Design Abstractions for Context-Awareness

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Architectures for Mobility

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Motivation

- System operation depends on **environmental** resources

  Network connectivity
  CPU
  Directory Information
  Bandwidth
  Memory
  Printers
  Battery Power
  Screen size
  …

- That are subject to **change**
  - **Mobility** of components / hosts
  - **Fragility** of communication
  - **Variety** of devices
  - …
- Yet contained in an "architectural" structure

Motivation

Dealing with the **Dynamics of Environments**

- **Traditional approach**: based on **Exceptions**.

  Systems are developed for being executed using particular resources; at runtime, changes on operating conditions are not anticipated and raise "exceptions".

- **Context-Aware Computing Paradigm**: based on a notion of **Context**.

  Systems have means to observe the surrounding environment and are developed taking into account different conditions in which they can be required to operate.

The challenge

Formalisms for designing ubiquitous systems need to

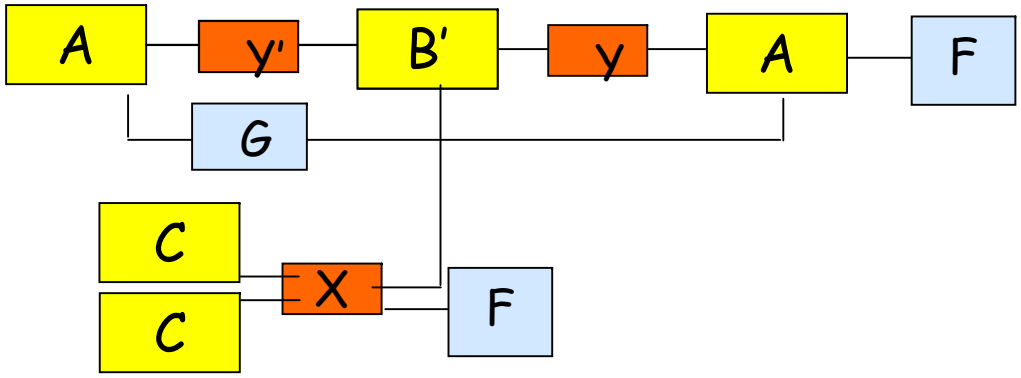
- address contexts as **first-class concerns**
- support **"personalised"** contexts
- relate **context awareness** with **architectural dimensions**

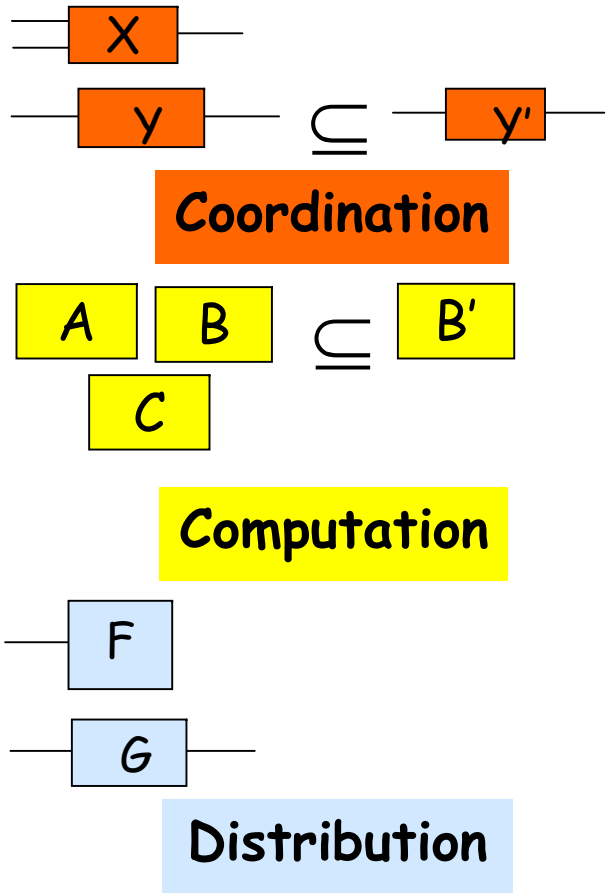
which requires

- the identification of essential features of contexts
- design primitives for defining contexts
- abstractions for modelling context-awareness

Separation of concerns

Mobility as a separate concern



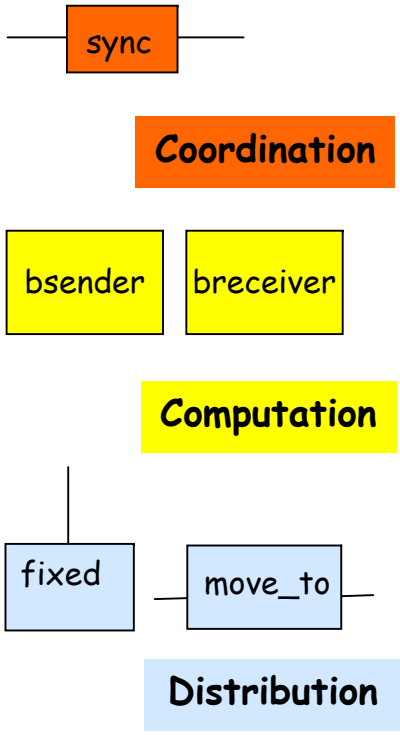


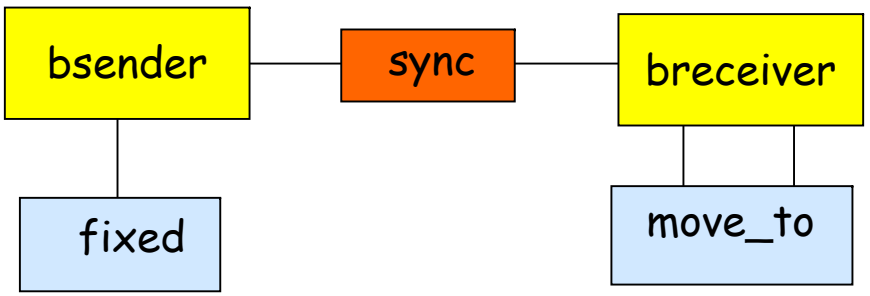
Compositionality wrt refinement

wrt evolution

Example

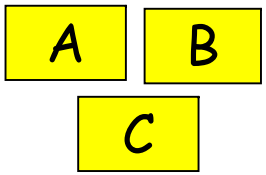
- In a **sender-receiver system**, a sender produces, in one go, words of N bits that are then transmitted, one by one, to a receiver through synchronous message passing.
- The sender is fixed and the receiver is a mobile component: once a word defining a location is received, the component should move its execution to that location; if this is not possible, it discards that word and starts receiving another one.





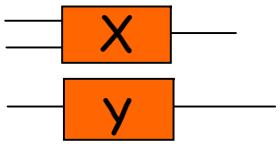
Context awareness

- Computations, as performed by individual components, are constrained by the **resources and services available** at the positions where the components are located



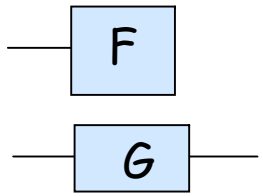
Computation

- Communication among components can only take place when they are located in positions that are **in touch** with each other



Coordination

- Movement of components from one position to another is constrained by **reachability**



Distribution

a piece of mobile code that relies on numerical operations with high precision will fail to compute when executing in locations where memory is scarce either because the the physical links that support communication between the positions of the space of mobility may be subject to failures or interruptions, making communication temporarily impossible

typically the space has some structure given by walls and doors or barriers erected in communication networks by system administrators

Mathematically speaking…

- Systems designed in terms of **actions**, **communication channels** and **context observables**
- **Architectural** aspects formalised over **categories** of designs (superposition and refinement as **morphisms**)
- **Behavioural** aspects formalised **algebraically**:
  - Algebraic specification of the data that can be transmitted and the operations that perform the computations that are required
  - Space of mobility represented by a distinguished data type **Loc**
  - Context observables defined over the algebra

    rssv: $\rightarrow nat_\infty \times 2^\Omega$ the **resources** and **services** that are available for **computation**

    bt: $\rightarrow 2^{Loc}$ how locations are **in-touch** through **communication**

    reach: $\rightarrow 2^{Loc}$ how locations can be **reached** through **movement**

Component Design in MMOCNITY

Example. Designing an airport luggage handling system

```
design located cart is
inloc pos:Loc
in next:Loc
prv busy@pos:bool, dest@pos:Loc
do move@pos[]: ¬busy∧pos≠dest,false → true
[] dock@pos[busy]: ¬busy∧pos=dest,false → busy'
[]                                          undock@pos[busy]:
          busy∧pos=dest,false → ¬busy'||dest'=next
```

Position controlled by the environment

Input channel

Private state

Actions

CommUnity with Distribution: Example

Example. Controlling how a cart moves

```
design controlled located cart is
outloc pos:Loc
inloc  cpoint:Loc
in  next:Loc
prv busy@pos:bool, dest@pos:Loc,
       in@cpoint:bool, mode@pos:[slow,fast]
do move@pos: ¬busy∧pos≠dest,false → c(pos,pos',mode)
[]  dock@pos: ¬busy∧pos=dest,false → busy'
[]  undock@pos: busy∧pos=dest,false → ¬busy'||dest'=next
[]  prv enter @pos: true → mode'=slow
            @cpoint: ¬in → in'
[]  prv leave @pos: true → mode'=fast
            @cpoint: in → ¬in'
```

Position controlled by the component

Position controlled by the environment

reach

bt

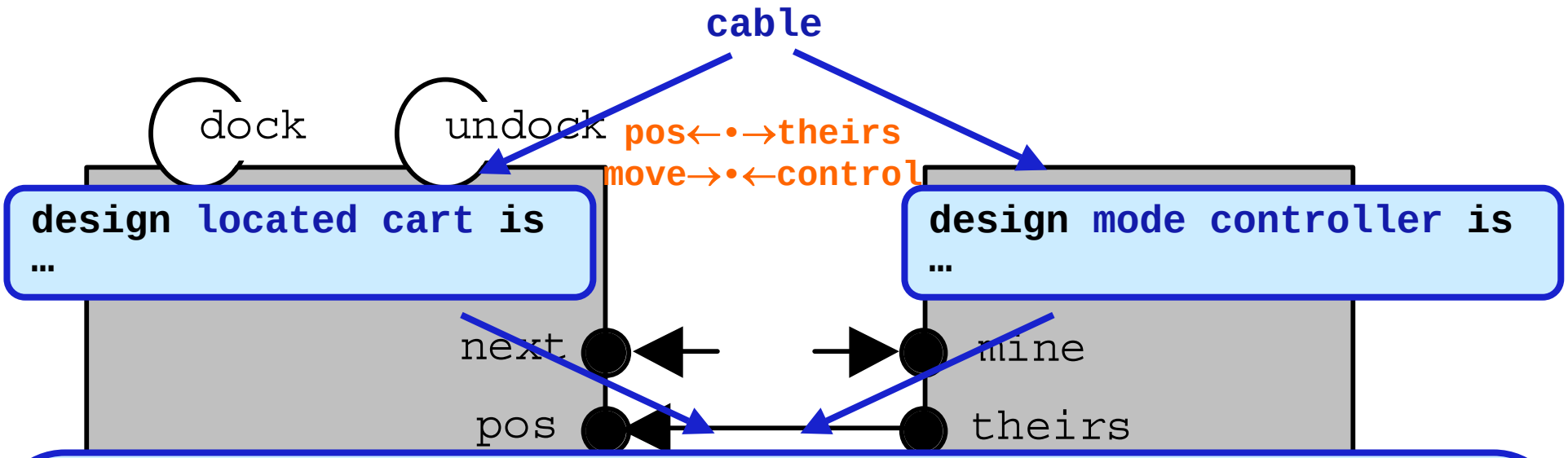
Externalisation of the distribution aspects

```
design controlled located cart is
outloc pos:Loc
inloc  cpoint:Loc
in  next:Loc
prv busy@pos:bool, dest@pos:Loc,
       in@cpoint:bool, mode@pos:[slow,fast]
do move@p
[]  dock@
[]  undoc
[]  prv e

[]  prv l
```

```
design mode controller is
outloc theirs:Loc
inloc  mine:Loc
in  next:Loc
prv in@cpoint:bool, mode@pos:[slow,fast]
do control@theirs: true → c(theirs,theirs',mode)
[]  prv enter @theirs: true → mode'=slow
              @mine: ¬in → in'
[]  prv leave @theirs : true → mode'=fast
              @mine: in → ¬in'
```

Categorical semantics

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prv busy@pos:bool, dest@pos:Loc, in@cpoint:bool, mode@pos:[slow,fast]
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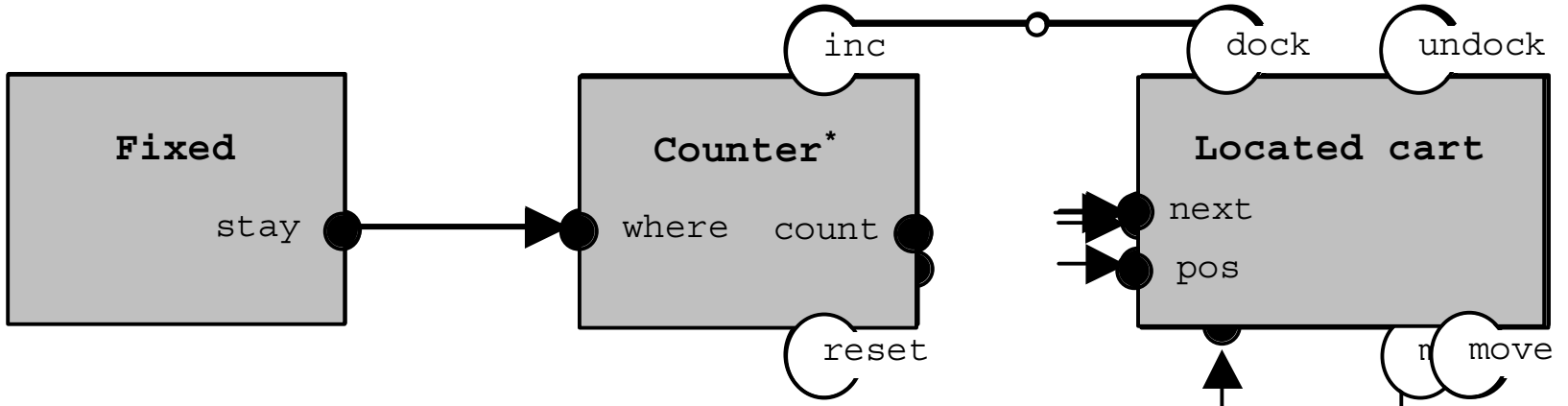
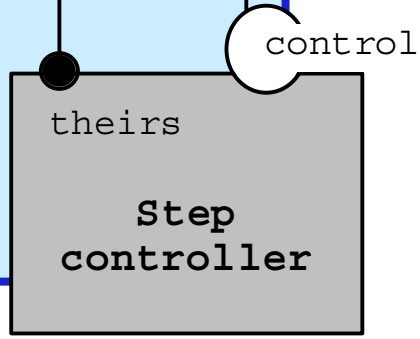
Separation of concerns




```
design fixed is
outloc  stay:Loc
out     count@where:nat
do inc@where: true → count'=count+1
[]  reset@where: true → count'=0
```



Conclusions

Our architectural approach supports

- an **incremental development** (**associativity**) of location-aware systems ; this makes it easier to cope with increased complexity and promotes reuse
- **principled-ways** of making models location-aware; in this process **designers can be assisted through libraries** with location and distribution connectors modelling standard solutions

www.fiadeiro.org/jose/CommUnity