A Petri net-based notation for normative modeling: evaluation on deontic paradoxes

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General Research Problem

• Aligning Law and Action
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  - law concerns a system of norms, that in abstract, in a fixed point in time, may be approached atemporally.
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  – when applied, law deals with a **continuous flow of events**.
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• Prototypical encounter: legal cases.
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• Prototypical encounter: legal cases.

• More general but similar problem: *narrative interpretation*. 
Looking for a notation
Steady states and transients

- Physical systems can be approached from steady state (equilibrium) or transient (non-equilibrium, dynamic) perspectives.
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- Steady states descriptions **omit** transient characteristics
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- Steady states descriptions omit transient characteristics
  
  ex. Ohm's Law
  \[ V = R \times I \]
Specifying transients and steady states

- Possible analogies:
  - steady state approach with
    - Logic
    - Declarative programming
Specifying transients and steady states

- Possible analogies:
  - *steady state* approach with
    - Logic
    - *Declarative* programming
  - *transient* approach
    - Process modeling
    - *Procedural* programming
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Petri Nets!
Specifying transients and steady states

- **Steady state** approach
  - Logic
  - **Declarative** programming

- **Transient** approach
  - Process modeling
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Petri Nets!
Specifying transients and steady states

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  - transient approach
    - Process modeling
    - Procedural programming

**Answer Set Programming**

**LPPN**
Logic Programming Petri Nets
procedural LPPN
procedural LPPN

- *token game*: transition disabled. It cannot fire.
procedural LPPN

- *token game*: transition enabled. It can fire.
procedural LPPN

- *token game*: transition fires: it will consume tokens from the input places.
procedural LPPN

- *token game*: ...and produce tokens in the outputs.
declarative LPPN for places

• Equivalent to

ASP/Prolog: \( p6 \leftarrow p4, p5. p5. \)
FOL: \( (p4 \land p5 \rightarrow p6) \land p5 \)
declarative LPPN for places

- Equivalent to

  ASP/Prolog: \( p6 \leftarrow p4, p5. p5. p4. \)

  FOL: \((p4 \land p5 \rightarrow p6) \land p5 \land p4\)
declarative LPPN for places

- Equivalent to
  
  ASP/Prolog: $p_6 :\neg p_4, p_5. p_5. p_4.$
  
  FOL: $(p_4 \land p_5 \rightarrow p_6) \land p_5 \land p_4$
declarative LPPN for transitions

- Equivalent to

  ASP/Prolog:  
  \[ t_4 :- \ t_2, \ p_8. \ t_3 :- \ t_2, \ p_9. \]

  FOL:  
  \[(t_2 \land p_8 \rightarrow t_4) \land (t_2 \land p_9 \rightarrow t_4)\]
declarative LPPN for transitions

- Equivalent to

   ASP/Prolog: \( t_4 :- t_2, p_8. \ t_3 :- t_2, p_9. \ t_2. \)

   FOL: \( (t_2 \land p_8 \rightarrow t_4) \land (t_2 \land p_9 \rightarrow t_4) \land t_2 \)
declarative LPPN for transitions

- Equivalent to
  ASP/Prolog:  \[ t4 \leftarrow t2, \ p8. \ t3 \leftarrow t2, \ p9. \ t2. \]
  FOL:  \((t2 \land p8 \rightarrow t4) \land (t2 \land p9 \rightarrow t4) \land t2\)
declarative LPPN for transitions

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• Contrary To Duty (CTD) structures:

  situations in which a primary obligation exists, and with its violation, a secondary obligation comes into existence.
Evaluating the LPPN notation

• Normative modeling is one of the purposes of the notation. We used it to model well-known problems defined by the deontic logic community.

• Contrary To Duty (CTD) structures:

  situations in which a primary obligation exists, and with its violation, a secondary obligation comes into existence.

• Common in e.g. compensatory norms.
A simple deontic paradox

• You are forbidden to cross the road.
• If you are crossing the road,
  (you have to) cross the road!
A simple deontic paradox

• You are forbidden to cross the road.

• If you are crossing the road, (you have to) cross the road!

• You are crossing.
A simple deontic paradox

- You are forbidden to cross the road.
- If you are crossing the road, (you have to) cross the road!
- You are crossing.

\[
\text{obl(not cross)} \\
\text{if cross then obl(cross)} \\
\text{cross}
\]
You mustn't cross the road.
If you are crossing the road, cross the road!

• Usual solution: preferences among possible worlds.
You mustn't cross the road.
If you are crossing the road, cross the road!

- Usual solution: preferences amongst possible worlds.
- Alternative solution:
  - implicit temporal meaning: *if you started crossing the road, finish to cross the road!*

→ Let us increase **granularity** of the model...
You mustn't cross the road.
If you are crossing the road, cross the road!
You mustn't cross the road.
If you are crossing the road, cross the road!

- You start crossing.
You mustn't cross the road.
If you are crossing the road, cross the road!

- You start crossing.
You mustn't cross the road. If you are crossing the road, cross the road!

- You start crossing.
You mustn't cross the road.
If you are crossing the road, cross the road!

- You are crossing.

- Not so realistic: intuitively, we still have such prohibition.
You mustn't cross the road.
If you are crossing the road, cross the road!

- You *finish* crossing.

- Not so realistic: intuitively, we still have such prohibition.
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- Not so realistic: intuitively, we still have such prohibition.
You mustn't cross the road.
If you are crossing the road, cross the road!
You mustn't cross the road.
If you are crossing the road, cross the road!

- You start crossing.

Diagram:
- Source firing
- Start crossing
- Crossing
- End crossing
- Obligation to cross
- Recognize satisfaction
- Recognize initiation
- Recognize violation
- Prohibition to cross
- Suspension
You mustn't cross the road. If you are crossing the road, cross the road!

• You start crossing.
You mustn't cross the road. If you are crossing the road, cross the road!

- You start crossing.

Diagram:
- Start crossing
- Crossing
- End crossing
- Recognition of violation
- Suspension
- Recognition of obligation to cross
- Production
You mustn't cross the road. If you are crossing the road, cross the road!

- You start crossing.
You mustn't cross the road. 
If you are crossing the road, cross the road!

- You *are* crossing.

Obligation has higher priority (topology captures *salience*).
Gentle murderer
[Forrester, 1984]

*It is forbidden to kill,*
*but if one kills,*
*one ought to kill gently.*
Gentle murderer
[Forrester, 1984]

It is forbidden to kill, but if one kills, one ought to kill gently.
Gentle murderer
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It is forbidden to kill, but if one kills, one ought to kill gently.

- He starts killing.
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Gentle murderer
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It is forbidden to kill, but if one kills, one ought to kill gently.

- He starts killing.
  (either he kills gently...)

Gentle murderer
[Forrester, 1984]

*It is forbidden to kill, but if one kills, one ought to kill gently.*

- He starts killing.
  *(either he kills gently or not.)*
There must be no fence.
*If there is a fence, it must be a white fence.*
*If the cottage is by the sea, there may be a fence.*
White fence

[Prakken & Sergot, 1996]

There must be no fence.
If there is a fence, it must be a white fence.
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exception, implicit default
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- There is a white fence.
White fence

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There must be no fence.  
If there is a fence, it must be a white fence.  
If the cottage is by the sea, there may be a fence.

- There is a white fence.
There must be no fence. If there is a fence, it must be a white fence. If the cottage is by the sea, there may be a fence.

- There is a white fence.
White fence

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If the cottage is by the sea, there may be a fence.

- There is a white fence.
Privacy Act

[Governatori, 2015]

- The collection of personal information is forbidden, unless acting on a court order authorising it.
- The destruction of illegally collected personal information before accessing it is a defence against the illegal collection of the personal information.
- The collection of medical information is forbidden, unless the entity collecting the medical information is permitted to collect personal information.
Privacy Act

[Governatori, 2015]

Forbidden A. If C, then Permitted A.
If Forbidden A and A, then Obligatory B.
Forbidden D. If Permitted A, then Permitted D.

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- A occurs.
Forbidden A. If C, then Permitted A.
If Forbidden A and A, then Obligatory B.
Forbidden D. If Permitted A, then Permitted D.

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Forbidden A. If C, then Permitted A.  
If Forbidden A and A, then Obligatory B.  
Forbidden D. If Permitted A, then Permitted D.

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extra-institutional ("brute") realm

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institutional realm

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constitutive rules
A bit further into deontic axioms
Factual detachment

\[ p \land \text{Obl}(q|p) \rightarrow \text{Obl}(q) \]
Deontic detachment

Obl(p) \land Obl(q|p) \rightarrow Obl(q)

Not implied by LPPN! It does not capture the anticipation.
Derived obligations

- *Bob’s promise to meet you commits him to meeting you.*
- *It is obligatory that if Bob promises to meet you, he does so.*
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  \[ p \rightarrow \text{Obl (m)} \]

- *It is obligatory that if Bob promises to meet you, he does so.*
  
  \[ \text{Obl (p } \rightarrow \text{ m)} \]
Derived obligations

- **Bob’s promise to meet you commits him to meeting you.**
  \[ p \rightarrow \text{Obl} \ (m) \]

- **It is obligatory that if Bob promises to meet you, he does so.**
  \[ \text{Obl} \ (p \rightarrow m) \]
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\[ 
\text{p,} \\
\text{either m..} 
\]
Derived obligations

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- \( p \),
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Derived obligations

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- \( p \),
- either \( m \), or \( \neg m \)
- but what about \( \neg p \)?
Derived obligations

- Bob’s promise to meet you commits him to meeting you.
  \[ p \rightarrow \text{Obl} (m) \]
- It is obligatory that if Bob promises to meet you, he does so.
  \[ \text{Obl} (p \rightarrow m) \]
Derived obligations

- Bob’s promise to meet you commits him to meeting you.
  \[ p \rightarrow \text{Obl} \ (m) \]

- It is obligatory that if Bob promises to meet you, he does so.
  \[ \text{Obl} \ (p \rightarrow m) \]

\[ p \land \neg m \]

\[ m \ldots \]
Derived obligations

- *Bob’s promise to meet you commits him to meeting you.*
  
  \[
  p \rightarrow \text{Obl} \ (m) \]

- *It is obligatory that if Bob promises to meet you, he does so.*
  
  \[
  \text{Obl} \ (p \rightarrow m) \]

- \(p \wedge \neg m\)
- \(m\) or \(\neg p\)
Chisholm’s paradox
[Chisholm, 1963]
Chisholm’s paradox
[Chisholm, 1963]

- It ought to be that Jones goes (to the assistance of his neighbors).
- It ought to be that if Jones goes, then he tells them he is coming.
- If Jones doesn’t go, then he ought not tell them he is coming.
- Jones doesn’t go.
Chisholm’s paradox
[Chisholm, 1963]

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- Jones doesn’t go.
Chisholm’s paradox
[Chisholm, 1963]

- You don't go.

\[
\begin{align*}
\text{Obl (go)} \\
\text{Obl (go }\rightarrow\text{ tell)} \\
\neg \text{go }\rightarrow\text{ Forb(tell)} \\
\neg \text{go} \\
\end{align*}
\]
Chisholm's paradox
[Chisholm, 1963]

- You don't go.
Chisholm’s paradox

[Chisholm, 1963]

\[ \text{Obl} \ (go) \]
\[ \text{Obl} \ (go \rightarrow \text{tell}) \]
\[ \neg \text{go} \rightarrow \text{Forb(tell)} \]
\[ \neg \text{go} \]

- You don't go ...
- You don't tell ...
Chisholm's paradox
[Chisholm, 1963]

\[ \text{Obl (go)} \]
\[ \text{Obl (go → tell)} \]
\[ \neg \text{go} \rightarrow \text{Forb(tell)} \]
\[ \neg \text{go} \]

- You don't go ...
- You tell them ...

\[ \begin{align*}
\text{Obl(go)} & \quad \text{satisfaction} \\
\text{violation} & \quad \text{go} \\
\neg \text{go} & \quad \text{satisfaction} \\
\neg \text{tell} & \quad \text{violation} \\
\text{tell} & \\
\end{align*} \]
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  - direct link with business process practices
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  - paradoxical cases are easily unveiled
  - direct link with business process practices
  - visual notation (animation of models through simulation make them in principle more accessible)
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- Defaults, exceptions, suspensions required extensions.
- \( \sim \) minimal commitment (cf. input/output logic)

\[
Obl(A) \land Obl(B) \sim Obl(A \land B)
\]
Conclusions

- We presented examples of application of a notation introduced for wider modeling purposes, but which can be applied for normative scenarios.
- Defaults, exceptions, suspensions required extensions.
- Interesting semantic correspondence with language
  - nouns, (imperfect) verbs ~ places/tokens
  - (perfect) verbs ~ transition/transition events
Conclusions

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- Defaults, exceptions, suspensions required extensions.
- Interesting semantic correspondence with **language**
  - nouns, (imperfect) verbs ~ places/tokens
  - (perfect) verbs ~ transition/transition events
- Working hypothesis: does the locutor usually provide the right granularity to avoid the paradox?