Disentangling Deontic Positions and Abilities: a Modal Analysis

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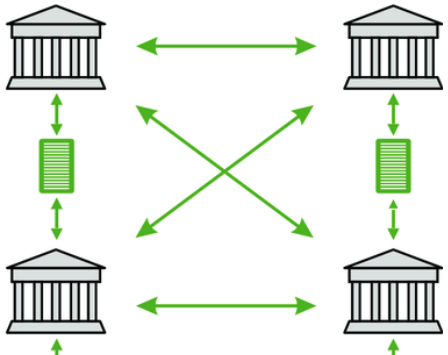
From individual devices to digital social systems...

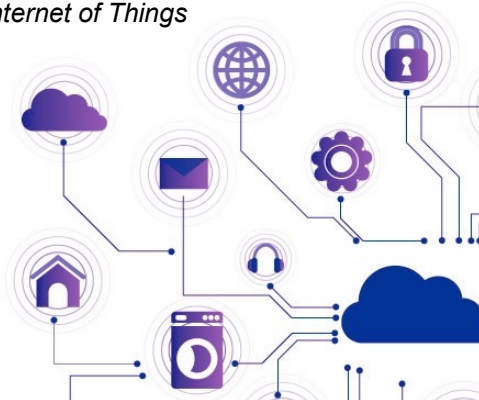
Social networks

Digital Markets

Distributed Ledgers

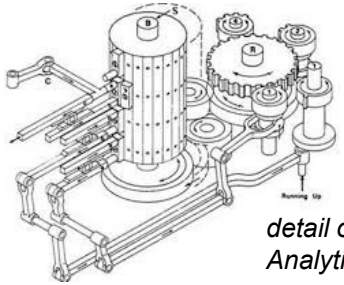


Internet of Things

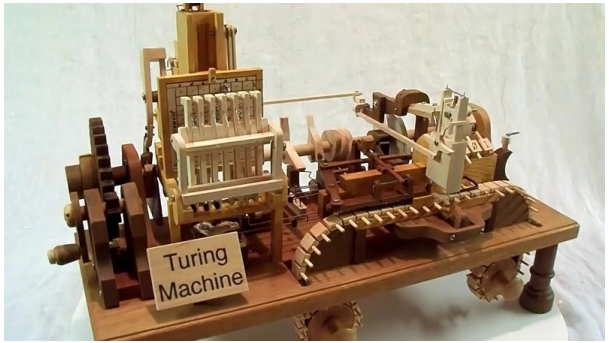


...from “mechanical” to institutional approaches to computation...

not *instructions,* but ***contracts***, ***regulations***, ***laws***..



detail of Babbage’s Analytical Engine



(finite) Turing machine

the medieval port of Genoa, flourishing with the introduction of insurances, contract options and other mechanisms of risk management

Contribution of the paper

- a language of multimodal logic with
  - alethic operators (w.r.t. *simultaneous* nodes)
  - temporal operators (w.r.t. *successive* nodes)
  - deontic operators

  involving **no** form of quantification

  capturing Hohfeld's framework of normative positions

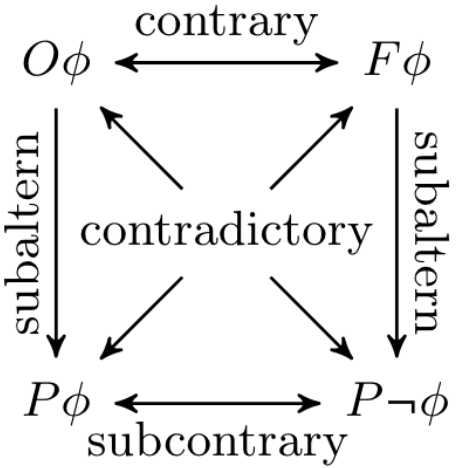
- first results on rendering fundamental coordination mechanisms
- proofs of soundness and completeness

Normative specifications (I): Control Models

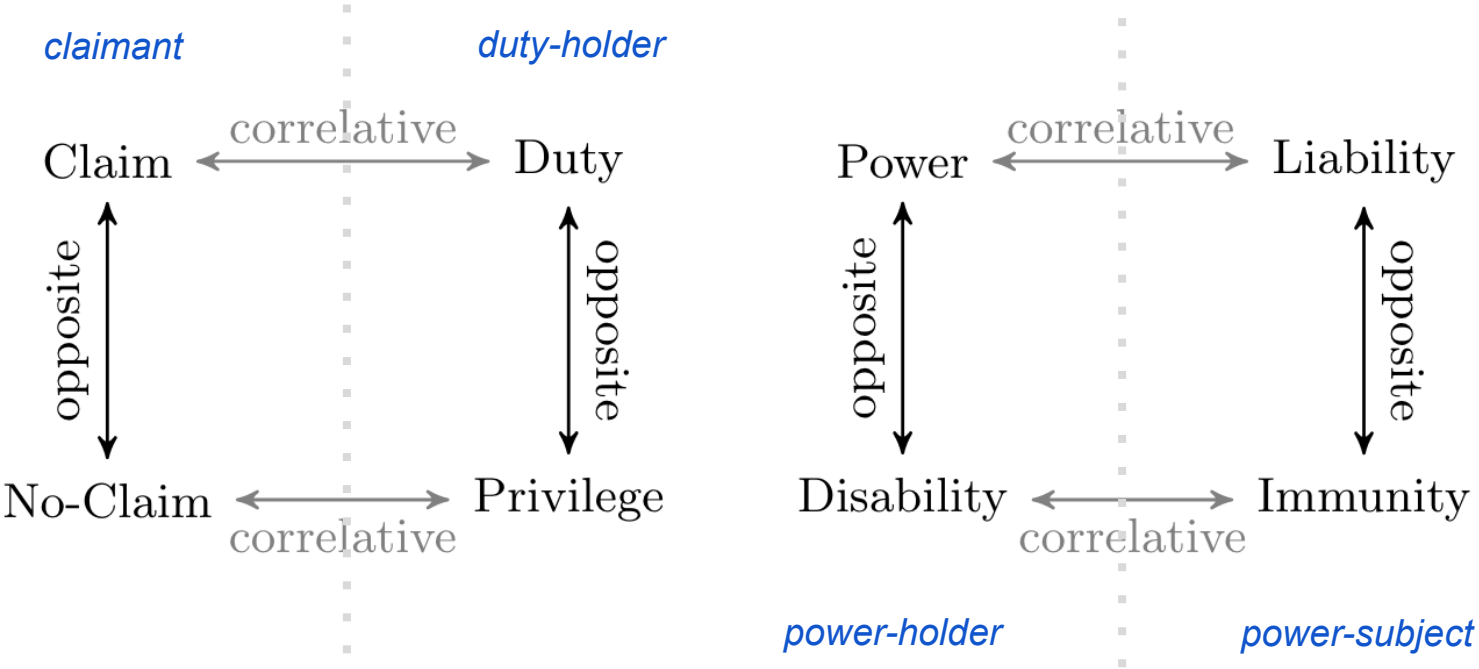
```
Order Deny,Allow
Deny from all
Allow from example.org
```

example from Apache webserver configuration

Normative specifications (II): Deontic Logic



Normative specifications (III): Hohfeld's framework



Types of normative specifications: Comparison

	Control models	Deontic Logic	Hohfeld's framework
permission	X	X	X
prohibition	X	X	X
obligation		**X**	X
power/ability			**X**
	1 party	1 party	**2 parties**
focus on	**actions**	**situations**	**actions**

Performer vs Observer perspectives

agent

action-type

```
def add(a, b):
    c = a + b
```

```
add(1, 3)
```

refined action

command

resource/object

```
global c
```

system

```
perform 1 + 3
write result in c
```

is agent enabled-allowed to do so?

consequence

```
c is set
to 4
```

observer/monitor

was agent allowed to do so?

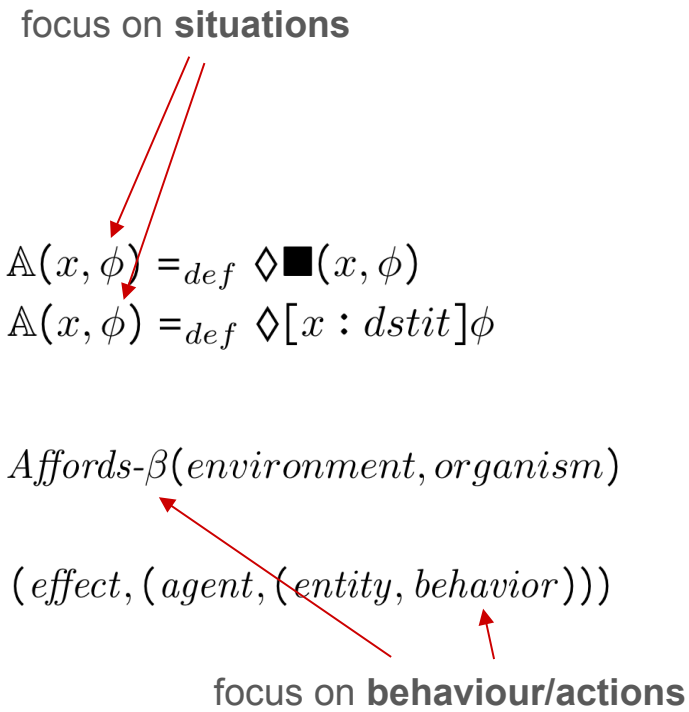
am I enabled to do so?
am I allowed to do so?

power/ability

permission

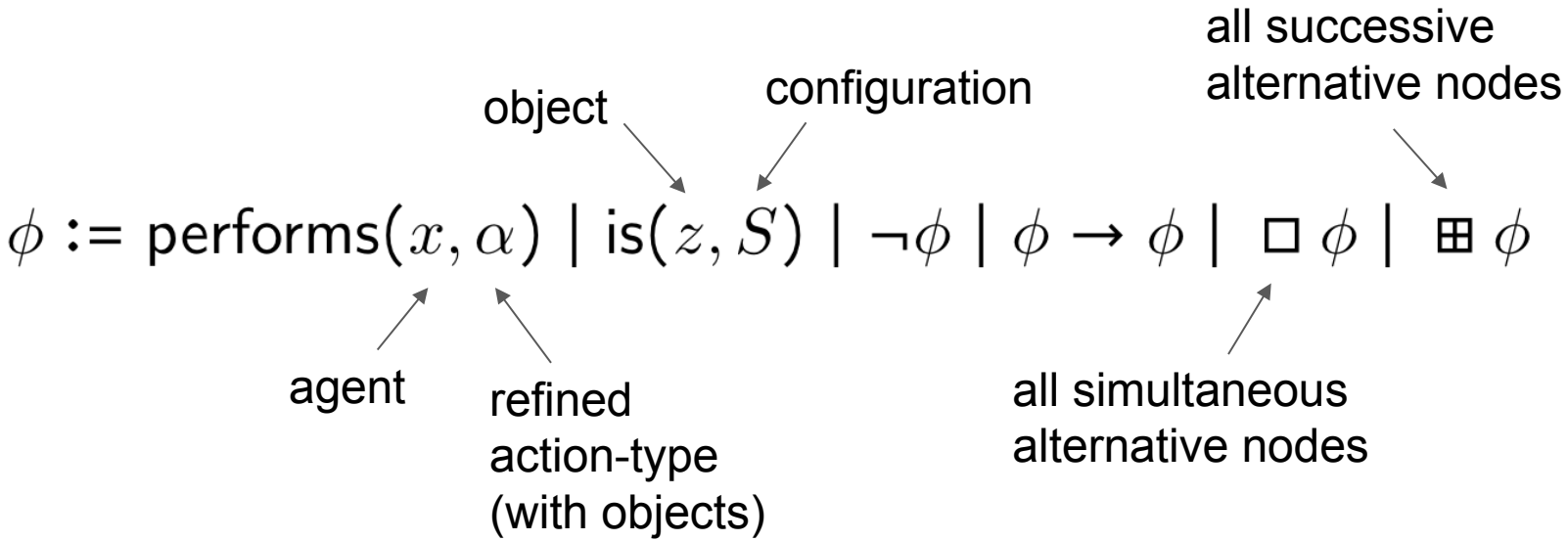
Ability

- Analytical literature
  - Brown [1988]
  - Brown [1992]
  - eg. Horty & Belnap [1995]
- Psychological literature
  - eg. Chemero [2003]
- Robotic literature
  - Sahin et al. [2007]
- `initiates` in Event Calculus



there is an analytical gap w.r.t. ability defined on actions!

Proposed Language



Configurations and propositions

- We consider a special object “*” for the ***whole system***. Configurations of the whole can be used to introduce 0-ary predicates in the language:

$$\mathsf{raining} =_{def} \mathsf{is}(*, raining)$$

- Vice versa, we can associate configurations of the whole system with the propositional formulas describing them:

$$\mathsf{is}(*, S_\phi) \leftrightarrow \phi$$

[Φ is here constrained not to contain any $\mathsf{is}(*, \ldots)$ to avoid recursion]

Ability as directed change

it is possible for the agent to perform the action

the target outcome is not present in all successive nodes

$$\mathsf{has\_ability}(x, \alpha, S_\phi) =_{def} \Diamond\mathsf{performs}(x, \alpha) \wedge \oplus\neg\mathsf{is}(*, S_\phi) \wedge$$
$$\Box\left[(\mathsf{performs}(x, \alpha) \wedge \neg\mathsf{is}(*, S_\phi)) \rightarrow \boxplus\mathsf{is}(*, S_\phi)\right]$$

in all simultaneous alternatives...

if the agent performs the action

and the target outcome is not present

then the target outcome is present in all successive nodes

Ability as directed change

it is possible for the agent to perform the action

the target outcome is not present in all successive nodes

CONTERFACTUALITY

$$\text{has\_ability}(x, \alpha, S_\phi) =_{def} \Diamond \text{performs}(x, \alpha) \wedge \oplus\!\!\!\!\!\!\diamond \neg \text{is}(*, S_\phi) \wedge$$

SUFFICIENCY

$$\Box \left[(\text{performs}(x, \alpha) \wedge \neg \text{is}(*, S_\phi)) \rightarrow \boxplus \text{is}(*, S_\phi) \right]$$

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in all simultaneous alternatives...

if the agent performs the action

and the target outcome is not present

then the target outcome is present in all successive nodes

we define similarly **negative ability** (inhibiting an outcome)..

Disability as uncontrollability

$$\mathsf{has\_disability}(x, \alpha, S_\phi) =_{def} \neg\mathsf{has\_ability}(x, \alpha, S_\phi) \wedge \neg\mathsf{has\_neg\_ability}(x, \alpha, S_\phi)$$

- Disability, positive and negative abilities can be used to introduce further notions as enabling and disabling actions, *interference*, etc.

Normative components

- We extend the language by allowing a finite prefixing sequence of deontic operators of the type ${}_xO_y$ (directed obligation)

$${}_xO_y\phi \iff \phi$$ is **obligatory**
for x (duty-holder)
w.r.t. y (claimant or claim-holder)

- We use the standard definitions of prohibition and permission:

$${}_xF_y\phi =_{def} {}_xO_y\neg\phi \quad {}_xP_y\phi =_{def} \neg{}_xO_y\neg\phi$$

Axiomatic Calculus

- We consider a calculus specified by the following axioms/rules:

$A0$ *All substitution instances of tautologies of the Propositional Calculus;*

$R0$ *Modus Ponens;*

$A1\text{-}R1$ $\mathbf{S5}$*-principles for the operator* $\Box$*;*

$A2\text{-}R2$ $\mathbf{K}$*-principles for the operator* $\boxplus$*;*

$R3$ *To infer* $({}_xO_y\phi \leftrightarrow {}_xO_y\psi)$ *from* $(\phi \leftrightarrow \psi)$*, for any* $x, y \in AGE$*.*

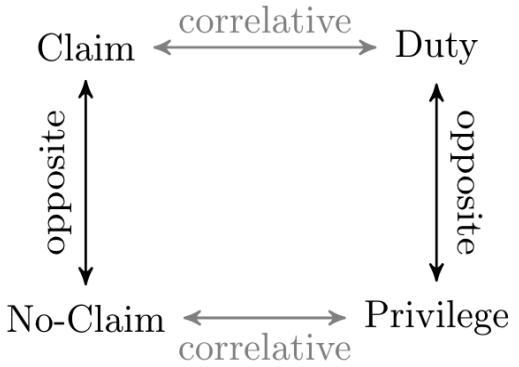
$A3$ $\Box \boxplus \phi \rightarrow \boxplus \Box \phi$*;*

$A4$ $\Diamond \boxplus \bot \rightarrow \Box \boxplus \bot$*;*

$A5$ ${}_xO_y\phi \rightarrow \Diamond \oplus \phi$*.*

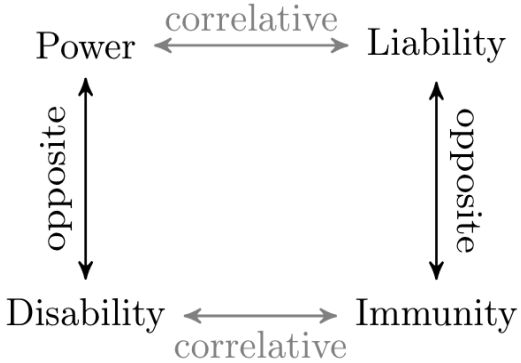
- Proven to be sound and complete w.r.t. its standard models.

Hohfeld's original framework



only actions performed by the duty-holder

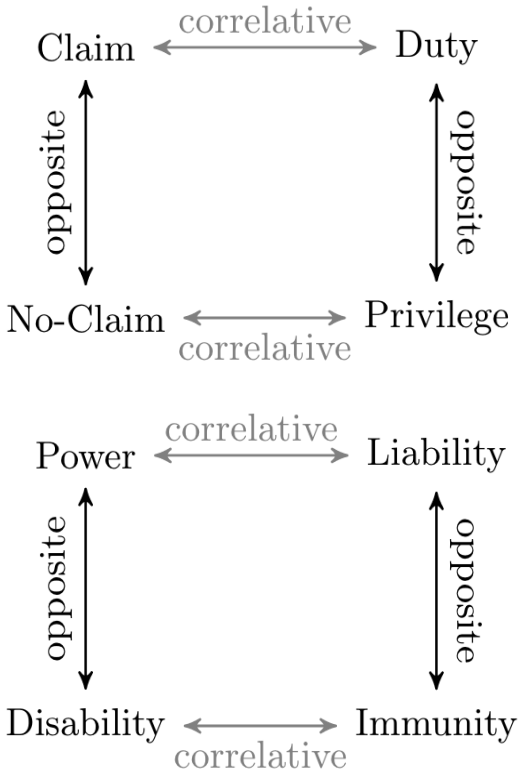
duty: ${}_xDT_y(\alpha) =_{def} {}_xO_y\mathsf{performs}(x,\alpha)$
claim-right: ${}_yCR_x(\alpha) =_{def} {}_xDT_y(\alpha)$
privilege (liberty): ${}_xPR_y(\alpha) =_{def} {}_xP_y\mathsf{performs}(x,\alpha)$
no-claim: ${}_yNC_x(\alpha) =_{def} {}_xPR_y(\alpha) \quad \wedge {}_xP_y\neg\mathsf{performs}(x,\alpha)$



only creation of obligations

power: ${}_xPOW_y(\alpha,\phi) =_{def} \mathsf{has\_ability}(x,\alpha,S_{{}_yO_x\phi})$
liability: ${}_yLBL_x(\alpha,\phi) =_{def} {}_xPOW_y(\alpha,\phi)$
disability: ${}_xDIS_y(\alpha,\phi) =_{def} \mathsf{has\_disability}(x,\alpha,S_{{}_yO_x\phi})$
immunity: ${}_yIMM_x(\alpha,\phi) =_{def} {}_xDIS_y(\alpha,\phi)$

Hohfeld's extended framework



any formula

duty: ${}_xDT_y(\phi) =_{def} {}_xO_y\phi$
claim-right: ${}_yCR_x(\phi) =_{def} {}_xDT_y(\phi)$
privilege (liberty): ${}_xPR_y(\phi) =_{def} {}_xP_y\phi \wedge {}_xP_y\neg\phi$
no-claim: ${}_yNC_x(\phi) =_{def} {}_xPR_y(\phi)$

any conjunction of normative positions

power: ${}_xPOW(\alpha, \phi') =_{def} \text{has\_ability}(x, \alpha, S_{\phi'})$
liability: ${}_yLBL_x(\alpha, \phi') =_{def} {}_xPOW_y(\alpha, \phi')$
disability: ${}_xDIS_y(\alpha, \phi') =_{def} \text{has\_disability}(x, \alpha, S_{\phi'})$
immunity: ${}_yIMM_x(\alpha, \phi') =_{def} {}_xDIS_y(\alpha, \phi')$

Examples of use: Sale contract

$$
\begin{aligned}
&{}_{y}POW(offer,\\
&\qquad {}_{x}POW(accept,\\
&\qquad\qquad {}_{x}DT_{y}(\mathsf{performs}(x, pay)) \wedge {}_{y}DT_{x}(\mathsf{performs}(y, deliver)))
\end{aligned}
$$

Examples of use: Data protection

$$ {}_{x}DT_{y}(\neg\mathsf{performs}(x, process)) \wedge $$
$$ {}_{x}POW(collect\_consent, {}_{x}PR_{y}(\mathsf{performs}(x, process))) $$

Examples of use: Exclusive delegation

$$
{}_{x}POW(\alpha, \phi) \wedge
$$

$$
{}_{x}POW(delegate, {}_{y}POW(\alpha, \phi) \wedge {}_{x}DIS(\alpha, \phi))
$$

Conclusion

- The paper reports on a research effort unifying insights from *modal logic* and *normative systems*, having in mind applications of complex cyber infrastructures and socio-technical systems.
- **Key message:** deep entrenchment between deontic and potestative categories, and the second ones are required to model complex coordination constructs (e.g. delegation).
- **Future developments**: investigation of enforcement mechanisms, of the relation of power with conditional obligations, introduction of objects/agents roles and more complex forms of refined actions.

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