(r)tioco : ioco with time

Timed Model-Based Testing

☞ In many systems real-time properties are crucial
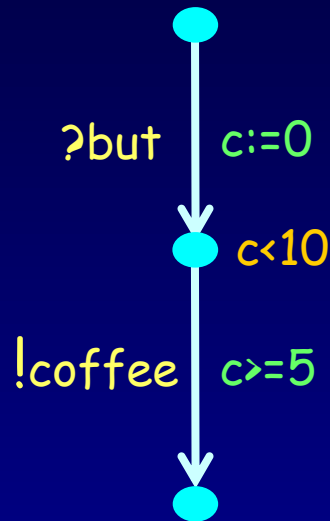
☞ Approach:

- ◆ Extension of IOTS/**ioco** theory
  - Timed Input Output Transition Systems (TIOTS)
  - Timed Implementation Relations: build on **ioco**

☞ Challenges:

- ◆ Is time input or output ?

- ◆ Quiescence: How long is there never eventually no output?

Timed Input-Output Transition Systems

?but   c:=0

c<10

!coffee   c>=5

TIOTS : $\langle$ **Q**, **L$_I$**, **L$_U$**, **R$_{\geq 0}$**, **T**, **q$_0$** $\rangle$

Observable actions: **L$_I$**, **L$_U$**

delay $d \in$ **R$_{\geq 0}$**

Unobservable action: τ

Specifications are TIOTS

Implementations are assumed

to behave as input-enabled TIOTS

The Untimed Implementation Relation ioco

$$i \textbf{ ioco } s \quad =_{def} \quad \forall \sigma \in Straces(s) : out(i \textbf{ after } \sigma) \subseteq out(s \textbf{ after } \sigma)$$

$$\downarrow \qquad\qquad \downarrow \qquad\qquad \downarrow$$

$$Straces \qquad \textbf{after} \qquad out$$

$$\delta(p) \quad = \quad \forall \ !x \in L_U \cup \{\tau\} . \quad p \xrightarrow{!x} \!\!\!\!\!\not\;\;$$

$$Straces(s) \quad = \quad \{ \ \sigma \in (L \cup \{\delta\})^* \ | \ s \xRightarrow{\sigma} \ \}$$

$$out(p) \quad = \quad \{ \ !x \in L_U \ | \ p \xRightarrow{!x} \ \} \ \cup \ \{ \ \delta \ | \ \delta(p) \ \}$$

$$out(P) \quad = \quad \cup \{ \ out(p) \ | \ p \in P \ \}$$

$$p \textbf{ after } \sigma \quad = \quad \{ \ p' \ | \ p \xRightarrow{\sigma} p' \ \}$$

Some Timed Implementation Relations

$$i \; \textbf{ioco} \; s \quad =_{def} \quad \forall \sigma \in \textit{Straces} \, (s) : \; \textit{out} \, (i \; \textbf{after} \; \sigma) \; \subseteq \; \textit{out} \, (s \; \textbf{after} \; \sigma)$$

$\downarrow$ $\downarrow$ $\downarrow$ $\downarrow$

tioco$_X$ **?**   **?**   **?**

A Timed Implementation Relation

$$i \text{ ioco } s \quad =_{def} \quad \forall \sigma \in Straces(s) : \quad out(i \text{ after } \sigma) \subseteq out(s \text{ after } \sigma)$$

$$\downarrow \qquad\qquad\qquad \downarrow \qquad\qquad\qquad \downarrow \qquad\qquad \downarrow$$

$$\textbf{tioco} \qquad\qquad\qquad ttraces \qquad\qquad \textbf{after}_t \qquad out_{AG}$$

$$\delta(p) \qquad\qquad = \quad \times$$

$$ttraces(s) \quad = \quad \{ \ \sigma \in (L \cup R_{\geq 0})^* \ | \ s \xRightarrow{\sigma} \ \}$$

$$out_{AG}(p) \quad = \quad \{ \ x \in L_U \cup R_{\geq 0} \ | \ p \xRightarrow{x} \}$$

$$p \text{ after}_t \sigma \quad = \quad \{ \ p' \ | \ p \xRightarrow{\sigma} p', \ \sigma \in (L \cup R_{\geq 0})^* \}$$

A Timed Implementation Relation tioco

?but c:=0
c<=7
!coffee c==7

tioco →

tioco (crossed out)

?but c:=0
c<=9
!coffee c>=3

?but c:=0
c<10
!coffee c>=5

?but c:=0
c<9
!coffee c>=7

tioco →

tioco (crossed out)

?but c:=0
true

8

Unbounded Delay

?but

ioco
untimed

?but

(true)

!coffee (true)

?but

tioco
timed

(true)
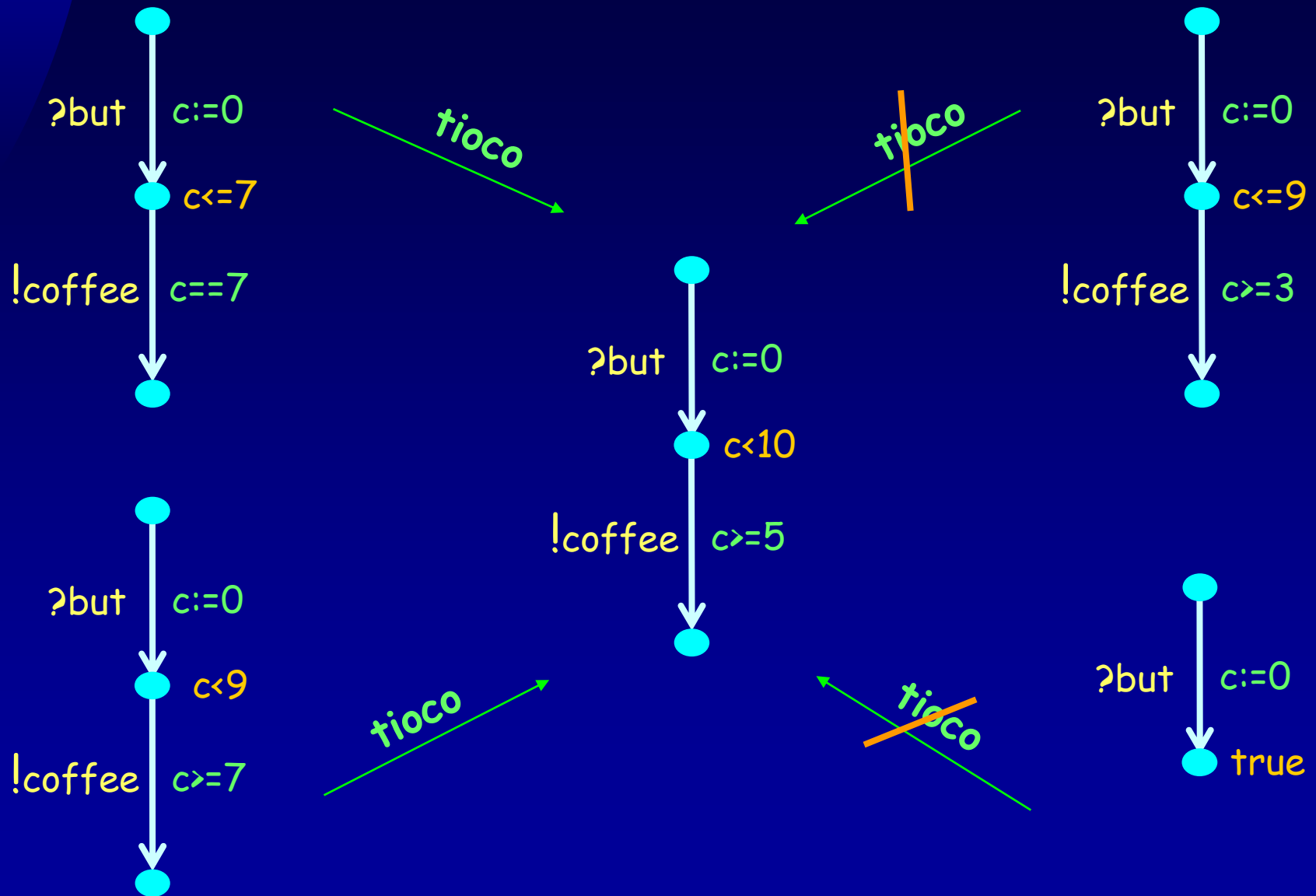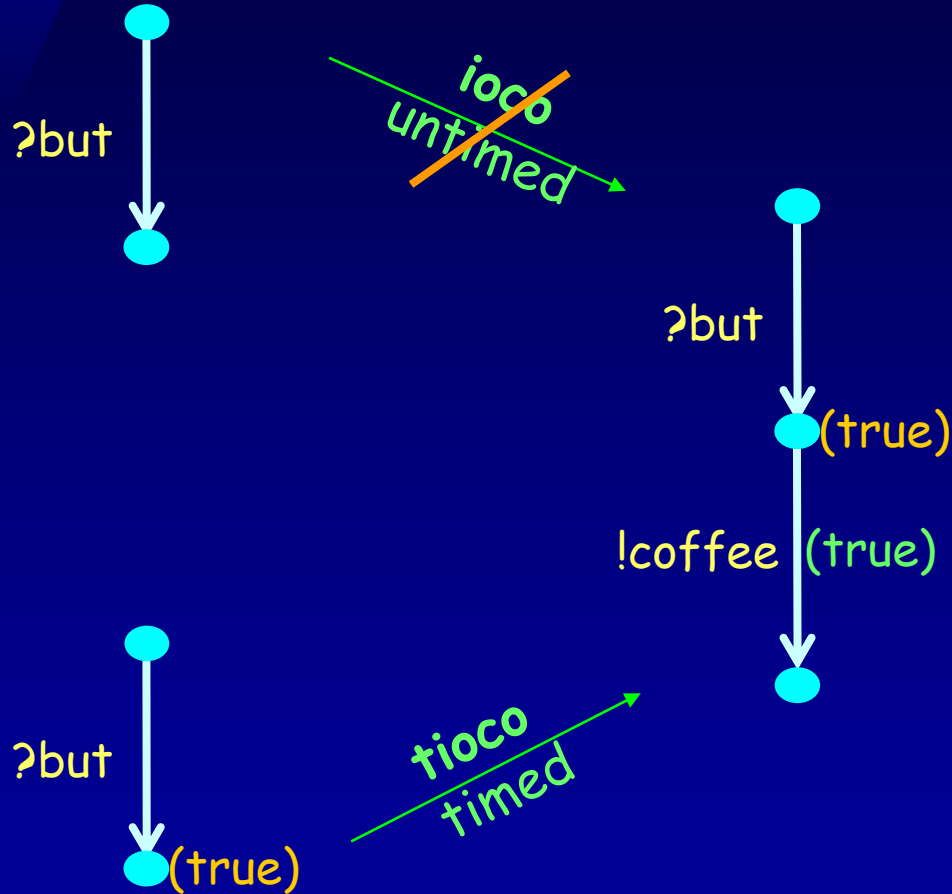
- And suppose you wish to reject this IUT: how long would you wait ?

- Untimed ioco: quiescence to express that there eventually is !coffee

- But when is eventually ?