translation to NTA: O



Translation to NTA: SEQ

app_enable_1 3?



app_enable_2_4?

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

UPPAAL requirement specification language

Name	Property	Equivalent to
Possibly	Ε<> φ	
Invariantly	Α[] φ	not E<> not φ
Potentially always	Ε[] φ	
Eventually	Α<> φ	not E[] not φ
Leads to	φ> ψ	A[] (φ imply A<> ψ)

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