

## Modeling Obligations with Event-Calculus

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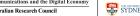
























Background



- Background
- Legal norms and issues with Event-Calculus



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- Extending Event-Calculus



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- Modeling obligations with Event-Calculus



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- Extending Event-Calculus
- Modeling obligations with Event-Calculus
- Conclusions





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  - must pay invoice before actual delivery of the goods



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  - continuously monitor patient's BP and ECG during the operation



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Generic Temporal Aspects of Obligations



# Background: continue...



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Norms control the behaviour of their subjects.

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- · Norms control the behaviour of their subjects.
- Deontic effects (a.k.a normative effects) are of interest from business process compliance perspective

#### The basic *deontic effects* are:

- Obligations
- Permissions
- Prohibitions







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- Formalism for reasoning about 'event and change' and effects of change over time



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- Formalism for reasoning about 'event and change' and effects of change over time
- Event-Calculus reifies fluents and events

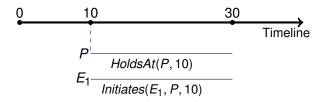
Axioms	Mearnings
Basic	
InitiallyTrue(P)	The fluent P is true from the beginning of time.
InitiallyFalse(P)	The fluent $P$ is false from the beginning of time.
Happens(X, T)	Event $X$ occurs at time $T$ .
Initiates(X, P, T)	Event $X$ initiates the variable (fluent) $P$ at time $T$ .
HoldsAt(P, T)	The variable (fluent) $P$ holds at time $T$ .
Terminates(X, P, T)	Event $X$ terminates the variable (fluent) $P$ at time $T$
Auxiliary	
Clipped $(T_1, P, T_2)$	The variable (fluent) P is interrupted sometime
	between $T_1$ and $T_2$ .
$Declipped(T_1, P, T_2)$	The variable (fluent) P is resumed/initiates
	sometime between $T_1$ and $T_2$ .
Independent	
$HoldsAt(P, T_2) \leftarrow$	$HoldsAt(P, T_1) \land (T_1 < T_2) \land \neg Clipped(T, P, T_1)$
$HoldsAt(P, T_2) \leftarrow$	$Happens(P, T_1) \land Initiates(X, P, T_1) \land (T_1 < T_2) \land \neg Clipped(T_1, P, T_2).$
$\neg HoldsAt(P, T_2) \leftarrow -$	$Happens(X, T_1) \land Terminates(X, P, T_1) \land (T_1 < T_2) \land \neg Declipped(T_1, P, T_2)$
$\neg HoldsAt(P, T_2) \leftarrow$	$\neg HoldsAt(P, T_1) \land (T_1 < T_2) \land \neg Declipped(T_1, P, T_2)$
$Clipped(T_1, P, T_2) \stackrel{\text{def}}{=}$	$\exists X, T : Happens(X, T) \land (T_1 \leq T < T_2) \land Terminates(X, P, T)$
$Declipped(T_1, P, T_2) \stackrel{\text{def}}{=}$	$\exists X, T : Happens(X, T) \land (T_1 \leq T < T_2) \land Initiates(X, P, T)$



<sup>&</sup>lt;sup>1</sup>Australian Telcos Consumer Protection Code http://www.commsalliance.com.au/Documents/all/codes/c628



 Issue-1: an obligation may enter into force at the same time of initiating an event but not from the next instant.



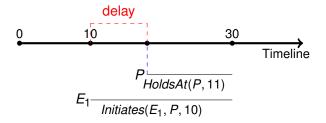
- Example: TCPC2012, Article 8.2.1<sup>1</sup>
  - (i) Acknowleding a complaint:
    - A *immediately* where the complaint is made in person or by phone.
    - A within 2 working days from the receipt where a written complaint is made e.g., by Email.

<sup>&</sup>lt;sup>1</sup> Australian Telcos Consumer Protection Code http://www.commsalliance.com.au/Documents/all/codes/c628





 Issue-2: an obligation may not enter into force immediately after the occurrence of the event but after some time delay

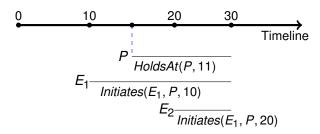


Example: LPMA Complaint Handing Guidelines(2009)
 A complaint cannot be acknowledged until all the relevant details have been received.





 Issue-3: base predicate initiates may not guarantee the fluent in its arguments is actually initiated by the event.





Proposed new predicates and events for modeling obligations

#### **Predicates**

DHoldsAt(P, T) DTerminates( $O^{x,T}X$ , N,  $T_{ter}$ ) FulfillTerminable( $O^{x,T}X$ ) ViolationTerminable( $O^{x,T}X$ )

#### **Events**

 $(trigger(O^{x,T}X, N), T_t)$   $(Deadline(O^{x,T}X), T_d)$   $(Violation(O^{x,T}X), T_v)$  $Compensation(O^{y,T_{sc}}Q, O^{y,T_s}P)$ 



DHoldsAt(P, T)

- Meanings the 'deontic fluent' P deontically holds at time T
- Differs from classical predicates HoldsAt on the conditions of Initiates
- Takes two arguments as HoldsAt predicate.



•  $(trigger(O^{X,T}X, N), T_t)$ 

- Meant to capture the deontic initiation of an obligation fluent
- Takes two arguments, where
  - O<sup>X</sup> is the obligation modality, T is time of obligation initiation and X is obligation fluent
  - N models delay and T<sub>t</sub> is time of triggering event



DTerminates(E, P, N, T<sub>ter</sub>)

- An event E, with time delay N, deontically termiantes the 'deontic fluent' P at time T<sub>der</sub>
- N determines the time distance between the terminating event happens and actual termination of the deontic fluent
- T<sub>ter</sub> is the time of termination



• Deadline( $O^{x,T}X, T_d$ )

- Aim to signal the deadline
- Takes two arguments, where
  - (O<sup>X,T</sup>X), X is deontic fluent with modality and time of initiation, and
  - T<sub>d</sub> represents the time of deadline event occurrence.



• (Violation( $O^{x,T}X$ ),  $T_v$ )

- Aim to signal the violation of an obligation
- (O<sup>x,T</sup>X) where O<sup>x,T</sup> is obligation with modality, X is a deontic fluent
- T<sub>V</sub> is time of violation



(Compensates( $O^{y,T_{s_c}}Q,O^{X,T_s}P$ ),  $T_{s_c}$ )

- (O<sup>y,T<sub>sc</sub></sup>Q), Q is a deotic fluent, with modality, compensating another deontic fluent P.
- T<sub>Sc</sub> is time of compensation



FulfillTerminable(O<sup>x,T</sup>X)

- A boolean switch to check whether an obligation terminable upon fulfillment
- The conditions for the predicate are provided by the Analyst.



ViolationTerminable(O<sup>x,T</sup>X)

- A boolean switch to check whether an obligation terminable upon violation
- The conditions for the predicate are provided by the Analyst.



# Allows to model all case of obligations

## **Auxiliary Predicates**





(A1)

 Fluent P continues to holds until an event occurs to terminates it (temporarily or permanently)

$$HoldsAt(P, T_2) \leftarrow Happens(P, T_1) \wedge Initiates(X, P, T_1) \wedge (T_1 < T_2) \wedge \neg Clipped(T_1, P, T_2)$$



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 (A1)

Fluent P does not continue to hold until an event occurs to resume it.

$$\neg HoldsAt(P, T_2) \longleftarrow Happens(X, T_1) \land Terminates(X, P, T_1) \land (T_1 < T_2) \land \neg Declipped(T_1, P, T_2)$$
 (A2)



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Not deontically Holds (after termination).

$$\neg DHoldsAt(X, T + 1) \longleftarrow \exists E : DTerminates(E, X, N, T)$$
 (A3)



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No fluent deontically holds.

$$\neg DHoldsAt(X, T_k) \longleftarrow \neg DHoldsAt(X, T) \land \\ Happens(trigger(X, N), T_i) \land (T \leq T_k) \land (T \leq T_i + N \leq T_k)$$
(A4)

# Modeling Obligations with Event-Calculus



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#### Example

Australian Telecommunications Consumers Protection Code 2012 (TCPC 2012)<sup>a</sup>. Article 8.2.1.

A Supplier must take the following actions to enable this outcome:

- (a) **Demonstrate fairness, courtesy, objectivity and efficiency:** Suppliers must demonstrate, fairness and courtesy, objectivity, and efficiency by:
  - (i) Acknowledging a Complaint:
    - A. immediately where the Complaint is made in person or by telephone;
    - B. within 2 Working Days of receipt where the Complaint is made by email; ...

<sup>a</sup>Australian Telecomm Consumers Protection Code (TCPC 2012), http://www.commsalliance.com.au/Documents/all/codes/c628



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Predicates for Punctual Obligation

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- Predicates for Punctual Obligation
  - DHoldsAt Predicate

$$DHoldsAt(O^{p,T_s}X,T_s) \leftarrow \\ \exists T_t, N : Happens(trigger(O^{p,T_s}X,N),T_t) \land \\ (T_s = T_t + N) \land N \geq 0$$
 (A5)



- Predicates for Punctual Obligation
  - DHoldsAt Predicate

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 (A5)

DTerminates Predicate

DTerminates(trigger(
$$O^{p,T_s}X, N$$
),  $T_e$ )  $\leftarrow \exists T_t, N : Happens(trigger( $O^{p,T_s}X, N$ ),  $T_t$ ) $\land (T_e = T_s) \land (T_s = T_t + N) \land N \ge 0$  (A6)$ 



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Violation Predicate

Happens(violation(
$$O^{p,T_s}X$$
),  $T_v$ )  $\leftarrow$ 

$$DHoldsAt(O^{p,T_s}X, T_s) \land (\neg Happens(X, T_s) \land \neg HoldsAt(X, T_s)) \land (T_v = T_s)$$
(A7)



(D1)

• Domain Predicates for TCPC (2012), Article 8.2.1 (A)

$$Happens(trigger(O^{p,T}Acknowledge, 0), T) \leftarrow Happens(complaint, T) \land (HoldsAt(inPerson, T) \lor HoldsAt(byPhone, T))$$



• Domain Predicates for TCPC (2012), Article 8.2.1 (A)

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 (D1) 
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• Domain Axiom D1 gives (trigger(Op,T Acknowledge, 0), T), and



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- Domain Axiom D1 gives (trigger(O<sup>p,T</sup> Acknowledge, 0), T), and
- From Axioms (A5, A6) and (A3),  $DHoldsAt(O^{p,T}X, T_s)$  and  $\neg DHoldsAt(X, T + 1)$



Domain Predicates for TCPC (2012), Article 8.2.1 (A)

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- From Axioms (A5, A6) and (A3), DHoldsAt(O<sup>p,T</sup>X, T<sub>s</sub>) and
   ¬DHoldsAt(X, T + 1)
- Modeling obligation as an Event Happens(Ackowledge, T), the conditions of violation do not hold.



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- Domain Axiom D1 gives (trigger(Op, T Acknowledge, 0), T), and
- From Axioms (A5, A6) and (A3),  $DHoldsAt(O^{p,T}X, T_s)$  and  $\neg DHoldsAt(X, T + 1)$
- Modeling obligation as an Event Happens(Ackowledge, T), the conditions of violation do not hold.
- Axiom (A7) gives ¬Happens(X, T<sub>s</sub>) ∧ ¬HoldsAt(X, T<sub>s</sub>)





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- Proposed Deontic extension to Event-Calculus
  - introduced new predicates and events
- Elegantly increases the expressive power for modeling legal norms
- Comparison with other formalisms e.g., Temporal Logic, FOL, Deontic-Logic is intended.



# Thank You

Suggestion & Comments email:{mustafa.hashmi,guido.governatori}@nicta.com.au m.wynn@qut.edu.au





A persistent obligation with natural deadline

$$DHoldsAt(O^{per,T_S}X,T_k) \leftarrow \\ \exists T_t, N : Happens(trigger(O^{per,T_S}X,N),T_t) \land \\ \neg DClipped(T_S,O^{per,T_S}X,T_k) \land \\ DTerminates(trigger(O^{per,T_S}X,N),T_e) \land \\ (T_S = T_t + N) \land (T_R > T_S) \land (T_S < T_k < T_R) \land N > 0 \end{cases}$$
(A8)



A persistent obligation with natural deadline

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ullet 'natural deadline' mean no other event happens between  $T_{\mathcal{S}}$  and  $T_{\mathcal{C}}$ 



A persistent obligation with natural deadline

$$DHoldsAt(O^{per,T_S}X,T_k) \leftarrow \\ \exists T_t, N : Happens(trigger(O^{per,T_S}X,N),T_t) \land \\ \neg DClipped(T_S,O^{per,T_S}X,T_k) \land \\ DTerminates(trigger(O^{per,T_S}X,N),T_e) \land \\ (T_S = T_t + N) \land (T_R > T_S) \land (T_S < T_k < T_e) \land N > 0 \end{aligned}$$
(A8)

- 'natural deadline' mean no other event happens between  $T_s$  and  $T_e$
- T<sub>e</sub> is determined by the same event.



- Cases of Achievement Obligations
  - 1 when the obligation has no temrination point.

$$DHoldsAt(O^{a,T_s}X, T_s) \leftarrow \\ \exists T_t, N : Happens(trigger(O^{a,T_s}X, N), T_t) \land \\ (T_s = T_t) \land N \ge 0$$
 (A9)

when the obligation holds at a particular time instance, deontically initiates and not clipped between interval

$$DHoldsAt(O^{a,T_s}X,T_k) \leftarrow \\ DHoldsAt(O^{a,T_s}X,T_s) \land \neg Declipped(T_s,O^{a,T_s}X,T_k) \land \\ (T_s \leq T_k)$$
 (A10)