



Coupling Interaction Resources: an Analytical Model

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Context

- ↓ Ubiquitous Computing
- ↓ Dynamic building of Interactive Space



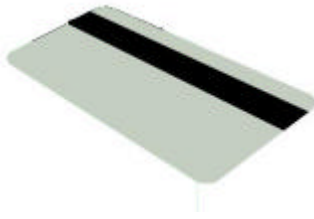
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Context

- ↓ Ubiquitous Computing
- ↓ Dynamic building of Interactive Space



[Smart-its friends]

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Coupling and usability

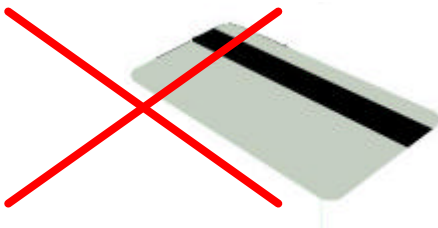
Conclusions

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Context

- ↓ Ubiquitous Computing
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[Smart-its friends]

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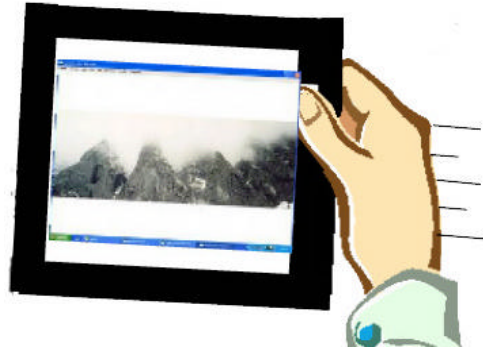
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Context

- ↓ Ubiquitous Computing
- ↓ Dynamic building of Interactive Space



[Hinckley]

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Context

- ↓ Ubiquitous Computing
- ↓ Dynamic building of Interactive Space



[Hinckley]

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- ↓ Dynamic building of Interactive Space



[Hinckley]

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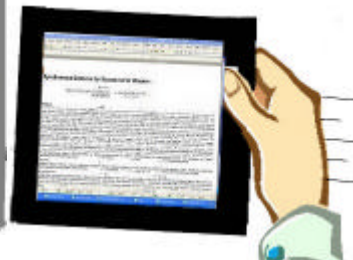
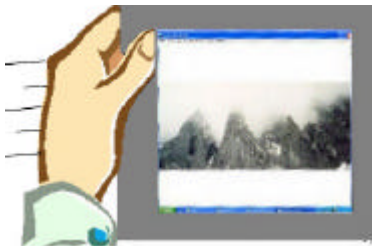
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Context

- ↓ Ubiquitous Computing
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[Hinckley]

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Coupling definition

Coupling two interaction resources is :

“the act of binding two entities so that they can operate together to provide a new set of functions that cannot be provided individually by the entities.”



Interaction Resource

↓ Interaction Resource : a physical entity that plays the role of

- ↗ Input device (keyboard, mouse, finger, ...)
- ↗ Output device (screen, table, ...)



Interaction Resource

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Interaction Resource

- ↓ Interaction Resource : a physical entity that plays the role of
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Interaction Resource

- ↓ Interaction Resource : a physical entity that plays the role of
 - ↗ Input device (keyboard, mouse, **finger**, ...)
 - ↗ Output device (screen, **table**, ...)

Example:

coupling two tablets

functions : « display extension », « display switching »

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Problem

- ↓ In conventional User Interfaces, coupling is taken for granted
 - ↗ Predefined
 - ↗ Number of interaction resources is limited
- ↓ Keyboard and mouse coupling
 - ↗ Mouse provides the focus for keyboard events
 - ↗ Keyboard modifies (ctrl, shift, alt, ...) mouse events

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Problem

- ↓ In Ubiquitous Computing, coupling is complex
 - ↗ Dynamic
 - ↗ Interaction Resources are unlimited



- ↓ **Human Factors**

- ↗ How can the user understand that a coupling is possible?
- ↗ Can the result function be predicted?

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Contribution

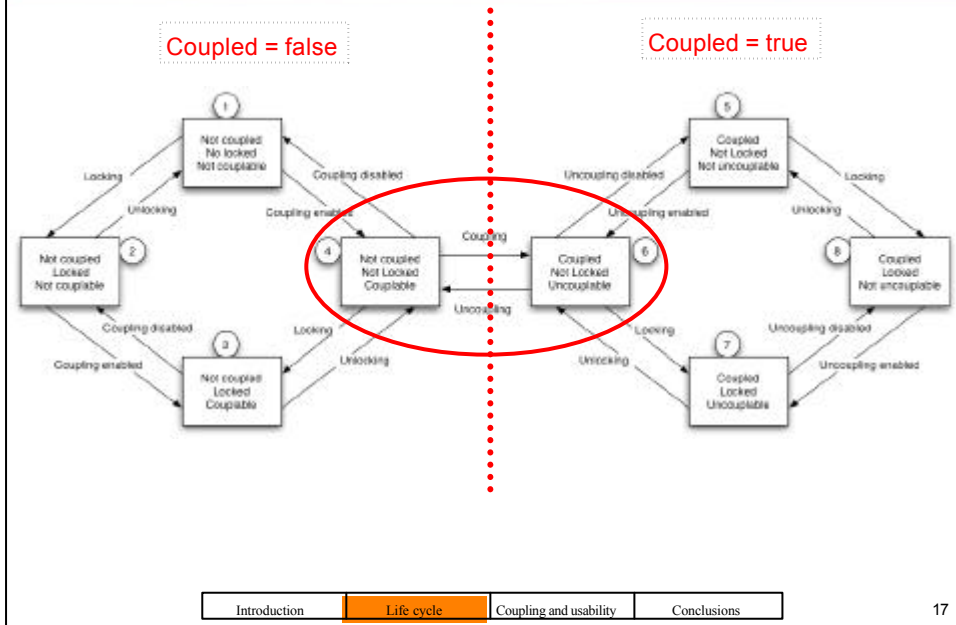
- ↓ Coupling analysis framework
 - ↗ Life cycle
 - ↗ IFIP properties

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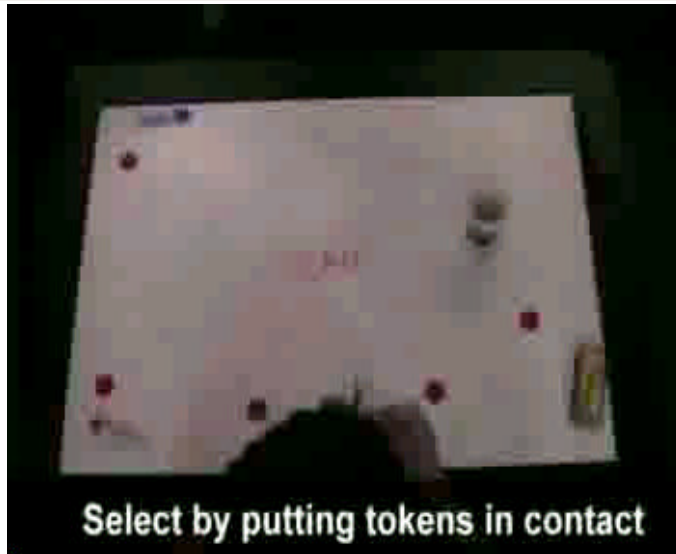
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Life cycle of (r1, c, r2)

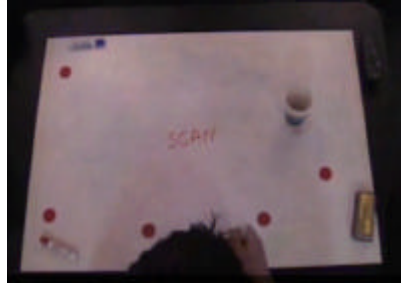


Example : Magic Table



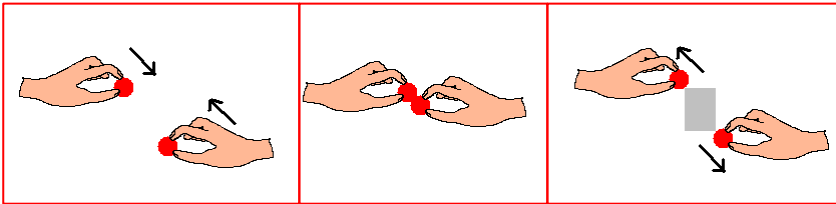


Example : Magic Table



[Bérard 98]

Selection function

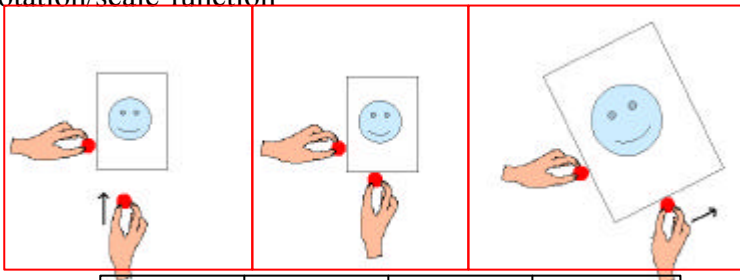


Example : Magic Table



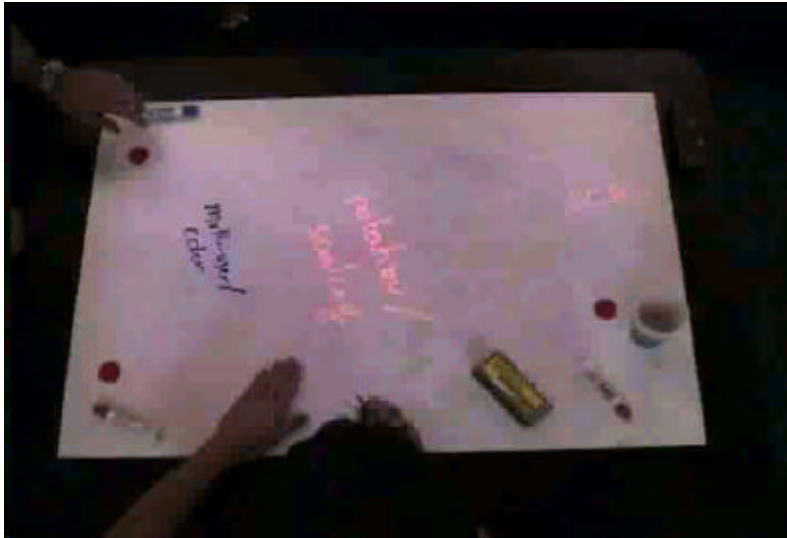
[Bérard 98]

Rotation/scale function





Example : Magic Table



[Bérard 98]

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One state as three predicates

↓ Let

- ↗ $r1$ and $r2$ be two interaction resources
- ↗ F be a set of functions resulting from the coupling c of $r1$ with $r2$ noted $(r1, c, r2)$

↓ Coupled

- ↗ $\text{Coupled}(r1, c, r2)$, true if and only if $F \neq \emptyset$

↓ Locked

- ↗ $\text{Locked}(r1, c, r2)$, true if $r1$ cannot exit the coupling c with $r2$

↓ Couplable

- ↗ $\text{Couplable}(r1, c, r2)$ expression of predicates other than Coupled and Locked

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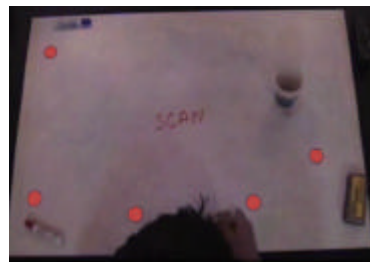
Transition

- ↓ Linked with the 3 state predicates:
 - ↗ Asking for coupling/uncoupling
 - ↗ Locking/Unlocking
 - ↗ Couplability/Uncouplability



Example

- ↓ t1 and t2 have the same color: red
 - ↗ $\text{Couplable}(t1, c, t2) = \text{true}$





Example

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 - ↗ $\text{Couplable}(t1, c, t2) = \text{true}$
- ↓ t1 and t2 are in contact: selection function
 - ↗ $\text{Coupled}(t1, c, t2) = \text{true}$



Example

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- ↓ t2 hidden
 - ↗ $\text{Coupled}(t1, c, t2) = \text{false}$



Example

- ↓ t1 and t2 have the same color: red
 - ↗ Couplable(t1, c, t2) = true
- ↓ t1 and t2 are in contact: selection function
 - ↗ Coupled (t1, c, t2) = true
- ↓ t2 hidden
 - ↗ Coupled (t1, c, t2) = false
 - ↗ t1 is attached to a patch
 - ↗ Locked(t1, c, t2) = **true** (selection function)



Example

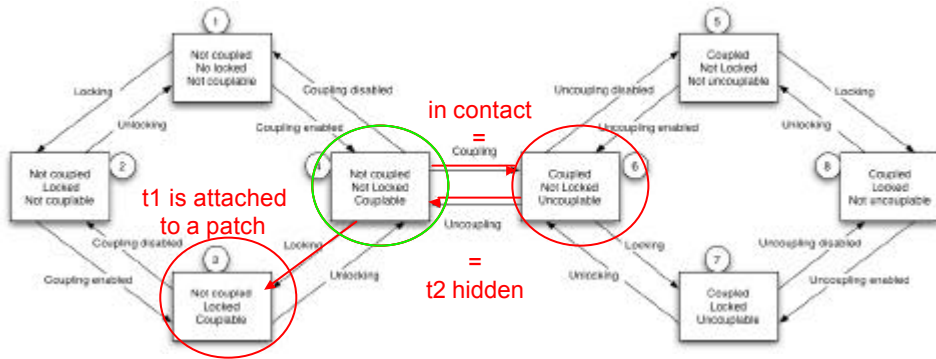
- ↓ t1 and t2 have the same color: red
 - ↗ Couplable(t1, c, t2) = true
- ↓ t1 and t2 are in contact: selection function
 - ↗ Coupled (t1, c, t2) = true
- ↓ t2 hidden
 - ↗ Coupled (t1, c, t2) = false
 - ↗ t1 is attached to a patch
 - ↗ Locked(t1, c, t2) = **true** (selection function)
 - ↗ Locked(t1, c2, t2) = **false** (rotation/scaling function)





Example

$(t1, c, t2)$ selection function



$(t1, c2, t2)$ rotation/scaling function



Plan

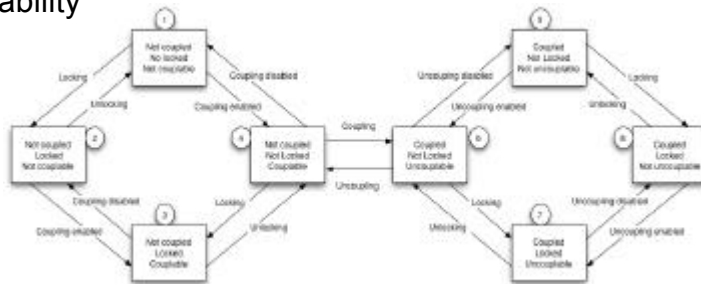
- ↓ Introduction
- ↓ Lifecycle of coupling
- ↓ Coupling and usability properties
 - ↗ Robustness
 - ↗ Flexibility
 - ↗ Learnability
- ↓ Conclusions



Coupling and usability properties

↓ IFIP properties

- Interaction robustness
- Interaction flexibility
- Learnability



C. Gram and G. Cockton, Eds. 1997 *Design principles for interactive software*. Chapman & Hall, Ltd.

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Ubiquitous Display

The Steerable Camera-Projector pair (SCP)



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Ubiquitous Display

The Portable Display Surface (PDS)



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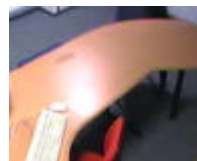


Ubiquitous Display

Interaction using the PDS

↓ Three entities

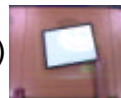
↗ A stationary surface, i.e. the table



↗ The SCP (projected image)



↗ The Portable Display Surface (PDS)



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Ubiquitous Display

Interaction using the PDS

↓ Three entities

↗ A stationary surface, i.e. the table



↗ The SCP (projected image)



↗ The Portable Display Surface (PDS)



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Ubiquitous Display

Interaction using the PDS

↓ Three entities

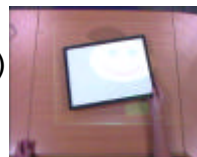
↗ A stationary surface, i.e. the table



↗ The SCP (projected image)



↗ The Portable Display Surface (PDS)



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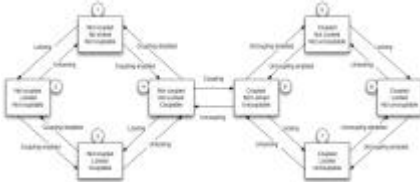
Ubiquitous Display

Interaction using the PDS

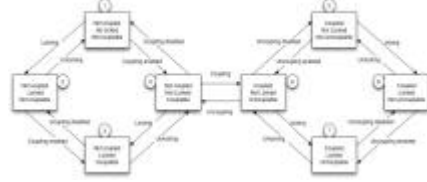
↓ Three entities

- ↗ Table
- ↗ The SCP (projected image)
- ↗ The PDS

(table, c1, SCP)



(PDS, c2, SCP)



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Ubiquitous Display

Interaction using the PDS

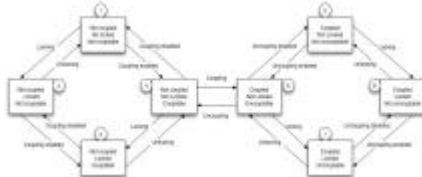
↓ Three entities

- ↗ Table
- ↗ The SCP (projected image)
- ↗ The PDS

Coupled(table, c1, SCP) = true



Coupled(PDS, c2, SCP) = false



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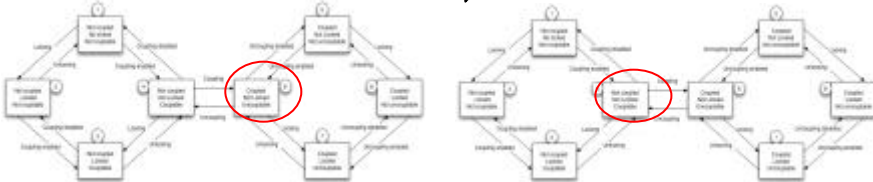
Ubiquitous Display

Interaction using the PDS

↓ Three entities

- ↗ Table
- ↗ The SCP (projected image)
- ↗ The PDS

$\text{Coupled}(\text{table}, c1, \text{SCP}) = \text{true}$  $\text{Coupled}(\text{PDS}, c2, \text{SCP}) = \text{false}$



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Ubiquitous Display

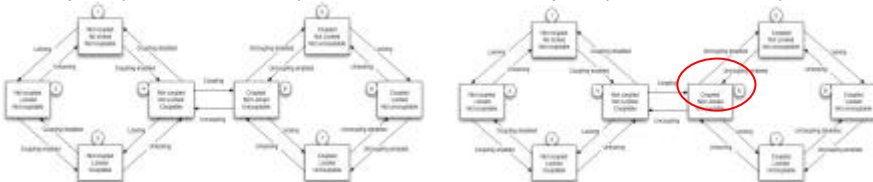
Interaction using the PDS

↓ Three entities

- ↗ Table
- ↗ The SCP (projected image)
- ↗ The PDS

$\text{Coupled}(\text{table}, c1, \text{SCP}) = \text{false}$

$\text{Coupled}(\text{PDS}, c2, \text{SCP}) = \text{true}$



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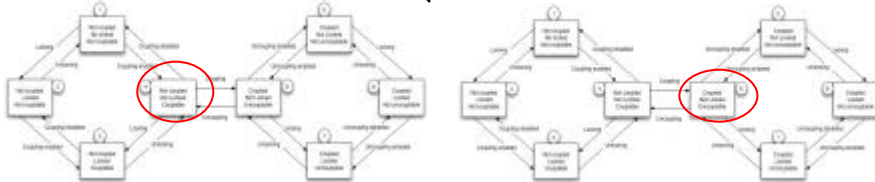
Ubiquitous Display

Interaction using the PDS

↓ Three entities

- ↗ Table
- ↗ The SCP (projected image)
- ↗ The PDS

$\text{Coupled}(\text{table}, c1, \text{SCP}) = \text{false}$ ← $\text{Coupled}(\text{PDS}, c2, \text{SCP}) = \text{true}$



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Robustness

↓ Observability

“Ability of the user to evaluate the internal state of the system from its perceivable representation”

↓ Design question:

Is it necessary to make all states observable?

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Coupling the PDS to the SCP

1. The couplability is not observable



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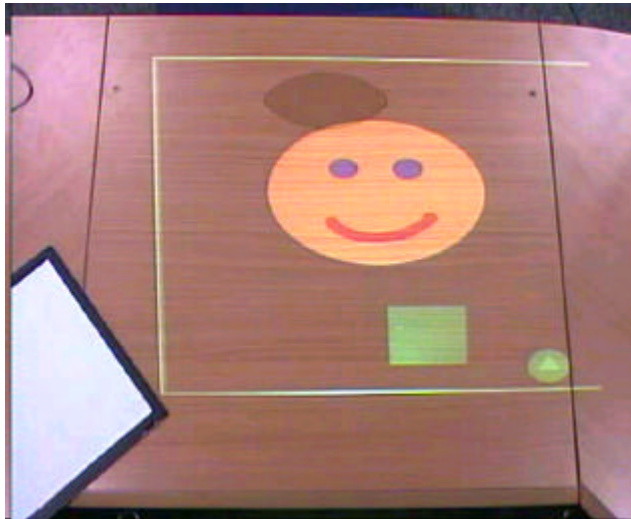
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Coupling the PDS to the SCP

2. A projected button makes the couplability observable



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↓ Reachability

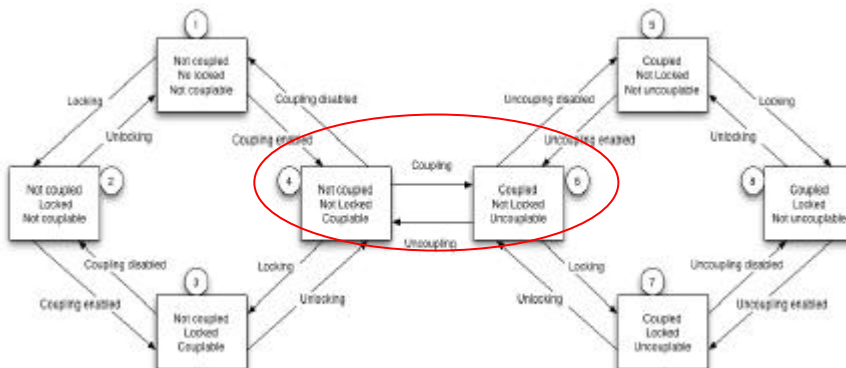
“Ability of the system to permit users to navigate within the observable states of the system to reach a desired state”

↓ Design question:

What are the automata states the user can reach?

1. The couplability is not observable

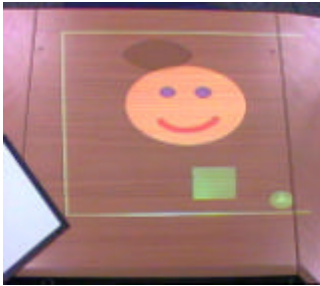
(table, c1, SCP) and (PDS, c2, SCP)





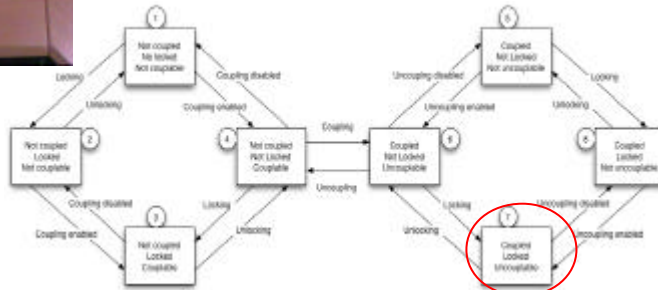
Reachability

2. A projected button makes the couplability observable



(table, c1, SCP)

Locked = true
Coupled = true
Uncouplable = true

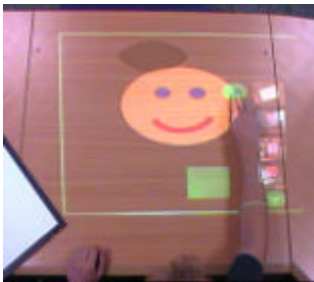


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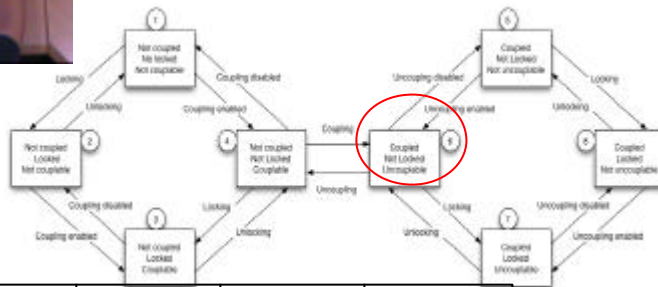
Reachability

2. A projected button makes the couplability observable



(table, c1, SCP)

Locked = false
Coupled = true
Uncouplable = true



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Reachability

2. A projected button makes the couplability observable



(table, c1, SCP)

Locked = false
Coupled = **false**
Couplable = true



Learnability

↓ Predictability

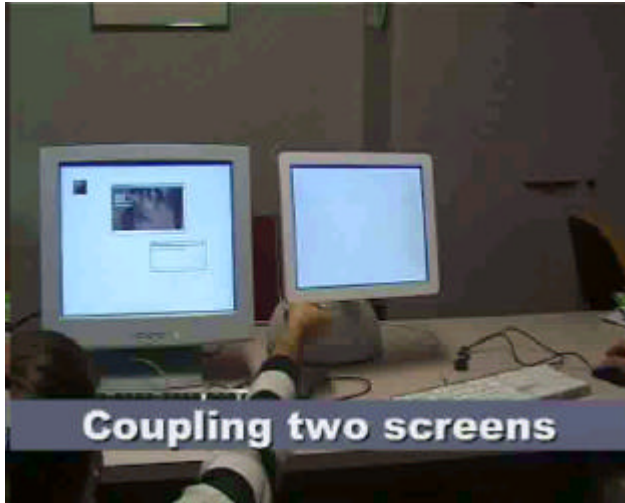
“Support for the user to determine the effect of future action based on past interaction history”

↓ Design question:

How to make the automata behavior predictable?



I-AM the Interaction-Abstract Machine



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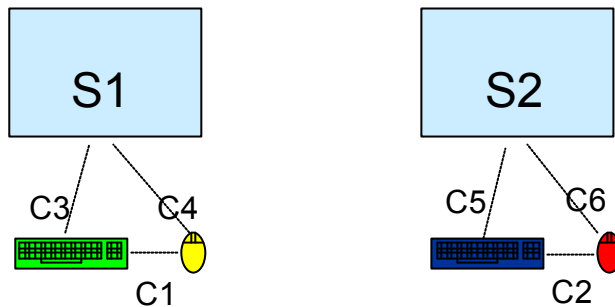
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Coupling interaction resources in I-AM



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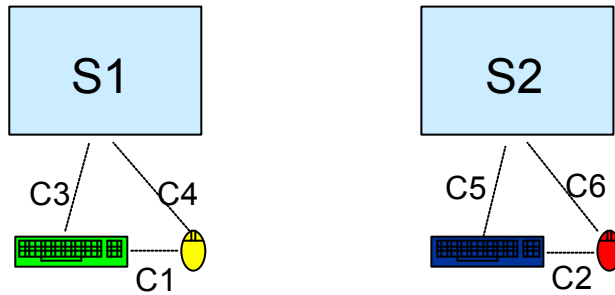
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Predictability

Coupling interaction resources in I-AM



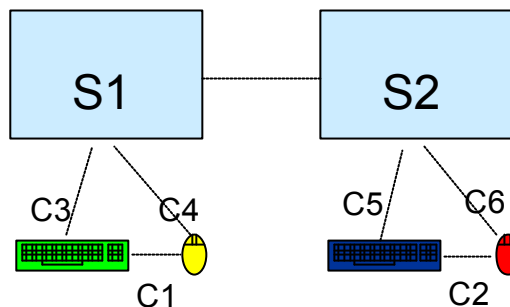
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Predictability

Coupling interaction resources in I-AM



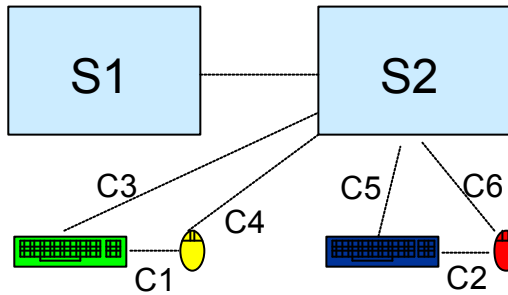
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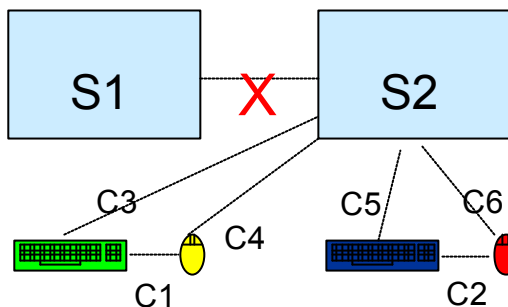
Predictability

Coupling interaction resources in I-AM



Predictability

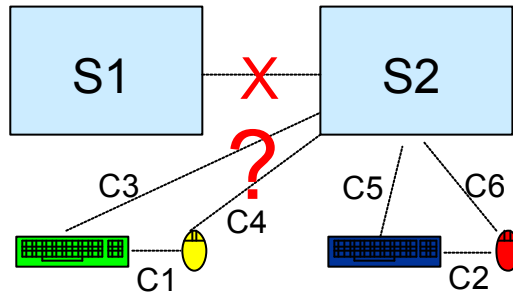
Coupling interaction resources in I-AM





Predictability

Coupling interaction resources in I-AM



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Conclusions

- ↓ Lifecycle model of coupling
 - ↗ Coupled/Locked/Couplable
 - ↗ Each state can be evaluated against usability criteria

- ↓ Future work
 - ↗ Devise interaction techniques that are adequate for coupling interaction resources

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Thank you for your attention

Joëlle Coutaz, Stan Borkowski, Nicolas Barralon

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↓ Interaction multifilaire

« Capacité du système à permettre la réalisation de plusieurs tâches simultanées »

