A Framework for the Design and Verification of Component-Based Systems

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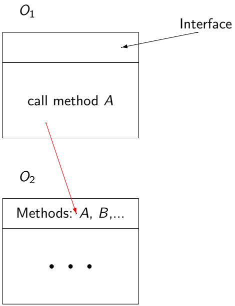
System Views

Object-Oriented



O_1 depends on
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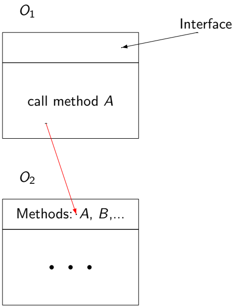

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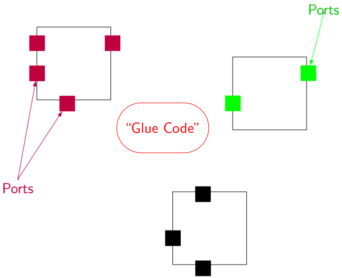
Component-Based



Components do not refer to other components. They offer ports and may be glued together.

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If we want to study properties of component-based systems more information is needed.

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This means: there are three independent description levels.

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- a set *Comp* of interactions α that are called complete. If $\alpha \subset c$ is complete then α may proceed no matter if the missing actions of c are available or not.

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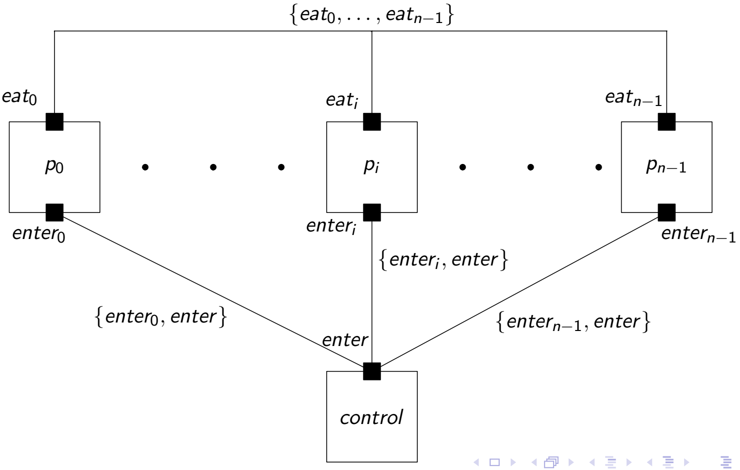
- n components f_i for $0 \leq i \leq n-1$ representing the forks. The ports for f_i are $\{get_i, put_i\}$.
- One component *control*. It controls when a philosopher may enter the room in which the table is located. Its ports are $\{enter, leave\}$.

Example - The Dining Philosophers, Static View

Part of the picture : the philosophers, the control and some connectors. Any nonempty subset of $\{eat_0, eat_1, ..., eat_{n-1}\}$ is declared complete.



Dynamics of our Model

- each component i has a local behavior given by a transition system $T_i = (Q_i, \rightarrow_i)$ where $\rightarrow_i \subseteq Q_i \times A_i \times Q_i$ and A_i is the (local) port set of i. It is assumed that every state offers some action.

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  - $q_i \xrightarrow{a_i} q'_i$ if $a_i \in \alpha$

Definition Interaction Systems

An **Interaction System** is given by

$$Sys = (K, C, Comp, T)$$

where

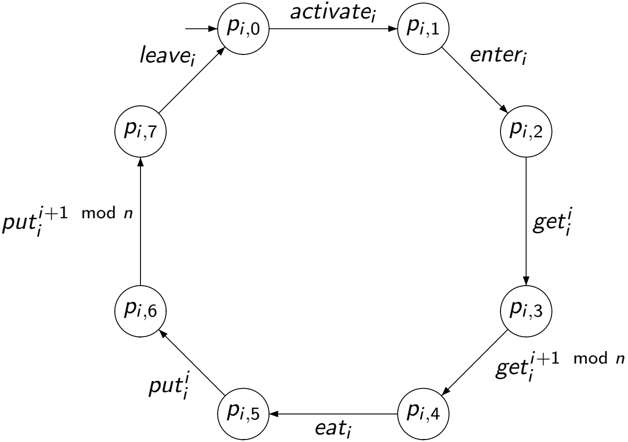
K, C, and *Comp* constitute the static part of the system

and

T constitutes the dynamic part of the system.

Example - The Dining Philosophers, Dynamics

The behavior of philosopher p_i is given by:



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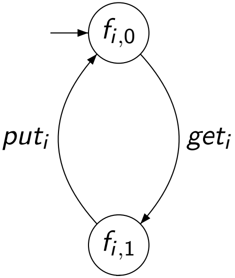
The behavior of fork f_i is given by:



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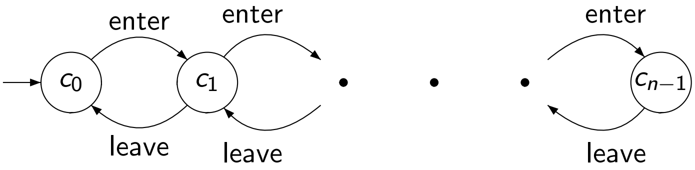
The behavior of *control* is given by:



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Example - The Dining Philosophers, Global Transitions

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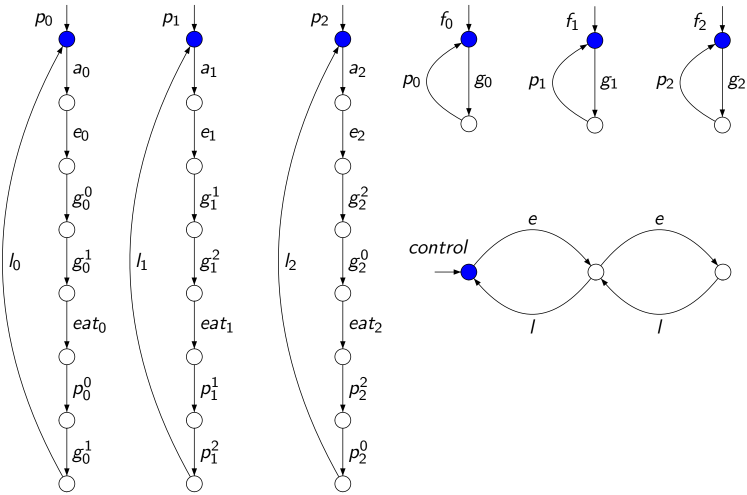

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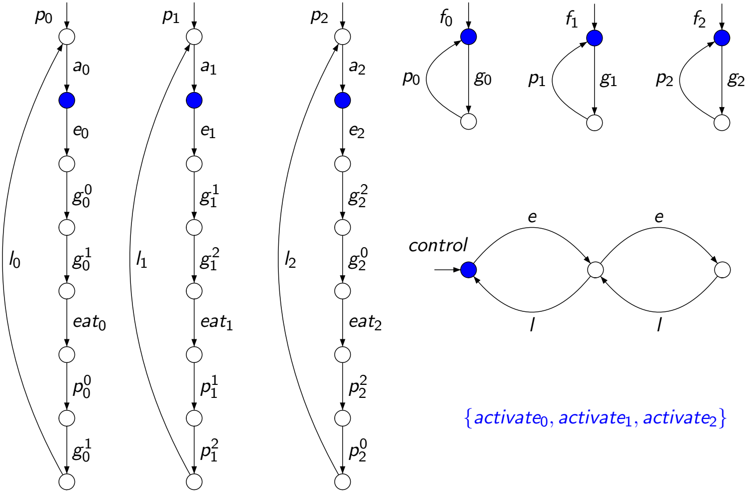

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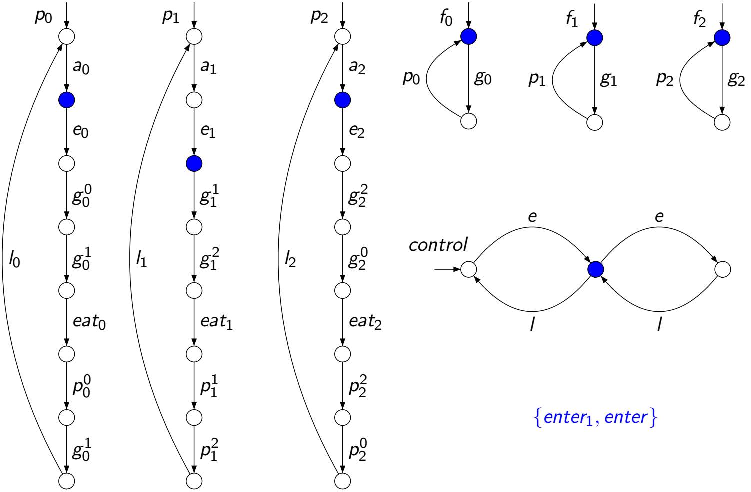

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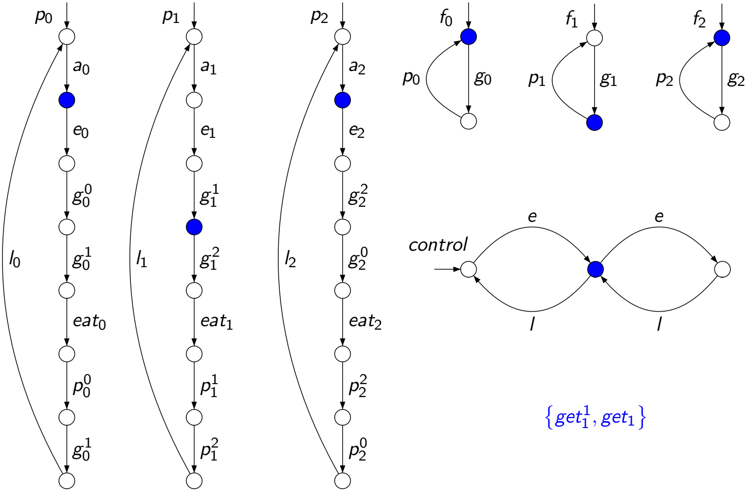

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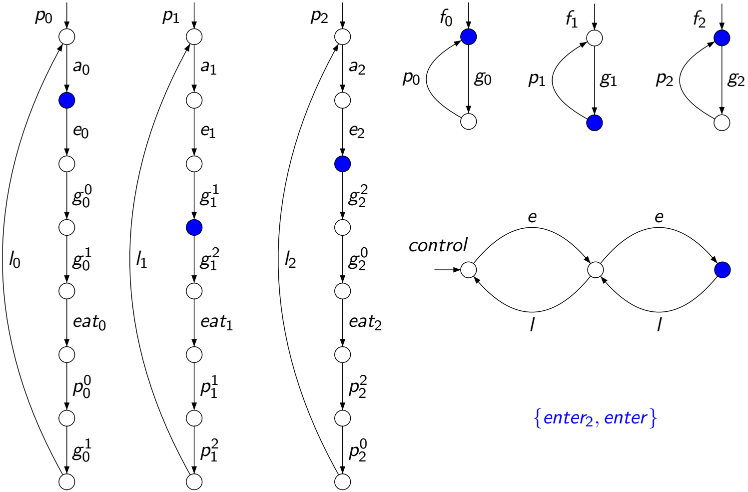

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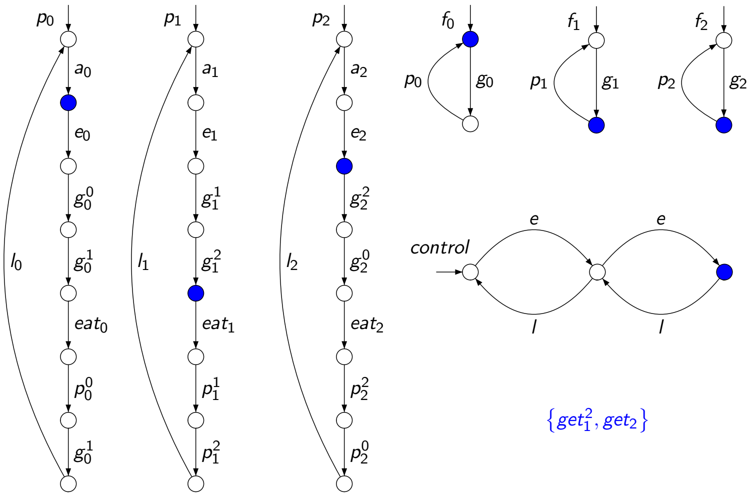

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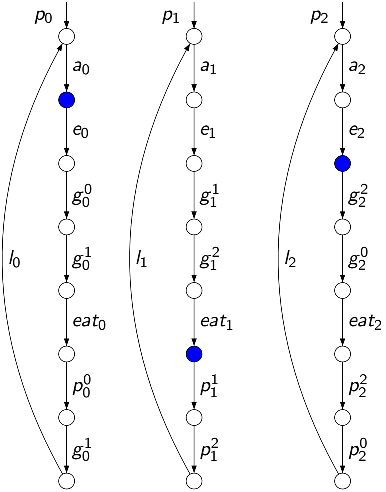

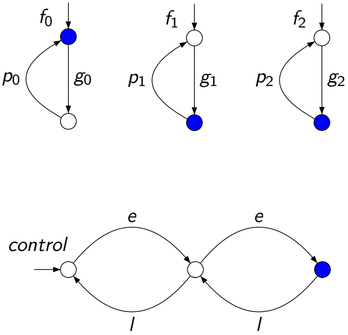

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Here we treat liveness.

P-Deadlock-Freedom

A predicate P on the state space Q is inductive if

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Sys is called P-deadlock-free if for every global state q with $P(q) = \mathit{true}$ there is a transition

$$q \xrightarrow{\alpha} q'$$

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$K' \subseteq K$ is called is called P-live if *every run* with $P(q_0)$

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of Sys encompasses an infinite number of transitions labelled with an interaction where some $i \in K'$ participates.

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If $i \rightarrow j$ then j will, when it proceeds, eventually need the cooperation of i.

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2. Observation: If Sys is finite and deadlock-free then in any run σ there must be some component j' that participates infinitely often in σ. If there is a path from k to j' in G then k participates infinitely often in that run σ.

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But we can do better.

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Consider a run σ where $h \in R_1(k)$ occurs infinitely often. Then, as the system is finite, there must be some α with which h occurs infinitely often in that run. Hence there must be some component $j \in R_0(k)$ with $j(\alpha) \neq \emptyset$. Hence j participates infinitely often in σ.

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By induction on i we obtain

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Theorem

Let Sys be a finite P-deadlock-free interaction system and $k \in K$ a component. If

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Cost: graph construction and "reachability" - polynomial in $|T_i|$, $|K|$, and $|C \cup Comp|$.

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It can be shown that modelling the dining philosophers as above is P-deadlock-free where P describes reachability from the designated initial state. This is due to the control component.

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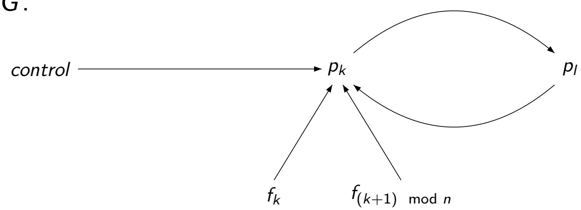
How can it be guaranteed that no philosopher starves?

It suffices to ensure that every philosopher is live because of the linearity of the behavior of the philosophers.

Example - The Dining Philosophers(continued)

The theorem can be used to show that every philosopher is live.

Part of G:



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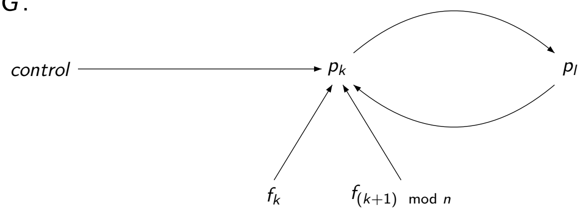

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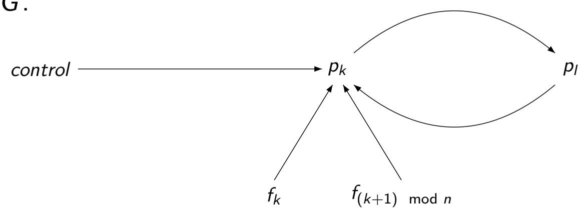

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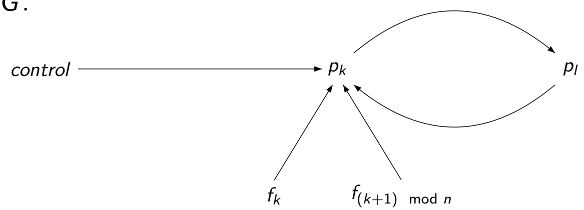

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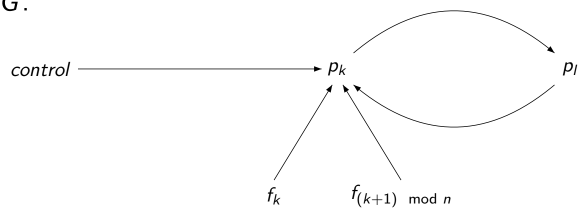

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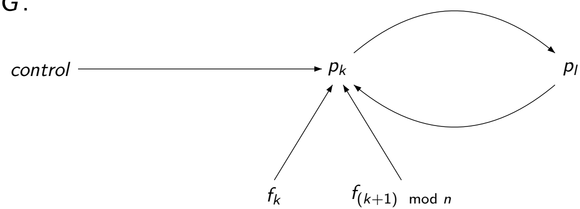

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$$\Rightarrow \bigcup_{i \geq 0} R_i(p_k) = K$$

Hence philosopher p_k is live in *Sys*.

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  - availability of interactions

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In addition we introduce probabilities to be able to make statements of the type:

With probability p no deadlock will occur.