Remedial interchange, Contrary-to-duties, and Commutation

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Introduction

- Research idea
  - Can deontic logic be used to capture the normative aspect(s) of dialogues?
- Standard ACL approach in MAS
  - Conversation policies = hard constraints
- What I'm after: a more flexible approach
  - NorMAS: breach of dialogue rules allowed ...
  - ... and dealt with
    - Norm violation: a hot topic in deontic logic
    - No easy answers

Talk overview

Focus on

- Logic for conditional obligation (Hansson, ...)

Case study (sort of)

- “Remedial Interchange" (Ervin Goffman)
  - Norms

Point twofold

- Contrary-to-duty paradox
- Solution using iterated belief change theory

What we get

- Dialogue model based on obligations
  - Rules of turn-taking
  - Tailored for a specific application domain

Layout

- CTD and remedial interchange
- Framework
- Example analysis

Contrary-to-duty (CTD)

Weakening the Consequent

$$\frac{\bigcirc(B/A) \qquad \Box(B \rightarrow C)}{\bigcirc(C/A)}\ (WC)$$

Factual Detachment

$$\frac{\bigcirc(B/A) \qquad A}{\bigcirc B}\ (FD)$$

Contrary-to-duty (CTD)

Weakening the Consequent

$$\frac{\bigcirc(B/A) \qquad \Box(B \to C)}{\bigcirc(C/A)}\ (WC)$$

Factual Detachment

$$\frac{\bigcirc(B/A) \qquad A}{\bigcirc B}\ (FD)$$

CTD paradox

$$\frac{\bigcirc\neg A \qquad \dfrac{\Box(B \to A)}{\Box(\neg A \to \neg B)}}{\bigcirc\neg B}\ (WC)$$

$$\frac{\bigcirc(B/A) \qquad A}{\bigcirc B}\ (FD)$$

Contrary-to-duty (CTD)

Weakening the Consequent

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CTD paradox

$$\frac{\bigcirc\neg A \qquad \dfrac{\Box(B \to A)}{\Box(\neg A \to \neg B)}}{\bigcirc\neg B}\ (WC)$$

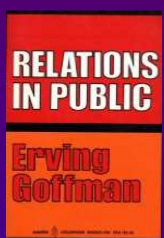
$$\frac{\bigcirc(B/A) \qquad A}{\bigcirc B}\ (FD)$$

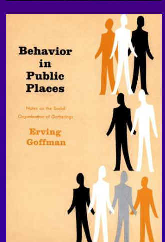
'Gentle murderer' scenario

$$\{\bigcirc\neg k, \Box(k \wedge g \to k), \bigcirc(k \wedge g/k), k\} \vdash \bot$$

Remedial interchange

Chap. 3 of *Relations in Public* (1971)





- Social life as norm-governed
- "Territories of the self"
  - Personal space
  - Possessionnal territory
  - Etc
- Remedial interchange
  - Offensive → acceptable
  - Social order

Remedial interchange

Goffman, *Relations in Public*, 1971

A: "Can I use your phone to make a local call?"

B: "Sure, go ahead"

A: "That's very good of you"

B: "It's okay"

Remedial interchange

Goffman, *Relations in Public*, 1971

remedy	*A: “Can I use your phone to make a local call?”*
relief	*B: “Sure, go ahead”*
appreciation	*A: “That’s very good of you”*
minimization	*B: “It’s okay”*

Remedial interchange

Goffman, *Relations in Public*, 1971

remedy	*A: "Can I use your phone to make a local call?"*
relief	*B: "Sure, go ahead"*
appreciation	*A: "That's very good of you"*
minimization	*B: "It's okay"*

Goffman's suggestion

By making a move, I put the other participant under the *obligation* to make the next one.

Dialogue game rules are soft rather than hard constraints

Logical representation

	Normative premisses (α)	Integrity constraints (β)
(I)	$\bigcirc \neg o$	
(II)	$\bigcirc(r_1/o)$	$\Box(r_1 \rightarrow o)$
	$\bigcirc(r_2/o \wedge r_1)$	$\Box(r_2 \rightarrow (o \wedge r_1))$
(III)	$\bigcirc(a/o \wedge r_1 \wedge r_2)$	$\Box(a \rightarrow (o \wedge r_1 \wedge r_2))$
	$\bigcirc(m/o \wedge r_1 \wedge r_2 \wedge a)$	$\Box(m \rightarrow (o \wedge r_1 \wedge r_2 \wedge a))$

with o= offence r_2= relief m= minimization

r_1= remedy a= appreciation

Conditional obligation

Preference-based semantics *à la* Hansson (1969)

$$\mathcal{M} \models \bigcirc(B/A) \Leftrightarrow \mathrm{min}_{\mathcal{M}}(A) \subseteq [B]_{\mathcal{M}}. \qquad \text{(Def}\bigcirc\text{)}$$

Intuitively: $\mathcal{M}$ satisfies $\bigcirc(B/A)$ iff in the most perfect worlds, where A holds, B holds too.

$\bigcirc B$ short for $\bigcirc(B/\top)$

Before the violation

S={ $\bigcirc\neg o$, $\bigcirc(r_1/o)$, $\bigcirc(r_2/o \wedge r_1)$,
$\bigcirc(a/o \wedge r_1 \wedge r_2)$, $\bigcirc(m/o \wedge r_1 \wedge r_2 \wedge a)$ }

Model $\mathcal{M}_1$

$w_1 : \neg o, \neg r_1, \neg r_2, \neg a, \neg m$ $\qquad$ $w_2 : o, r_1, r_2, a, m$

$w_3 : o, \neg r_1, \neg r_2, \neg a, \neg m$ $\qquad$ $w_4 : o, r_1, \neg r_2, \neg a, \neg m$

$w_5 : o, r_1, r_2, \neg a, \neg m$ $\qquad$ $w_6 : o, r_1, r_2, a, \neg m.$

$\bullet w_i$ (for all $i = 3, ..., 6$)

more perfect $\downarrow$

$\bullet w_2$

$\downarrow$

$\bullet w_1$

Before the violation

S={ $\bigcirc\neg o$, $\bigcirc(r_1/o)$, $\bigcirc(r_2/o \wedge r_1)$,
$\bigcirc(a/o \wedge r_1 \wedge r_2)$, $\bigcirc(m/o \wedge r_1 \wedge r_2 \wedge a)$ }

Model $\mathcal{M}_1$

$$w_1 : \neg o, \neg r_1, \neg r_2, \neg a, \neg m \qquad w_2 : o, r_1, r_2, a, m$$

$$w_3 : o, \neg r_1, \neg r_2, \neg a, \neg m \qquad w_4 : o, r_1, \neg r_2, \neg a, \neg m$$

$$w_5 : o, r_1, r_2, \neg a, \neg m \qquad w_6 : o, r_1, r_2, a, \neg m.$$

$\bullet w_i$ (for all $i = 3, ..., 6$)

more perfect $\downarrow$

$\bullet w_2$

$\bullet w_1$

$$\boxed{\mathcal{M}_1 \models \bigcirc\neg r_1, \mathcal{M}_1 \not\models \bigcirc r_1}$$

(WC) vs (FD)

$$(\mathcal{WC})\ \frac{\bigcirc\neg o \qquad \dfrac{\Box(r_1 \rightarrow o)}{\Box(\neg o \rightarrow \neg r_1)}}{\bigcirc\neg r_1}$$

$$\frac{\bigcirc(r_1/o)}{\bigcirc r_1}$$

(WC) vs (FD)

$$\text{(WC)}\ \frac{\bigcirc\neg o \qquad \dfrac{\Box(r_1 \rightarrow o)}{\Box(\neg o \rightarrow \neg r_1)}}{\bigcirc\neg r_1}$$

$$\frac{\bigcirc(r_1/o) \qquad \color{red}{o}}{\bigcirc r_1}\ \text{(FD)}$$

(WC) vs (FD)

$$\text{(WC)}\ \dfrac{\bigcirc\neg o \qquad \dfrac{\Box(r_1 \rightarrow o)}{\Box(\neg o \rightarrow \neg r_1)}}{\bigcirc\neg r_1} \qquad\qquad \dfrac{\bigcirc(r_1/o) \qquad o}{\bigcirc r_1}\ \text{(FD)}$$

An old idea ...

- Both rules allowed
- In case of conflict, (FD) overrides (WC)

(WC) vs (FD)

$$\text{(WC)}\ \frac{\bigcirc\neg o \qquad \dfrac{\Box(r_1 \rightarrow o)}{\Box(\neg o \rightarrow \neg r_1)}}{\bigcirc\neg r_1} \qquad\qquad \frac{\bigcirc(r_1/o) \qquad o}{\bigcirc r_1}\ \text{(FD)}$$

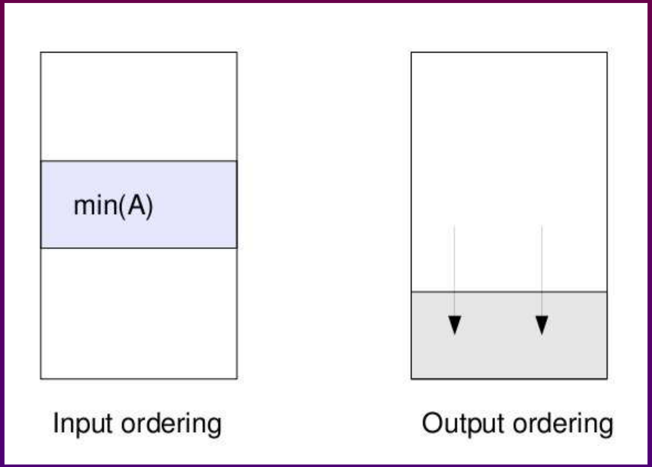
An old idea ...

- Both rules allowed
- In case of conflict, (FD) overrides (WC)

... in a new guise

- Iterated belief change theory
- Norm violation triggers a revision.

Natural Revision



$(\mathbf{P}_1)$ If $w_1 \in \min_{\mathcal{M}}(A)$ then:

$$w_1 \preceq' w_2 \text{ for all } w_2 \in W \text{ and} \tag{a}$$

$$w_2 \preceq' w_1 \text{ iff } w_2 \in \min_{\mathcal{M}}(A) \tag{b}$$

$(\mathbf{P}_2)$ If $w_1, w_2 \notin \min_{\mathcal{M}}(A)$ then: $w_1 \preceq' w_2$ iff $w_1 \preceq w_2$.

Commutation

Model $\mathcal{M}_1$ (Before the offence)

o=*offence*

r_1=*remedy*

In $\mathcal{M}_1$:

$\bigcirc \neg r_1$

not-$\bigcirc r_1$

$$\begin{tikzcd}
\bullet w_3 : o \ \neg r_1 \arrow[d] & & \bullet w_3 \arrow[d] \\
\bullet w_2 : \ o \ r_1 \arrow[d] & \arrow[r, Rightarrow, "\mathcal{M}_1^{\star} o"] & \bullet w_1 \arrow[d] \\
\bullet w_1 : \neg o \ \neg r_1 & & \bullet w_2
\end{tikzcd}$$

In $\mathcal{M}_1^{\star} o$:

$\bigcirc r_1$

not-$\bigcirc \neg r_1$

Commutation

Model $\mathcal{M}_1$ (Before the offence)

o=*offence*

r_1=*remedy*

In $\mathcal{M}_1$:

$\bigcirc \neg r_1$

not-$\bigcirc r_1$

$$\begin{array}{ccc} \bullet w_3 : o\ \neg r_1 & & \bullet w_3 \\ \downarrow & & \downarrow \\ \bullet w_2 : o\ r_1 & \overset{\mathcal{M}_1^\star o}{\Longrightarrow} & \bullet w_1 \\ \downarrow & & \downarrow \\ \bullet w_1 : \neg o\ \neg r_1 & & \bullet w_2 \end{array}$$

In $\mathcal{M}_1^\star o$:

$\bigcirc r_1$

not-$\bigcirc \neg r_1$

Round 1

Input	Induced ordering		Perms	Output
o	$\mathcal{M}_1^\star o$	$w_2 \prec w_1 \prec w_{i(i\geq 3)}$	1	$\bigcirc r_1$
$\neg o$	$\mathcal{M}_1^\star \neg o$	$w_1 \prec w_2 \prec w_{i(i\geq 3)}$	0	$\bigcirc \neg r_1$

Turn-taking & obligation update

Round 2

o=*offence*

r_1= *remedy*

r_2= *relief*

Input sequence	Induced ordering		Perms	Output
1. o, r_1	$(\mathcal{M}_1^\star o)^\star r_1$	$w_2 \prec w_1 \prec w_i$	1	$\bigcirc r_2$
2. $o, \neg r_1$	$(\mathcal{M}_1^\star o)^\star \neg r_1$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc \neg r_2$
3. $\neg o, r_1$	$(\mathcal{M}_1^\star \neg o)^\star r_1$	$w_2 \prec w_1 \prec w_i$	1	$\bigcirc r_2$
4. $\neg o, \neg r_1$	$(\mathcal{M}_1^\star \neg o)^\star \neg r_1$	$w_1 \prec w_2 \prec w_i$	0	$\bigcirc \neg r_2$

Turn-taking & obligation update

o=*offence*

r_1= *remedy*

r_2= *relief*

Round 2

Input sequence	Induced ordering		Perms	Output
1. o, r_1	$(\mathcal{M}_1^\star o)^\star r_1$	$w_2 \prec w_1 \prec w_i$	1	$\bigcirc r_2$
3. $\neg o, r_1$	$(\mathcal{M}_1^\star \neg o)^\star r_1$	$w_2 \prec w_1 \prec w_i$	1	$\bigcirc r_2$

Turn-taking & obligation update

Round 2

o=*offence*

r_1= *remedy*

r_2= *relief*

Input sequence	Induced ordering		Perms	Output
2. $o, \neg r_1$	$(\mathcal{M}_1^\star o)^\star \neg r_1$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc \neg r_2$
4. $\neg o, \neg r_1$	$(\mathcal{M}_1^\star \neg o)^\star \neg r_1$	$w_1 \prec w_2 \prec w_i$	0	$\bigcirc \neg r_2$

Turn-taking & obligation update

Round 2

o=*offence*
r_1= *remedy*
r_2= *relief*

Input sequence	Induced ordering		Perms	Output
1. o, r_1	$(\mathcal{M}_1^\star o)^\star r_1$	$w_2 \prec w_1 \prec w_i$	1	$\bigcirc r_2$
2. $o, \neg r_1$	$(\mathcal{M}_1^\star o)^\star \neg r_1$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc \neg r_2$
3. $\neg o, r_1$	$(\mathcal{M}_1^\star \neg o)^\star r_1$	$w_2 \prec w_1 \prec w_i$	1	$\bigcirc r_2$
4. $\neg o, \neg r_1$	$(\mathcal{M}_1^\star \neg o)^\star \neg r_1$	$w_1 \prec w_2 \prec w_i$	0	$\bigcirc \neg r_2$

Turn-taking & obligation update

o= *offence* r_1= *remedy*
r_2= *relief* a= *appreciation*

Round 3

Input sequence	Induced ordering		Perm	Output
1. o, r_1, r_2	$((\mathcal{M}_1^\star o)^\star r_1)^\star r_2$	$w_2 \prec w_1 \prec w_i$	1	$\bigcirc a$
2. $o, r_1, \neg r_2$	$((\mathcal{M}_1^\star o)^\star r_1)^\star \neg r_2$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc \neg a$
3. $o, \neg r_1, r_2$	$((\mathcal{M}_1^\star o)^\star \neg r_1)^\star r_2$	$w_2 \prec w_1 \prec w_i$	3	$\bigcirc a$
4. $o, \neg r_1, \neg r_2$	$((\mathcal{M}_1^\star o)^\star \neg r_1)^\star \neg r_2$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc \neg a$
5. $\neg o, r_1, r_2$	$((\mathcal{M}_1^\star \neg o)^\star r_1)^\star r_2$	$w_2 \prec w_1 \prec w_i$	1	$\bigcirc a$
6. $\neg o, r_1, \neg r_2$	$((\mathcal{M}_1^\star \neg o)^\star r_1)^\star \neg r_2$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc \neg a$
7. $\neg o, \neg r_1, r_2$	$((\mathcal{M}_1^\star \neg o)^\star \neg r_1)^\star r_2$	$w_2 \prec w_1 \prec w_i$	2	$\bigcirc a$
8. $\neg o, \neg r_1, \neg r_2$	$((\mathcal{M}_1^\star \neg o)^\star \neg r_1)^\star \neg r_2$	$w_1 \prec w_2 \prec w_i$	0	$\bigcirc \neg a$

Turn-taking & obligation update

o= *offence* r_1= *remedy*

r_2= *relief* a= *appreciation*

Round 3

Input sequence	Induced ordering		Perm	Output
1. o, r_1, r_2	$((\mathcal{M}_1^\star o)^\star r_1)^\star r_2$	$w_2 \prec w_1 \prec w_i$	1	$\bigcirc a$
3. $o, \neg r_1, r_2$	$((\mathcal{M}_1^\star o)^\star \neg r_1)^\star r_2$	$w_2 \prec w_1 \prec w_i$	3	$\bigcirc a$
5. $\neg o, r_1, r_2$	$((\mathcal{M}_1^\star \neg o)^\star r_1)^\star r_2$	$w_2 \prec w_1 \prec w_i$	1	$\bigcirc a$
7. $\neg o, \neg r_1, r_2$	$((\mathcal{M}_1^\star \neg o)^\star \neg r_1)^\star r_2$	$w_2 \prec w_1 \prec w_i$	2	$\bigcirc a$

Turn-taking & obligation update

o= *offence* r_1= *remedy*
r_2= *relief* a= *appreciation*

Round 3

Input sequence	Induced ordering		Perm	Output
2. $o, r_1, \neg r_2$	$((\mathcal{M}_1^\star o)^\star r_1)^\star \neg r_2$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc \neg a$
4. $o, \neg r_1, \neg r_2$	$((\mathcal{M}_1^\star o)^\star \neg r_1)^\star \neg r_2$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc \neg a$
6. $\neg o, r_1, \neg r_2$	$((\mathcal{M}_1^\star \neg o)^\star r_1)^\star \neg r_2$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc \neg a$
8. $\neg o, \neg r_1, \neg r_2$	$((\mathcal{M}_1^\star \neg o)^\star \neg r_1)^\star \neg r_2$	$w_1 \prec w_2 \prec w_i$	0	$\bigcirc \neg a$

Turn-taking & obligation update

Round 4

Revision sequence	Induced ordering	Perm	Output
1. $(((\mathcal{M}_1^\star o)^\star r_1)^\star r_2)^\star a$	$w_2 \prec w_1 \prec w_{i(i\geq 3)}$	1	$\bigcirc m$
2. $(((\mathcal{M}_1^\star o)^\star r_1)^\star r_2)^\star \neg a$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc \neg m$
3. $(((\mathcal{M}_1^\star o)^\star r_1)^\star \neg r_2)^\star a$	$w_2 \prec w_1 \prec w_i$	3	$\bigcirc m$
4. $(((\mathcal{M}_1^\star o)^\star r_1)^\star \neg r_2)^\star \neg a$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc \neg m$
5. $(((\mathcal{M}_1^\star o)^\star \neg r_1)^\star r_2)^\star a$	$w_2 \prec w_1 \prec w_i$	3	$\bigcirc m$
6. $(((\mathcal{M}_1^\star o)^\star \neg r_1)^\star r_2)^\star \neg a$	$w_1 \prec w_2 \prec w_i$	4	$\bigcirc \neg m$
7. $(((\mathcal{M}_1^\star o)^\star \neg r_1)^\star \neg r_2)^\star a$	$w_2 \prec w_1 \prec w_i$	3	$\bigcirc m$
8. $(((\mathcal{M}_1^\star o)^\star \neg r_1)^\star \neg r_2)^\star \neg a$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc \neg m$
9. $(((\mathcal{M}_1^\star \neg o)^\star r_1)^\star r_2)^\star a$	$w_2 \prec w_1 \prec w_i$	1	$\bigcirc m$
10. $(((\mathcal{M}_1^\star \neg o)^\star r_1)^\star r_2)^\star \neg a$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc \neg m$
11. $(((\mathcal{M}_1^\star \neg o)^\star r_1)^\star \neg r_2)^\star a$	$w_2 \prec w_1 \prec w_i$	3	$\bigcirc m$
12. $(((\mathcal{M}_1^\star \neg o)^\star r_1)^\star \neg r_2)^\star \neg a$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc \neg m$
13. $(((\mathcal{M}_1^\star \neg o)^\star \neg r_1)^\star r_2)^\star a$	$w_2 \prec w_1 \prec w_i$	1	$\bigcirc m$
14. $(((\mathcal{M}_1^\star \neg o)^\star \neg r_1)^\star r_2)^\star \neg a$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc \neg m$
15. $(((\mathcal{M}_1^\star \neg o)^\star \neg r_1)^\star \neg r_2)^\star a$	$w_2 \prec w_1 \prec w_i$	1	$\bigcirc m$
16. $(((\mathcal{M}_1^\star \neg o)^\star \neg r_1)^\star \neg r_2)^\star \neg a$	$w_1 \prec w_2 \prec w_i$	0	$\bigcirc \neg m$

o= *offence*
r_1= *remedy*
r_2= *relief*
a= *appreciation*
m= *minimization*

Turn-taking & obligation update

Round 4

Revision sequence	Induced ordering	Perm	Output
1. $(((\mathcal{M}_1^\star o)^\star r_1)^\star r_2)^\star a$	$w_2 \prec w_1 \prec w_{i(i\geq 3)}$	1	$\bigcirc m$
3. $(((\mathcal{M}_1^\star o)^\star r_1)^\star \neg r_2)^\star a$	$w_2 \prec w_1 \prec w_i$	3	$\bigcirc m$
5. $(((\mathcal{M}_1^\star o)^\star \neg r_1)^\star r2)^\star a$	$w_2 \prec w_1 \prec w_i$	3	$\bigcirc m$
7. $(((\mathcal{M}_1^\star o)^\star \neg r_1)^\star \neg r_2)^\star a$	$w_2 \prec w_1 \prec w_i$	3	$\bigcirc m$
9. $(((\mathcal{M}_1^\star \neg o)^\star r_1)^\star r_2)^\star a$	$w_2 \prec w_1 \prec w_i$	1	$\bigcirc m$
11. $(((\mathcal{M}_1^\star \neg o)^\star r_1)^\star \neg r_2)^\star a$	$w_2 \prec w_1 \prec w_i$	3	$\bigcirc m$
13. $(((\mathcal{M}_1^\star \neg o)^\star \neg r_1)^\star r_2)^\star a$	$w_2 \prec w_1 \prec w_i$	1	$\bigcirc m$
15. $(((\mathcal{M}_1^\star \neg o)^\star \neg r_1)^\star \neg r_2)^\star a$	$w_2 \prec w_1 \prec w_i$	1	$\bigcirc m$

o= *offence*
r_1= *remedy*
r_2= *relief*
a= *appreciation*
m= *minimization*

Turn-taking & obligation update

Round 4

Revision sequence	Induced ordering	Perm	Output
2. $(((\mathcal{M}_1^\star o)^\star r_1)^\star r_2)^\star\neg a$	$w_1 \prec w_2 \prec w_{i(i\geq 3)}$	2	$\bigcirc\neg m$
4. $(((\mathcal{M}_1^\star o)^\star r_1)^\star\neg r_2)^\star\neg a$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc\neg m$
6. $(((\mathcal{M}_1^\star o)^\star\neg r_1)^\star r_2)^\star\neg a$	$w_1 \prec w_2 \prec w_i$	4	$\bigcirc\neg m$
8. $(((\mathcal{M}_1^\star o)^\star\neg r_1)^\star\neg r_2)^\star\neg a$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc\neg m$
10. $(((\mathcal{M}_1^\star\neg o)^\star r_1)^\star r_2)^\star\neg a$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc\neg m$
12. $(((\mathcal{M}_1^\star\neg o)^\star r_1)^\star\neg r_2)^\star\neg a$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc\neg m$
14. $(((\mathcal{M}_1^\star\neg o)^\star\neg r_1)^\star r_2)^\star\neg a$	$w_1 \prec w_2 \prec w_i$	2	$\bigcirc\neg m$
16. $(((\mathcal{M}_1^\star\neg o)^\star\neg r_1)^\star\neg r_2)^\star\neg a$	$w_1 \prec w_2 \prec w_i$	0	$\bigcirc\neg m$

o= *offence*
r_1= *remedy*
r_2= *relief*
a= *appreciation*
m= *minimization*

Conclusion

Main contribution

- Dialogue model based on obligations
  - Rules of turn-taking

Related research

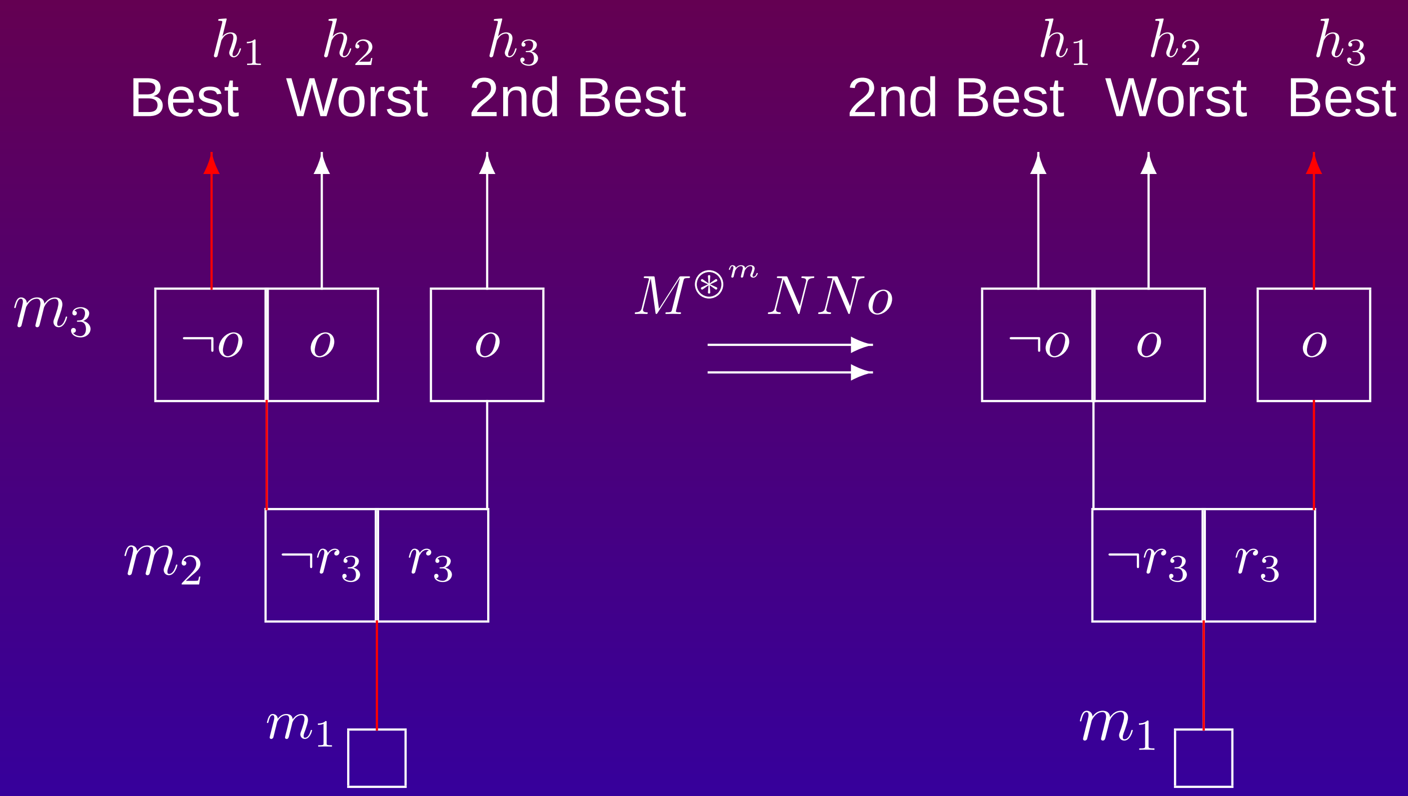
- Hulstijn and Maudet 2003, ‘Uptake and conditional obligations’

Problems with my account

- Request: Consequent Before the Antecedent
- Drowning problem - revise too much

Consequent Before the Antecedent

$\{\bigcirc NN\neg o, \bigcirc(Nr_3/NNo), \Box(Nr_3 \to NNo)\}$



At m_1/h_1: $\bigcirc N\neg r_3$

At m_1/h_1: $\bigcirc Nr_3$

For $\mathfrak{M}^{\circledast^m}\phi$, read "the model obtained from $\mathfrak{M}$ once the happening of ϕ has been anticipated at moment m"