24.973 Advanced Semantics

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(1) Tense identification analysis
$[\![\text{believe}]\!]^{w,t} = \lambda p_{<s,t>}\lambda x.\forall w'.w'$ compatible with x's belief in w at t $\rightarrow$ p(<w',t>) = 1

(2) 'At 4am, John believes it to be raining'
$[\![$ pres [4am [john believe rain]] $]\!]^{w^*,t^*} = 1$ iff
$[\![4\text{am [john believe rain}]\!]^{w^*,t'} = 1$, iff
$[\![4\text{am}]\!]^{w^*,t'} = 1$ & $[\![\text{john believe rain}]\!]^{w^*,t'} = 1$, iff
$[\![\text{john believe rain}]\!]^{w^*,4\text{am}} = 1$, iff
$[\![\text{believe}]\!]^{w^*,4\text{am}}([\![\text{rain}]\!]_{¢})(j) = 1$, iff
$\forall w'.w'$ compatible with j's belief in w* at 4am $\rightarrow$ $[\![\text{rain}]\!]_{¢}$(<w',4am> = 1, iff
for each w' compatible with j's belief in w* at 4am, it rains in w' at 4am

(3) (a) *Scenario* 1: In w*, it rains only at 4am, John wakes up at 4am, thinking "it's 5am and it's raining"
(b) *Intuition*: $[\![$At 4am, John believes it to be raining$]\!]^{w^*,t^*} = 1$
(b) *Prediction*: $[\![$At 4am, John believes it to be raining$]\!]^{w^*,t^*} = 0$
(c) *Proof*: Let it rain in w' at 5am but not at 4am, and let John wake up at 5am in w'. Then w' is compatible with John's belief in w* at 4am. But it is not raining in w' at 4am.

(4) (a) *Scenario* 2: In w*, John wakes up at 4am, thinking "it' 5am, it rained at 4am but it has stopped"
(b) *Intuition*: $[\![$At 4am, John believes it to be raining$]\!]^{w^*,t^*} = 0$
(b) *Prediction*: $[\![$At 4am, John believes it to be raining$]\!]^{w^*,t^*} = 1$
(c) *Proof*: Take any w' compatible with John's belief in w* at 4am. John wakes up at 5am in w' and there is rain at 4am in w'. Thus, for any world w' compatible with John's belief in w* at 4am, it rains in w' at 4am.

(5) Fixing the problem
(a) $[\![\text{believe}]\!]^{w,t} = \lambda p_{<s,t>}\lambda x.\forall$<w',t'>.<w',t'> compatible with x's belief in w at t $\rightarrow$ p(<w',t'>) = 1
(b) $[\![4\text{am [john believes rain}]\!]^{w^*,t^*} = 1$ iff
$[\![\text{john believe rain}]\!]^{w^*,4\text{am}} = 1$, iff
$[\![\text{believe}]\!]^{w^*,4\text{am}}([\![\text{rain}]\!]_{¢})(j) = 1$, iff
$\forall$<w',t'>.<w',t'> compatible with j's belief in w* at 4am $\rightarrow$ $[\![\text{rain}]\!]_{¢}$(<w',t'>) = 1, iff
for each <w',t'> compatible with j's belief in w* at 4am, it is raining in w' **at t'**

(6) Proof that in scenario 1, the sentence is true:
Take any <w',t'> compatible with John's belief in w* at 4am. By hypothesis, t' = 5am and it rains in w' at t'. Thus, it rains in w' at t'.

(7) Proof that in scenario 2, the sentence is false:
Let it rain in w' only at 4am, and let t' = 5am. By hypothesis, <w',t'> is compatible with John's belief in w* at 4am. But it does not rain in w' at t'.