Multiple viewpoints contracts for embedded systems

INSTITUT NATIONAL
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EN INFORMATIQUE
ET EN AUTOMATIQUE

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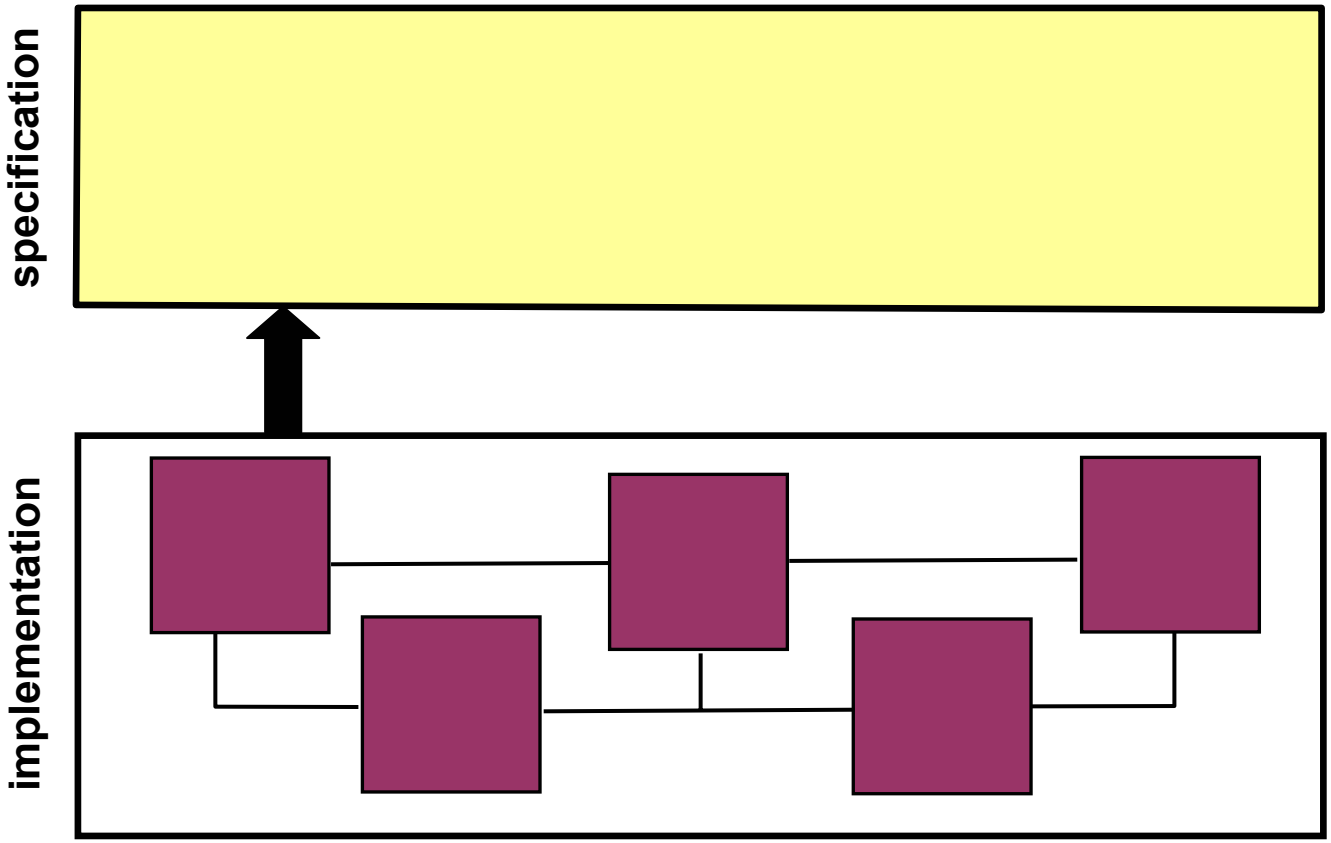
Foundations of Component Based dDesign,
ESWEEK, 30 september 2007

Motivations and Contribution

Principles of component based design: interfaces + substituability in any context



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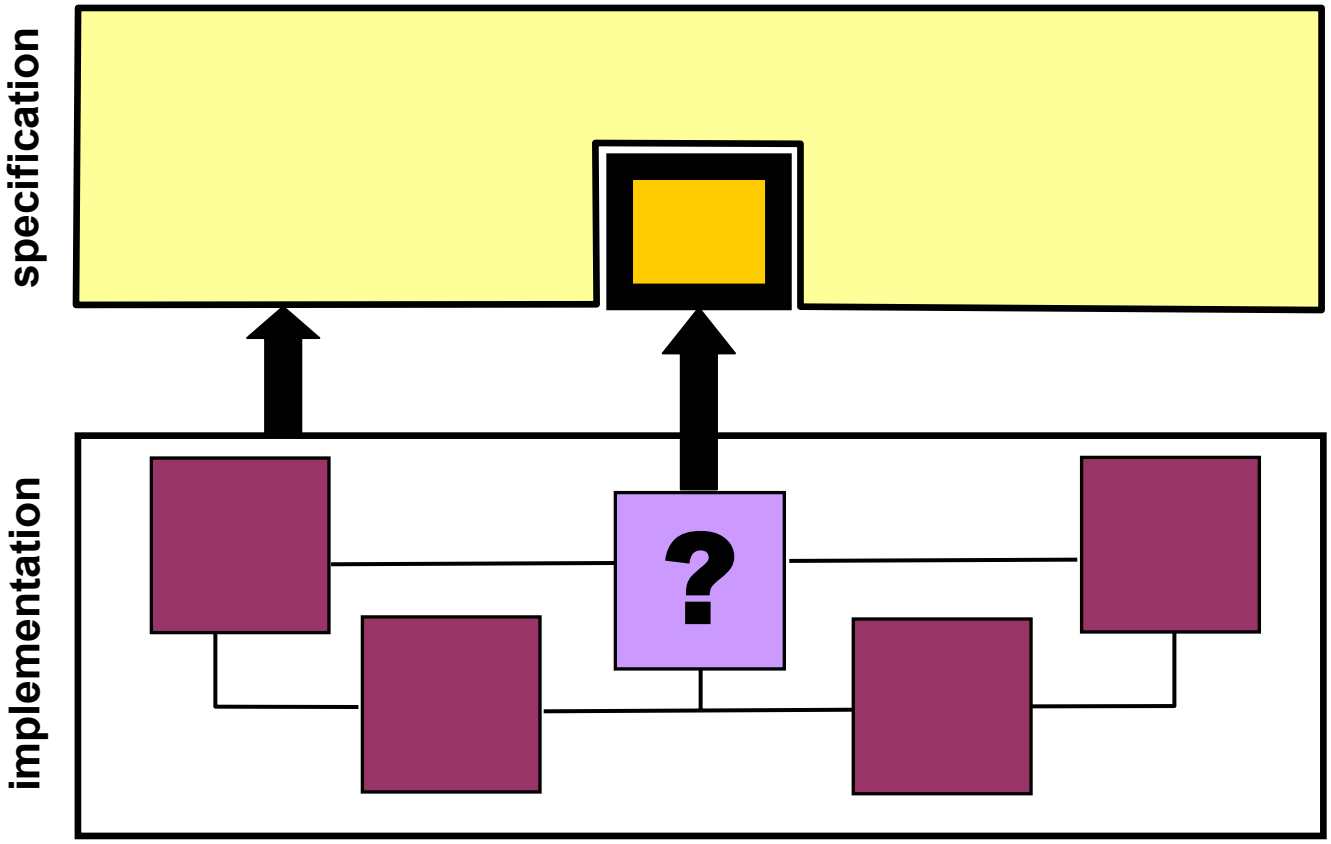
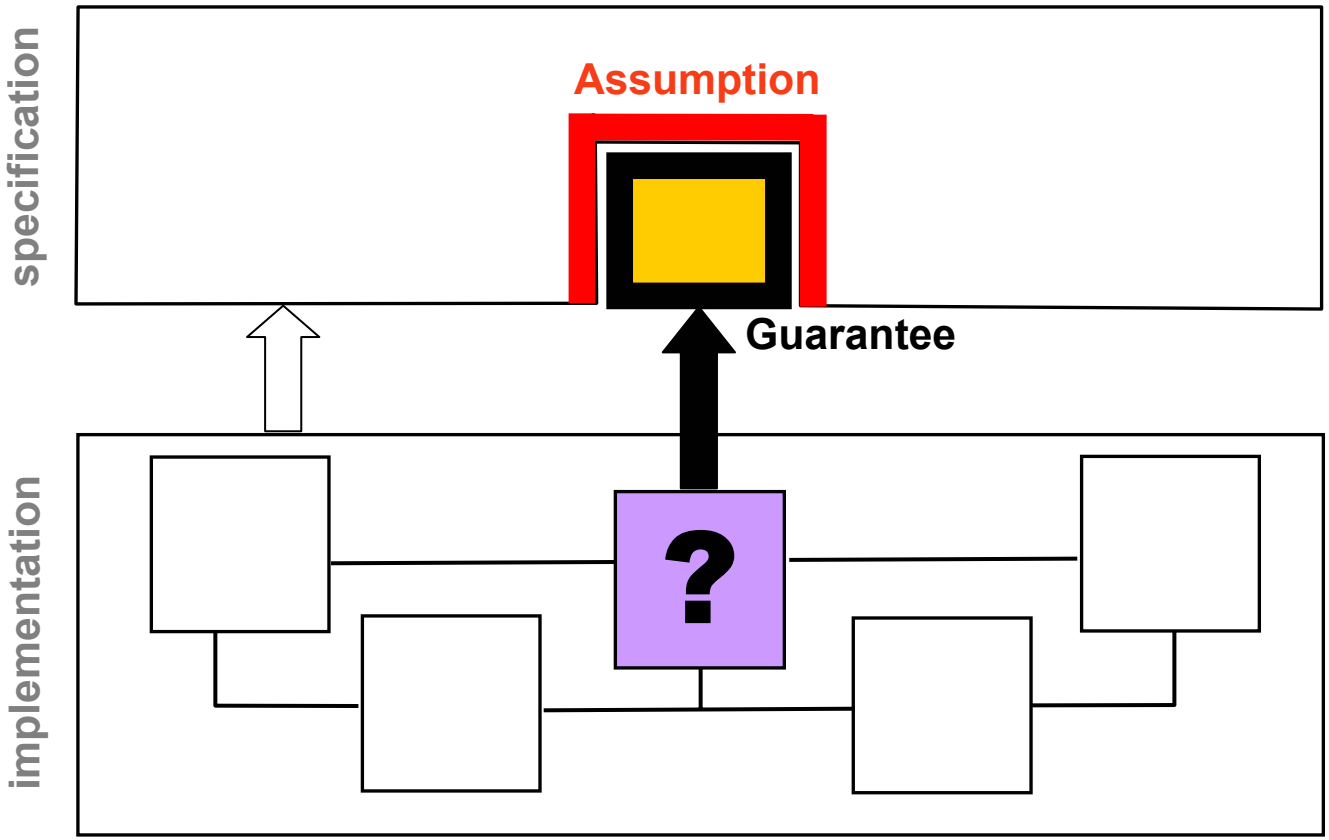


Principles of component based design: splitting of responsibilities ⇒ A/G reasoning



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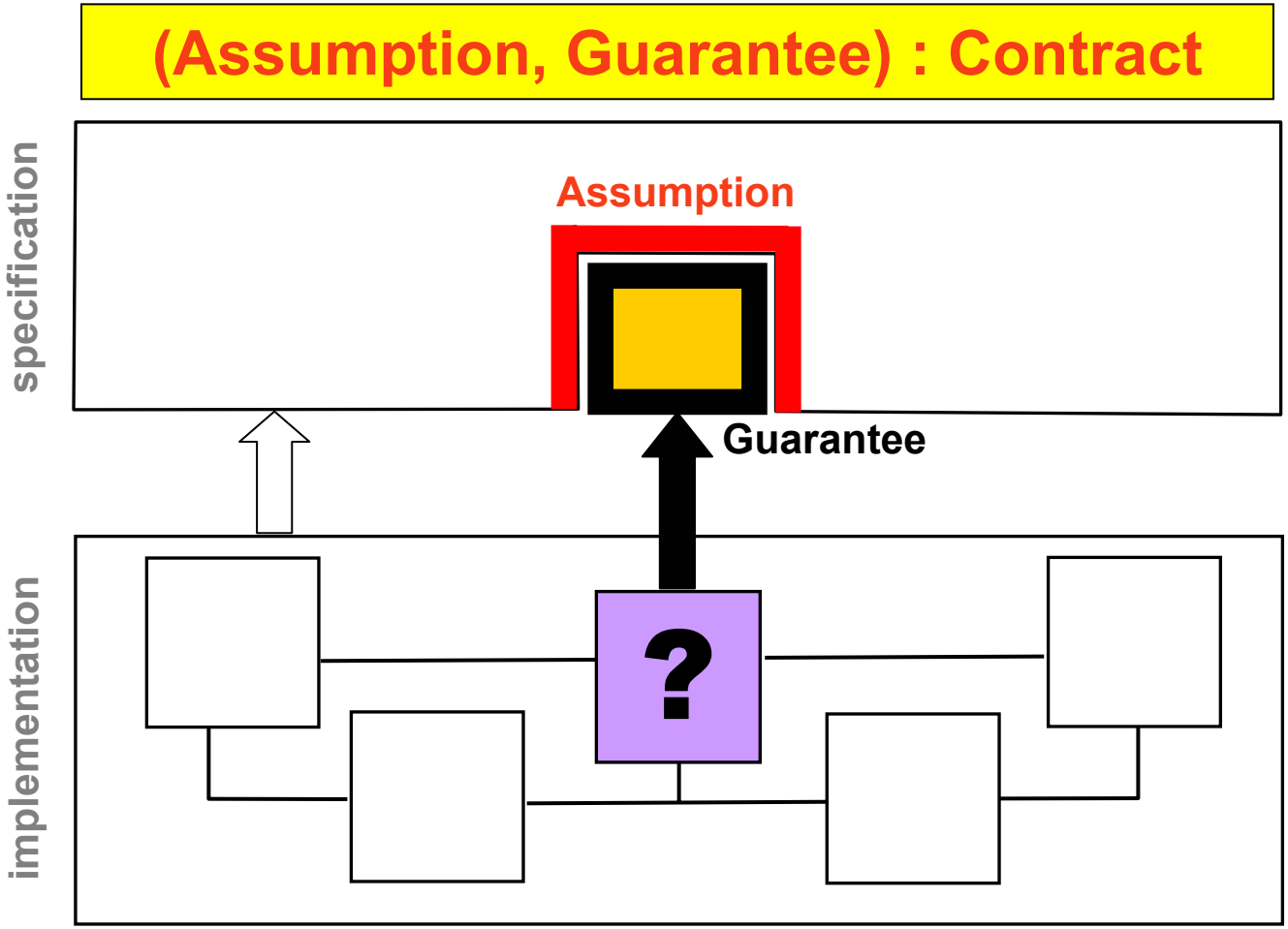

Embedded systems possess many components + different viewpoints

- Function
- Timing
- Reliability
- Energy
- QoS
- …

- The designer may want to:
  - consider all viewpoints for each component
  - implement each component
  - compose the implementations

- Alternatively she may want to consider viewpoints incrementally:
  - consider all viewpoints for each component except Safety + QoS
  - implement each component
  - compose the implementations
  - Revisit her design for safety and QoS, possibly with a different, coarser grain, architecture

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- **Combining contracts for the different viewpoints of a same component**

  ≠

- **Combining contracts for different components**

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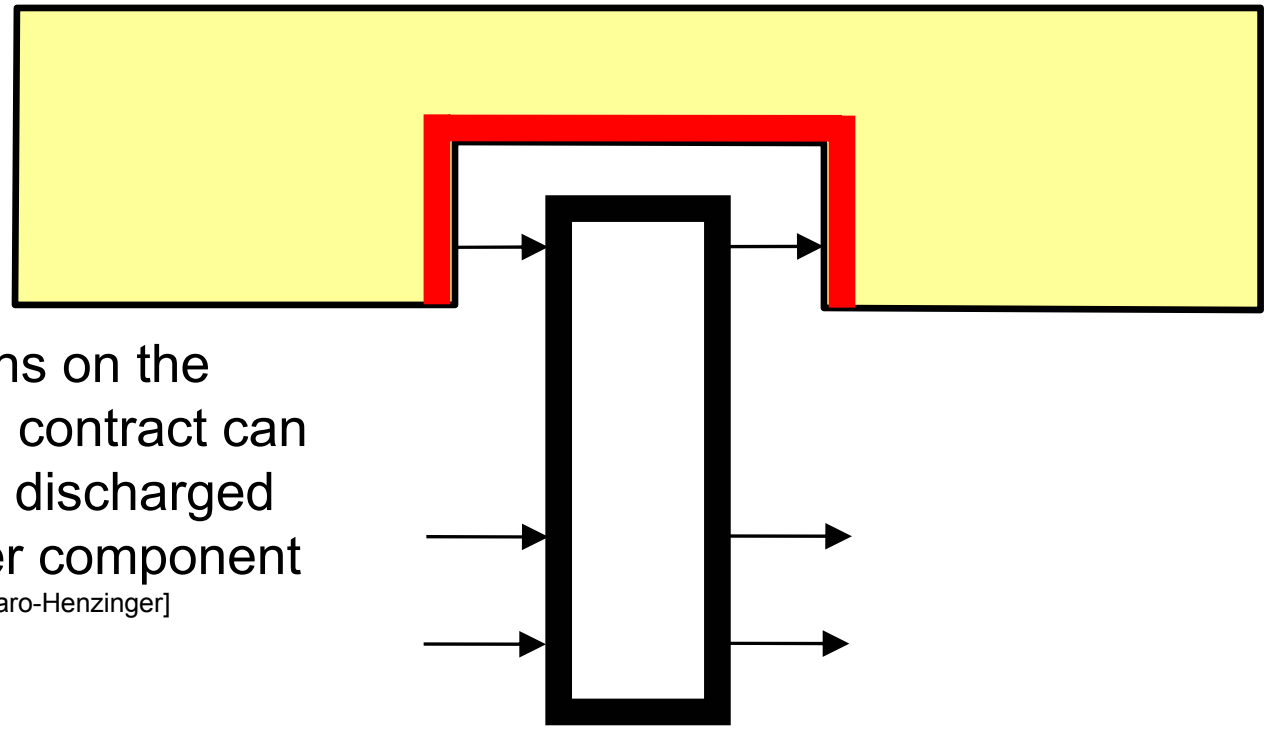
- **Is it a problem? Yes, for A/G reasoning…**

Always: conjunction of Guarantees

Assumptions when combining components?



Assumptions on the considered contract can be (in part) discharged by the other component

[Dill,Negulescu,de Alfaro-Henzinger]

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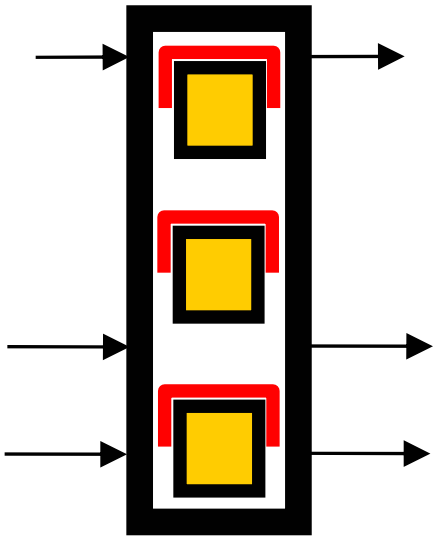
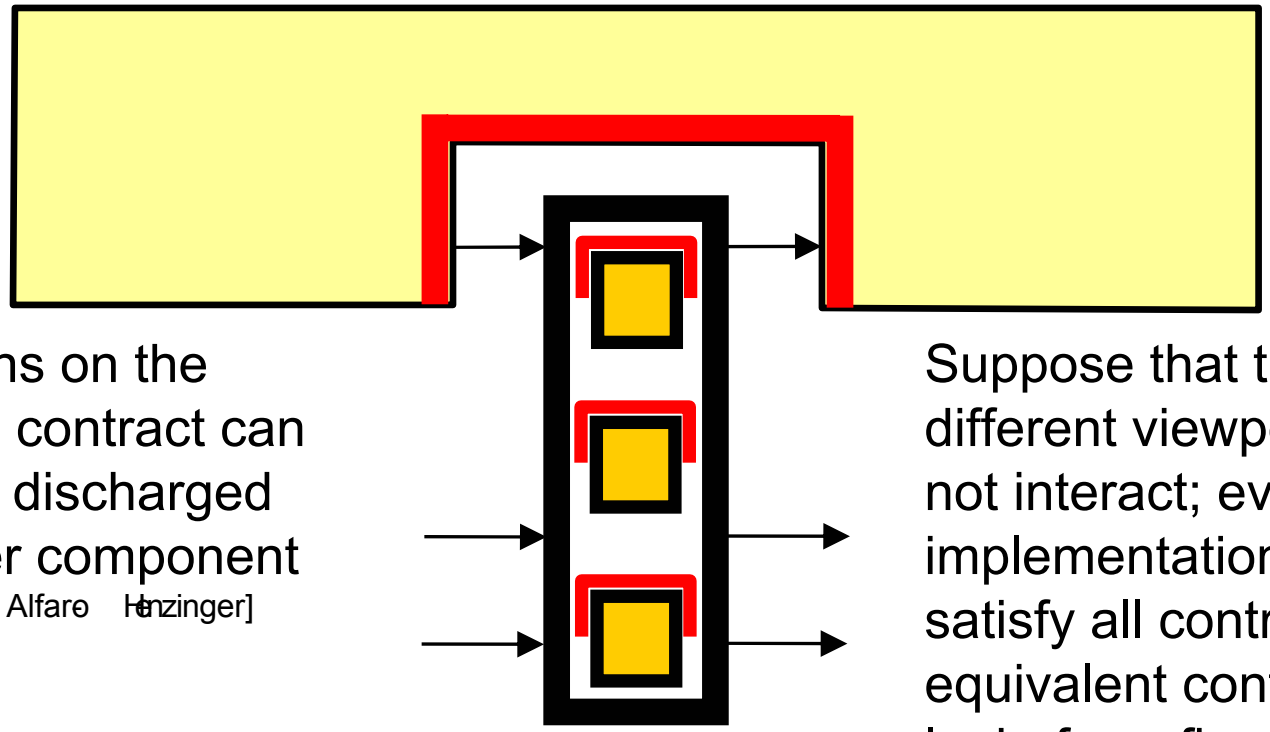


Suppose that the different viewpoints do not interact; every implementation should satisfy all contracts the equivalent contract is l.u.b. for refinement

Always: conjunction of Guarantees

Combining Assumptions in general?



Assumptions on the considered contract can be (in part) discharged by the other component
[Dill,Negulescu,de Alfaro Henzinger]

Suppose that the different viewpoints do not interact; every implementation should satisfy all contracts the equivalent contract is l.u.b. for refinement

A blend of the above two is needed

Main contribution

- ***Fusion*** of contracts: new operation that subsumes the above two cases
- Supports:
  - Combining contracts for different components
  - Combining contracts for different (possibly interacting) viewpoints in a same component
- Supports:
  - Incremental design in both components and viewpoints
  - With consistent results in terms of possible implementations

Framework and Results

Contracts and Implementations

M (implementations), A (assumptions), G (guarantees) are sets of runs composing by intersection and equipped with negation

Contract: $C = (A,G)$

Implementation: $M \models C$ iff $M \cap A \subseteq G$
ensures that M guarantees G in any context offering A

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Maximal implementation of C : $M_C = G \cup \neg A$
contracts having identical sets of implementations are said equivalent
contract C in canonical form if: $G = M_C \Leftrightarrow G \supseteq \neg A$

Substituability

Say that contract $C = (A,G)$ refines $C' = (A',G')$, written

$$C \leq C'$$

iff any implementation of C is also an implementation of C'

$C \leq C'$ is ensured by

$$A \supseteq A' \text{ and } G \subseteq G'$$

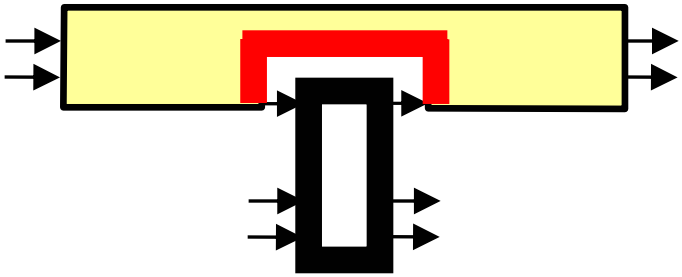
Operations on Contracts (in canonical form): Combining Components [Dill,Negulescu,de Alfaro-Henzinger]

Let $C' = (A',G')$ and $C'' = (A'',G'')$ be two contracts associated with two interacting components

$C = C' \| C''$ is the contract in which guarantees are composed (by conjunction) and assumptions are, in part, discharged by the other component:

$$G = G' \cap G''$$

$$A = (A' \cap A'') \cup \neg(G' \cap G'')$$



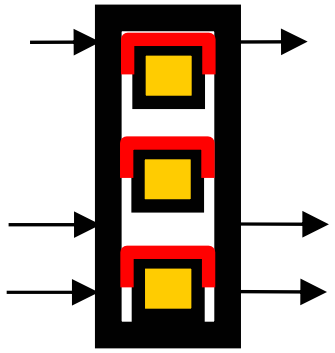
Operations on Contracts (in canonical form): Combining Viewpoints for 1 component

Let $\wedge$ be the least upper bound for the dominance partial order $\leq$

Contract $C \wedge C'$ subsumes the two contracts C and C'

$G = G' \cap G''$

$A = A' \cup A$



Operations on Contracts (in canonical form): Combining Viewpoints for 1 component

$$M \models C \text{ and } M \models C' \text{ iff } M \models C \wedge C'$$

Hence, assuming C and C' do not interact:

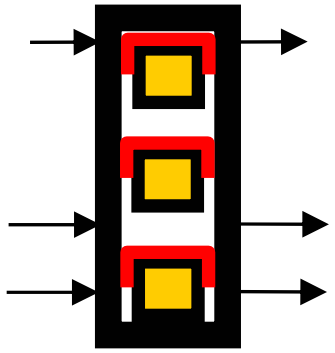
M satisfies the two contracts C and C'

$\Leftrightarrow$

$$M \models C \wedge C'$$

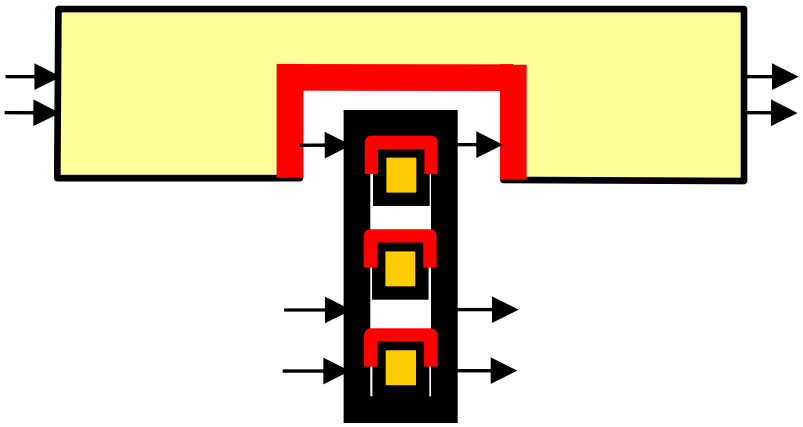
$$G = G' \cap G''$$

$$A = A' \cup A$$



Operations on Contracts (in canonical form): General case??

Fusion of contracts

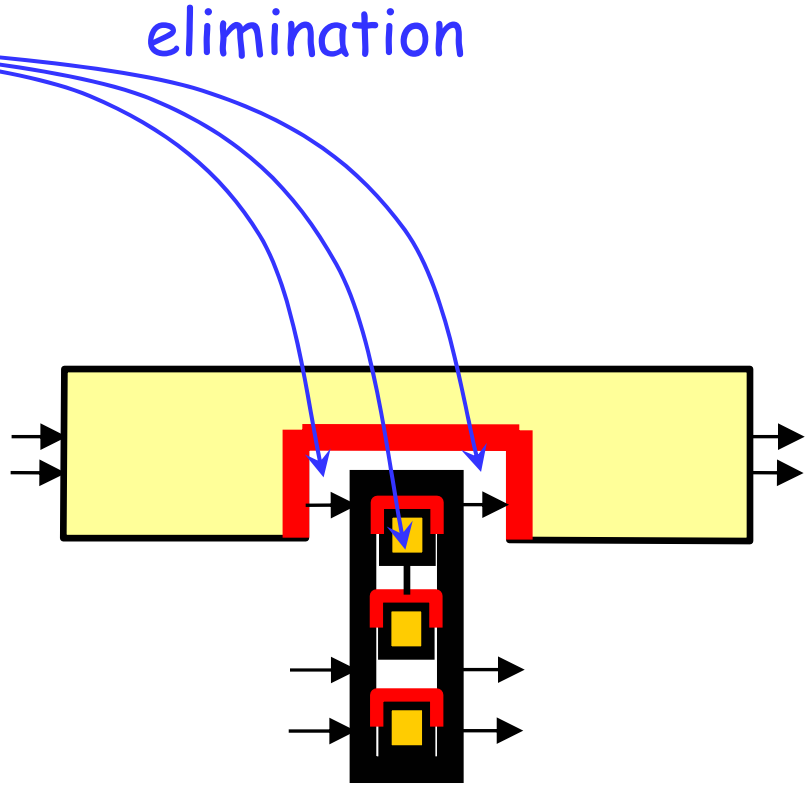


Operations on Contracts (in canonical form): Contract Fusion

$$\mathrm{fuse}[(C_i)_{i\in I}]_Q$$

$$=$$

$$\wedge_{J\subseteq I}\,[\|_{j\in J}\,C_j\,]_Q$$



A theorem regarding system design methodology

Suppose you have several viewpoints (function, QoS, safety…) to be addressed and you have several sub-systems or components

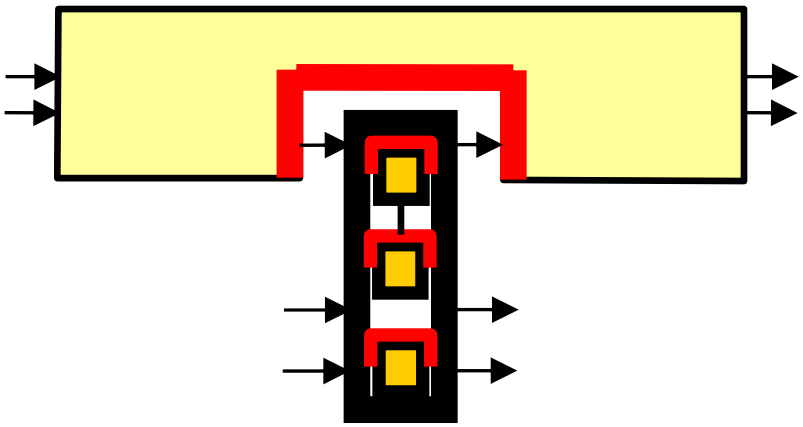
What if

- You consider viewpoints incrementally for the entire system

  equivalent

- You consider all viewpoints for each component and then compose implementations

by special associativity rule for fusion



Discussion and conclusion

- A generic theory of contracts addressing the new problems raised by multiple viewpoints
- Good: the issue of multiple viewpoints in A/G reasoning is now solved
- But:

Discussion and conclusion

- A generic theory of contracts addressing the new problems raised by multiple viewpoints
- Good: the issue of multiple viewpoints in A/G reasoning is now solved
- But:
  - Dealing with assumptions as in the theory may not be user friendly (the user may not want to state « obvious » facts about what the environment should not do)
  - Making effective the operations $\cap$, $\cup$, $\exists Q.A$, $\neg$

? Investigating residuation as a substitute for $\neg$


THANK
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