Appendix A

The Formal Language

The definitions of the syntax of the formal language are collected here.

The Basic Language

$\mathcal{L}$ is the basic formal language; $\mathcal{L}_s$ is the set of "scenario-formulae," which is used as an auxiliary definition. It contains formulae that are evaluated relative to scenarios in the model, rather than relative to moments. In the following,

- Φ is a set of atomic propositional symbols,
- $\mathcal{A}$ is a set of agent symbols,
- $\mathcal{B}$ is a set of basic action symbols, and
- $\mathcal{X}$ is a set of variables.

Time, Actions, and Propositional Logic

SYN-1. $\psi \in \Phi$ implies that $\psi \in \mathcal{L}$

SYN-2. $p, q \in \mathcal{L}$ implies that $p \wedge q \in \mathcal{L}$

SYN-3. $p \in \mathcal{L}$ implies that $\neg p \in \mathcal{L}$

SYN-4. $\mathcal{L} \subseteq \mathcal{L}_s$

SYN-5. $p, q \in \mathcal{L}_s$ implies that $p \wedge q \in \mathcal{L}_s$

SYN-6. $p \in \mathcal{L}_s$ implies that $\neg p \in \mathcal{L}_s$

SYN-7. $p \in \mathcal{L}_s$ implies that $\mathsf{A}p, \mathsf{R}p \in \mathcal{L}$

SYN-8. $p \in \mathcal{L}$ implies that $\mathsf{P}p \in \mathcal{L}$

SYN-9. $p \in \mathcal{L}$ and $a \in \mathcal{X}$ implies that $(\bigvee a : p) \in \mathcal{L}$

SYN-10. $p, q \in \mathcal{L}_s$ implies that $p\mathsf{U}q \in \mathcal{L}_s$

SYN-11. $p \in \mathcal{L}$, $x \in \mathcal{A}$, and $a \in \mathcal{B}$ implies that $x[a]p, x\langle a\rangle p, x|\!\langle a\rangle\!|p \in \mathcal{L}_s$

Strategies

STRAT-1. $\mathbf{skip} \in \mathcal{L}_y$

STRAT-2. $q \in \mathcal{L}$ implies that $\mathbf{do}(q) \in \mathcal{L}_y$

STRAT-3. $Y_1, Y_2 \in \mathcal{L}_y$ implies that $Y_1;Y_2 \in \mathcal{L}_y$

STRAT-4. $q \in \mathcal{L}$ and $Y_1, Y_2 \in \mathcal{L}_y$ implies that $\mathbf{if}\ q\ \mathbf{then}\ Y_1\ \mathbf{else}\ Y_2 \in \mathcal{L}_y$

STRAT-5. $q \in \mathcal{L}$ and $Y_1 \in \mathcal{L}_y$ implies that $\mathbf{while}\ q\ \mathbf{do}\ Y_1 \in \mathcal{L}_y$

Intentions

The formal language of Chapter 3, $\mathcal{L}^i$, is $\mathcal{L}$ augmented with four operators, $\langle\,\rangle_i$, $\langle\!\langle\,\rangle\!\rangle$, $*$, and I (which stands for **Intends**).

SYN-12. All the rules for $\mathcal{L}$, with $\mathcal{L}^i$ substituted for $\mathcal{L}$

SYN-13. All the rules for $\mathcal{L}_s$, with $\mathcal{L}^i_s$ substituted for $\mathcal{L}_s$

SYN-14. All the rules for $\mathcal{L}_y$, with $\mathcal{L}^i_y$ substituted for $\mathcal{L}_y$

SYN-15. $p \in \mathcal{L}^i_s$, $x \in \mathcal{A}$, and $Y \in \mathcal{L}^i_y$ implies that $x\langle Y\rangle_i p$ and $\langle\!\langle Y\rangle\!\rangle p \in \mathcal{L}^i_s$

SYN-16. $p \in \mathcal{L}^i_s$, $x \in \mathcal{A}$, and $Y \in \mathcal{L}^i_y$ implies that $x * Y \in \mathcal{L}^i$

SYN-17. $p \in \mathcal{L}^i_s$ and $x \in \mathcal{A}$ implies that $(x\mathsf{I}p) \in \mathcal{L}^i$

Ability and Know-How

Trees

Let Υ be the set of trees. $\emptyset$ is the empty tree. Then Υ is defined as follows.

TREE-1. $\emptyset \in \Upsilon$

TREE-2. $a \in \mathcal{B}$ implies that $a \in \Upsilon$

TREE-3. $\tau_1, \ldots, \tau_m \in \Upsilon$; $\tau_1, \ldots, \tau_m$ have different radices, and $a \in \mathcal{B}$ implies that $\langle a; \tau_1, \ldots, \tau_m \rangle \in \Upsilon$

Ability and Know-How

The formal language of this chapter, $\mathcal{L}^h$, is an extension of $\mathcal{L}$. The operator $\boldsymbol{(}\ \boldsymbol{)}$ denotes ability relative to trees and the operator $\langle\!\langle\ \rangle\!\rangle$ ability relative to strategies. The operators K_{rab} and K_{sab} are, respectively, the reactive and strategic versions of ability.

SYN-18. All the rules for $\mathcal{L}$, with $\mathcal{L}^h$ substituted for $\mathcal{L}$

SYN-19. All the rules for $\mathcal{L}_s$, with $\mathcal{L}_s^h$ substituted for $\mathcal{L}_s$

SYN-20. All the rules for $\mathcal{L}_y$, with $\mathcal{L}_y^h$ substituted for $\mathcal{L}_y$

SYN-21. $p \in \mathcal{L}_s^h$ and $x \in \mathcal{A}$ implies that $(x\mathsf{K}_{rab}p), (x\mathsf{K}_{sab}p) \in \mathcal{L}^h$

SYN-22. $p \in \mathcal{L}_s^h$, $Y \in \mathcal{L}_y^h$, and $x \in \mathcal{A}$ implies that $(x\langle\!\langle Y \rangle\!\rangle p) \in \mathcal{L}^h$

SYN-23. $\tau \in \Upsilon$, $x \in \mathcal{A}$, and $p \in \mathcal{L}^h$ implies that $x\boldsymbol{(}\tau\boldsymbol{)}p \in \mathcal{L}^h$

SYN-24. $p \in \mathcal{L}_s^h$ and $x \in \mathcal{A}$ implies that $(x\mathsf{K}_{\mathsf{hr}}p), (x\mathsf{K}_{\mathsf{hs}}p) \in \mathcal{L}^h$

SYN-25. $p \in \mathcal{L}_s^h$, $Y, Y' \in \mathcal{L}_y^h$, and $x \in \mathcal{A}$ implies that $(x[\langle Y \rangle]p), (x\lceil Y \rceil Y')$, $(x\lfloor Y \rfloor Y') \in \mathcal{L}^h$

SYN-26. $\tau \in \Upsilon$, $x \in \mathcal{A}$, and $p \in \mathcal{L}^h$ implies that $x[\!(\tau)\!]p \in \mathcal{L}^h$

SYN-27. $p \in \mathcal{L}_s^h$, $x \in \mathcal{A}$, and $Y \in \mathcal{L}_y^h$ implies that $x[Y]_h p, x\langle Y \rangle p \in \mathcal{L}_s^h$

Combining Intentions and Know-How

The formal language of Chapter 5, $\mathcal{L}^c$, is obtained by combining the rules for $\mathcal{L}^i$ and $\mathcal{L}^h$.

SYN-28. All the rules for $\mathcal{L}^i$, $\mathcal{L}^i_s$, $\mathcal{L}^i_y$, $\mathcal{L}^h$, $\mathcal{L}^h_s$, and $\mathcal{L}^h_y$, with $\mathcal{L}^c$ substituted for $\mathcal{L}^i$ and $\mathcal{L}^h$, $\mathcal{L}^c_s$ substituted for $\mathcal{L}^i_s$ and $\mathcal{L}^h_s$, and $\mathcal{L}^c_y$ substituted for $\mathcal{L}^i_y$ and $\mathcal{L}^h_y$

SYN-29. $p \in \mathcal{L}^c_s$, $Y, Y' \in \mathcal{L}^c_y$, and $x \in \mathcal{A}$ implies that $(x[Y]Y') \in \mathcal{L}^c$

Communications

The formal language of Chapter 6, $\mathcal{L}^m$ is $\mathcal{L}^c$ augmented with the operator, W. In the following, $\mathcal{F}$ = {assertive, directive, commissive, permissive, prohibitive, declarative} is the set of illocutionary forces. $\mathcal{M}$ is the set of *messages.* The set of basic actions, $\mathcal{B}$, is extended with illocutionary actions, which are generated from the messages and are treated as the actions of the sending agent.

SYN-30. All the rules for $\mathcal{L}^c$ with $\mathcal{L}^m$ substituted for $\mathcal{L}^c$

SYN-31. All the rules for $\mathcal{L}^c_s$ with $\mathcal{L}^m_s$ substituted for substituted for $\mathcal{L}^c_s$

SYN-32. All the rules for $\mathcal{L}^c_y$ with $\mathcal{L}^m_y$ substituted for substituted for $\mathcal{L}^c_y$

SYN-33. $p \in \mathcal{L}^m_s$ implies that $\mathsf{W}p \in \mathcal{L}^m_s$

SYN-34. $p \in \mathcal{L}^m$ and $i \in \mathcal{F}$ implies that $\langle i, p\rangle \in \mathcal{M}$

SYN-35. $x, y \in \mathcal{A}$ and $m \in \mathcal{M}$ implies that $\mathbf{comm}(x, y, m) \in \mathcal{L}^m_s$

SYN-36. $x, y \in \mathcal{A}$ and $m \in \mathcal{M}$ implies that $\mathbf{says\text{-}to}(x, y, m) \in \mathcal{B}$

Interrogatives

In order to include interrogatives in the formal language, I introduce a set of constants, $\mathcal{D}$, and a set of predicates, $\mathcal{PRED}$. $\mathcal{L}^q_q$ denotes the set of query expressions. $\mathcal{L}^q$ is the version of the formal language that includes interrogatives.

SYN-37. All the rules for $\mathcal{L}^m$ with $\mathcal{L}^q$ substituted for $\mathcal{L}^m$

SYN-38. All the rules for $\mathcal{L}_s^m$ with $\mathcal{L}_s^q$ substituted for $\mathcal{L}_s^q$

SYN-39. All the rules for $\mathcal{L}_y^m$ with $\mathcal{L}_y^q$ substituted for $\mathcal{L}_y^m$

SYN-40. $\vec{b} \in (\mathcal{D} \cup \mathcal{X})^n$ and $P \in \mathcal{PRED}$ implies that $P(\vec{b}) \in \mathcal{L}^q$

SYN-41. $u \in \mathcal{X}$ and $p \in \mathcal{L}^q$ implies that $(\exists u : p) \in \mathcal{L}^q$

SYN-42. $\vec{a} \in \mathcal{X}^n$, $p \in \mathcal{L}^q$ implies that $(\lambda\vec{a} : p) \in \mathcal{L}_q^q$

SYN-43. $p \in \mathcal{L}_q^q$ implies that $\langle$interrogative, $p\rangle \in \mathcal{M}$

SYN-44. $\langle$interrogative, $p\rangle \in \mathcal{M}$ and $\mathbf{Ans} \in \mathcal{D}^n$ implies that $\mathbf{answer}(p, \mathbf{Ans}) \in \mathcal{L}^q$

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