RobMoSys

RobMoSys Building Blocks: Modelling Motion, Perception and World Model Stacks

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Building Blocks:
Motion, Perception and World Model Stacks

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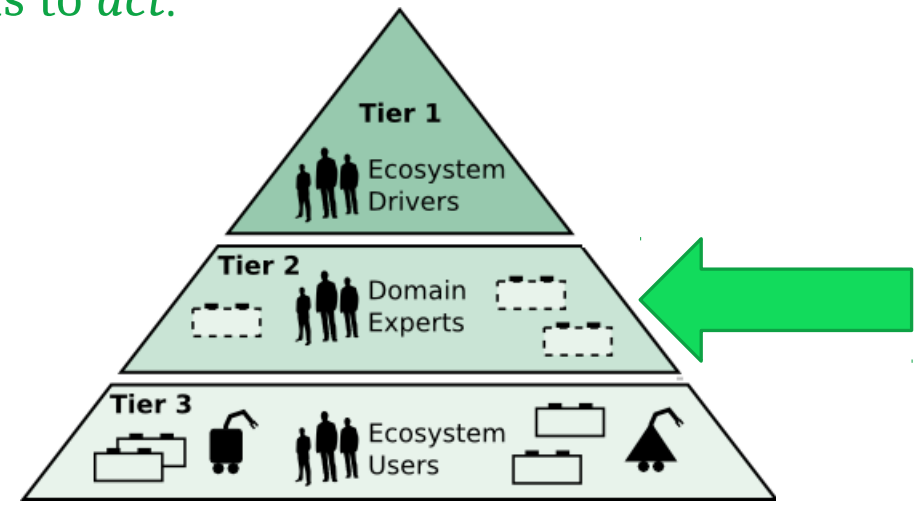
Basic functionalities that allows the robot systems to *act*.



- **Digital Platform**
  - covering all possible robotic systems
  - only 100% well-consolidated functionalities
- **Composability**
  - of algorithms: data + function + control flow
  - *“composition over inheritance”*
  - sequential, concurrent, and distributed programming
- **Mechanisms and policies**
  - structure = graphs, tools = graph traversal
  - behavior: kin. & dyn. functionalities/solvers
  - no magic numbers: all structure & behaviour parameters in models

Modelling Principles

Motion, Perception and World Model stacks are about ***functionalities***

- **Composability:** new functionalities are created by composing existing ones, not by inheriting their behaviour
- **Reusability:** minimize duplication in different contexts
- **Usability:** easy to use, intuitive, user-friendly

(Who are my users?)

Models should be **designed** for **composability** and **reusability**.

Usability is provided by **tools** and **domain-specific languages**

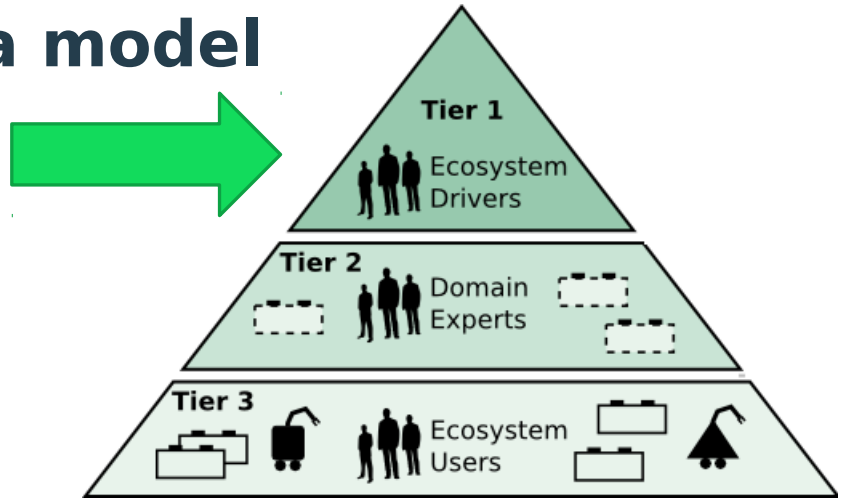
Composability at functional level is different from composability at component level:

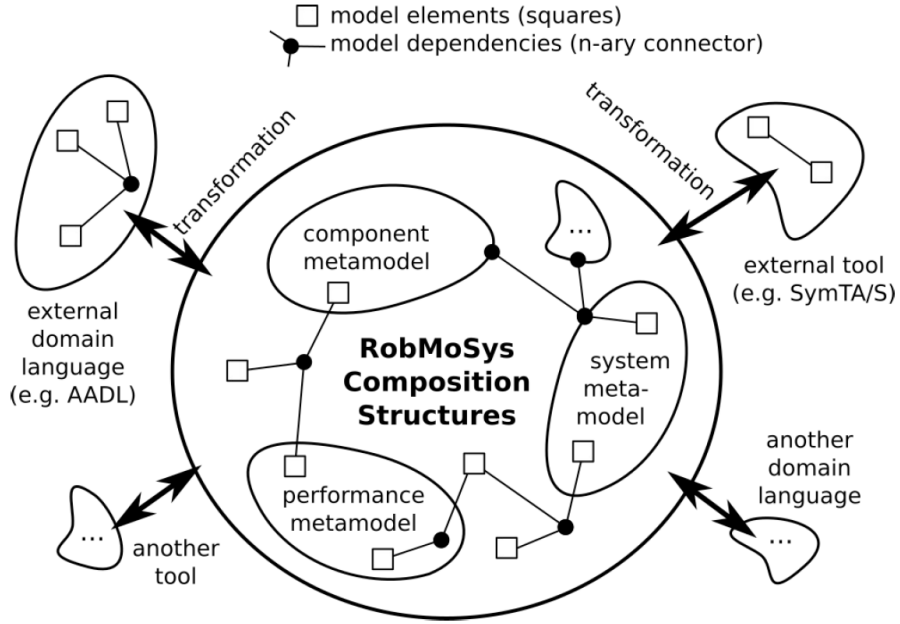
- Component-based architecture is about **activities**, **services**, etc;
- Functional architecture is about **data**, **functions**, and **control flows**;
- Concurrency is modelled as **constraints** in **information architectures**, and instantiated in function execution control flow
- Parallelism is instantiated in component-based architectures (deploying functionalities into components)

RobMoSys Composition Structures: Block-Port-Connector meta meta model (BPC)

- Entity-Relation **hypergraphs**
- Mereological information (`has-a`)
- Topological information (`contains, connects`)
- Common structure ↔ common tools!

All models conform to the BPC structural meta meta model





Motion Stack Models: an overview

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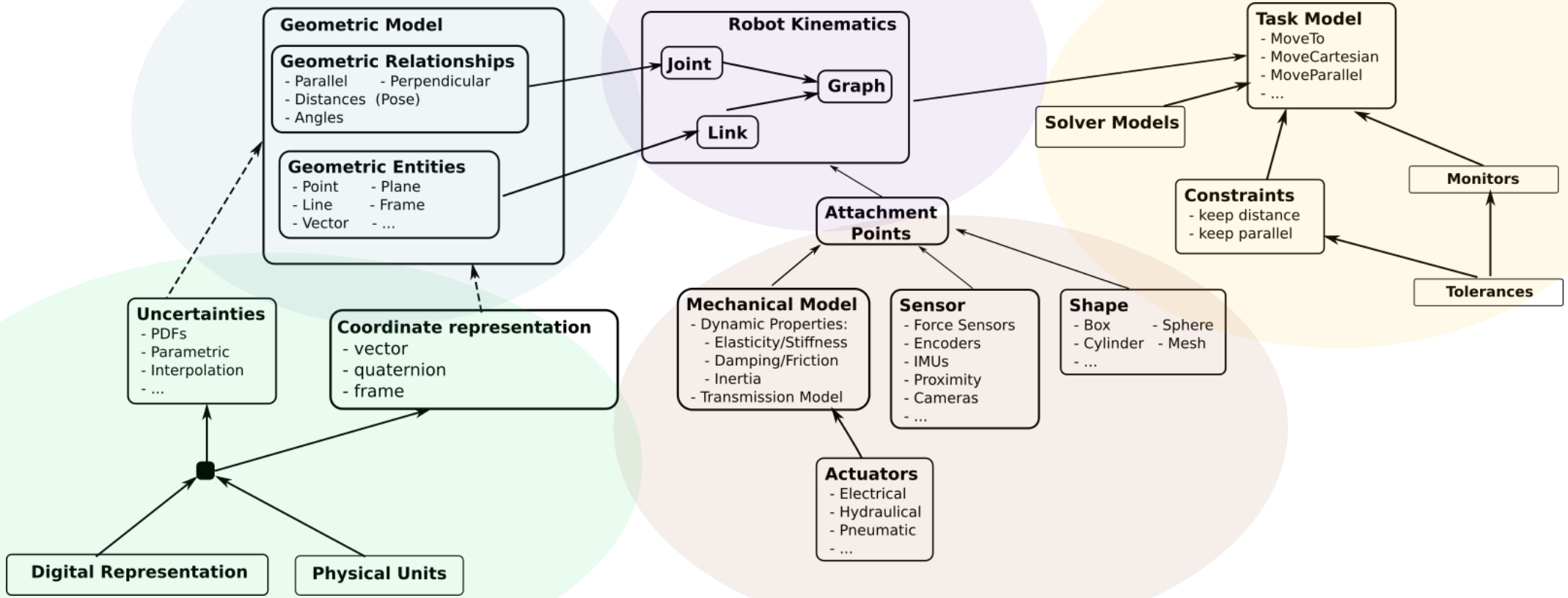

Motion Stack

Knowledge-based system (database) conforms to BPC

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Natural hierarchy (physics):

- battery/mains
- power convertor
- motor
- transmission
- joint
- kinematic chain
- end effectors

Artificial hierarchy (tasks):

- sustainable lifetime, efficiency
- minimal heath and vibration
- mechanical & electrical safety
- Move, MoveTo, MoveConstrained
- MoveCoordinated, MoveOrchestrated, MoveChoreographed

Energy, force and voltage are composable,
time, motion and current are not.

Models of Kinematic Chains

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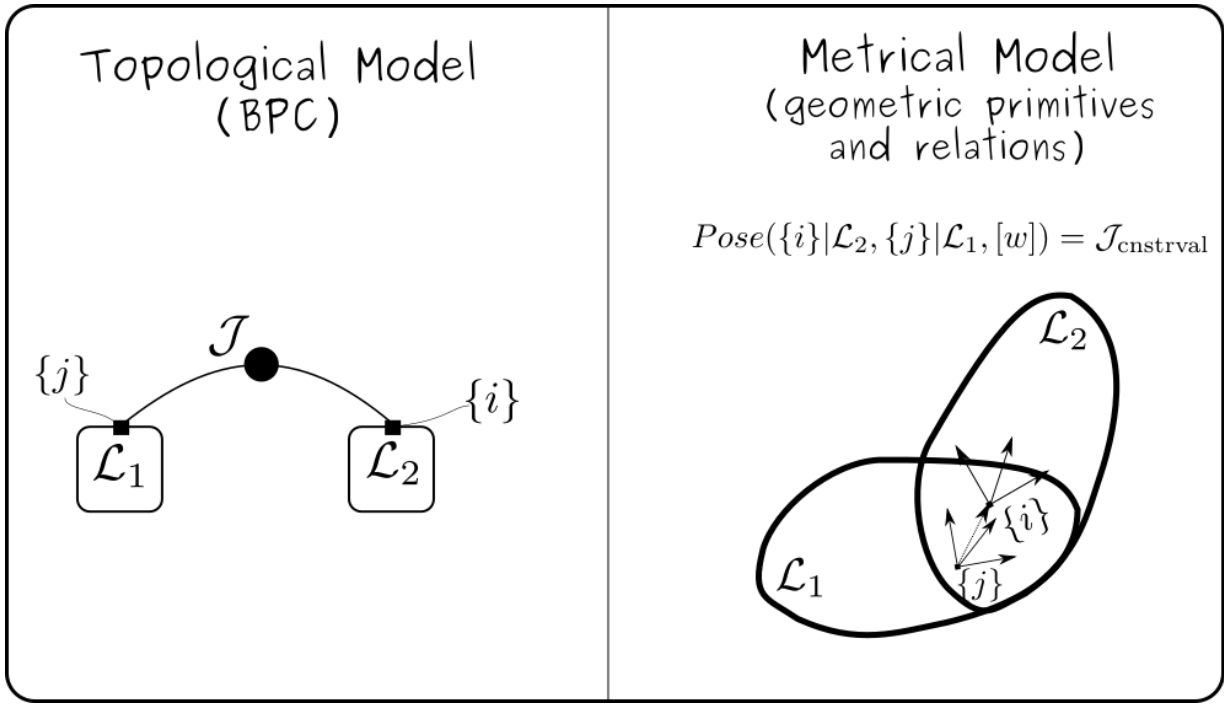
Domain: geometric semantics of rigid bodies

Geometric Entities
Point, vector, line, plane, orientation frame, displacement frame, rigid bodies, ...

Geometric Relationships
Position, orientation, pose, linear and angular velocities, ...

- **Link:** a rigid body
- **Joint**: (mechanical) constraint **-** *relationship of relationships*
- **Kinematic chain:** a graph



joint constraining value

kinematic constraint

$$\text{Pose}(\{j\}|\mathcal{L}_2, \{i\}|\mathcal{L}_1) = \mathcal{J}_{\text{cstrval}}$$

geometric relationship

Motion Stack (2)

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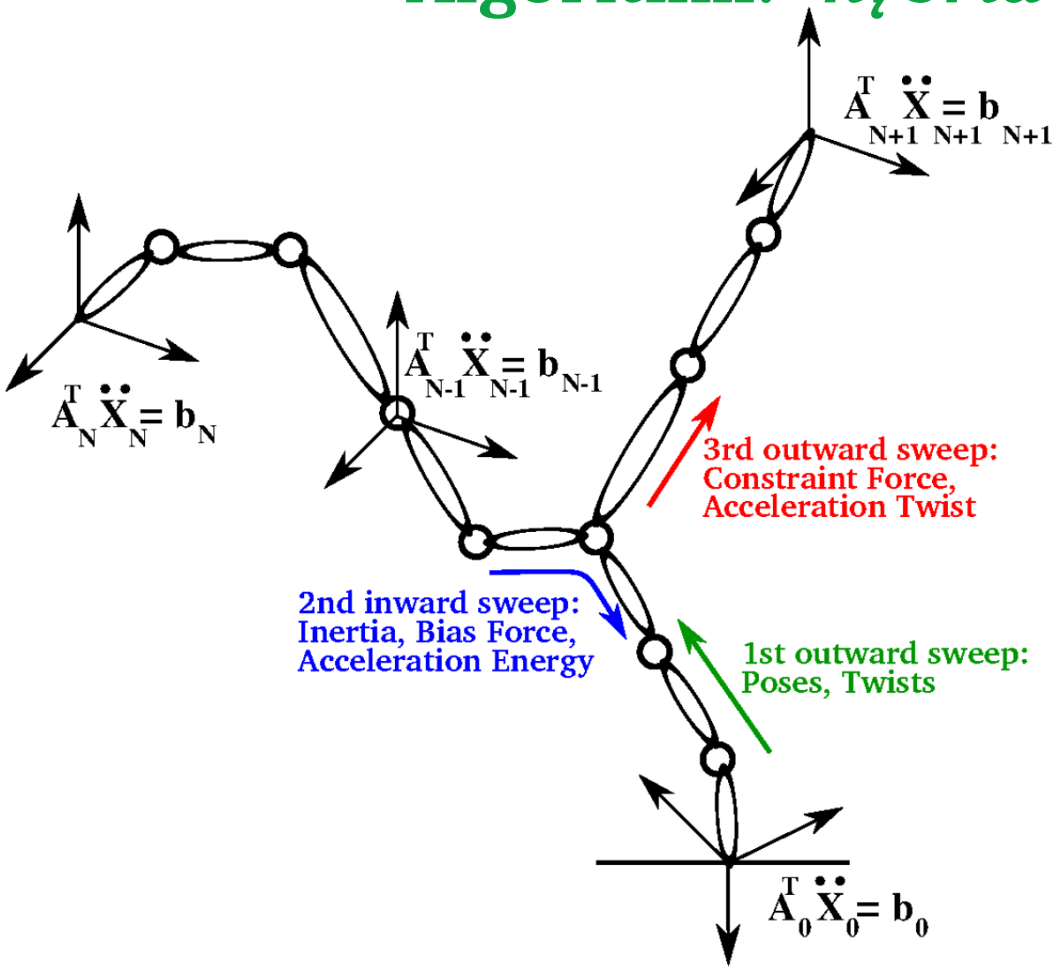
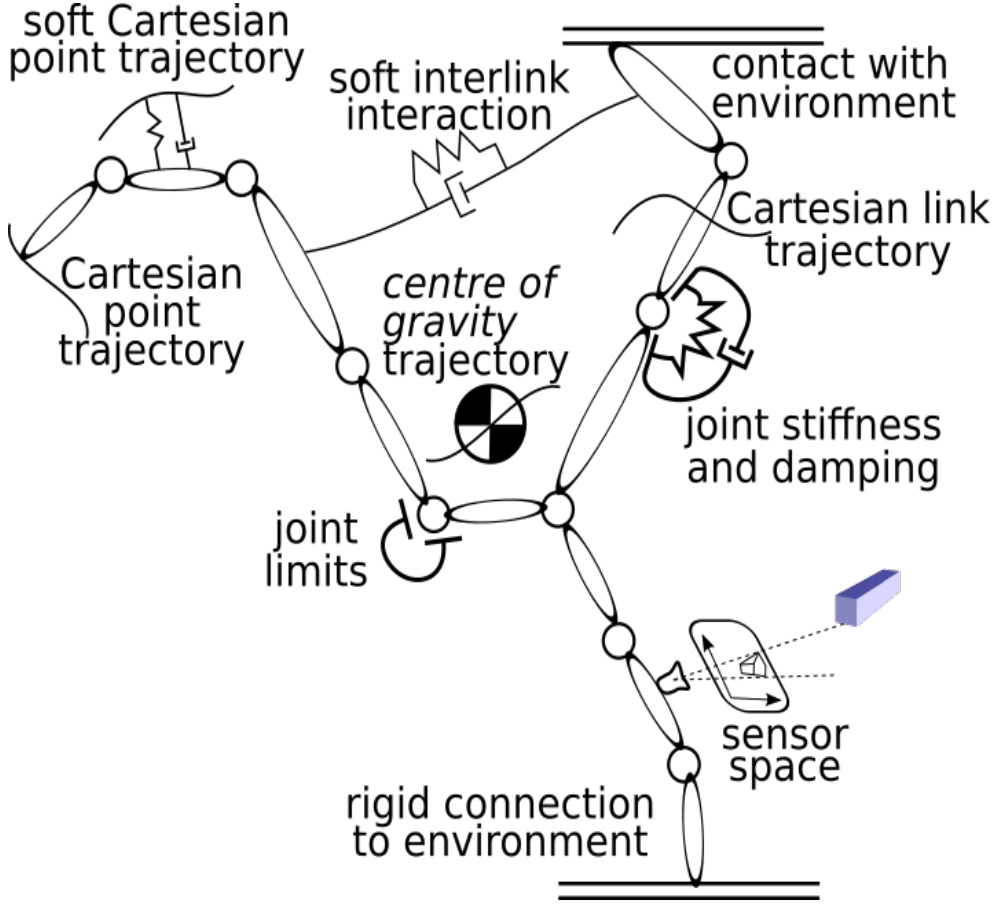
Algorithm: *"hybrid dynamics" solver*





Solver sweeps: structural model, to connect "fusion" to, with perception and world model in most efficient way.

Models of Algorithms

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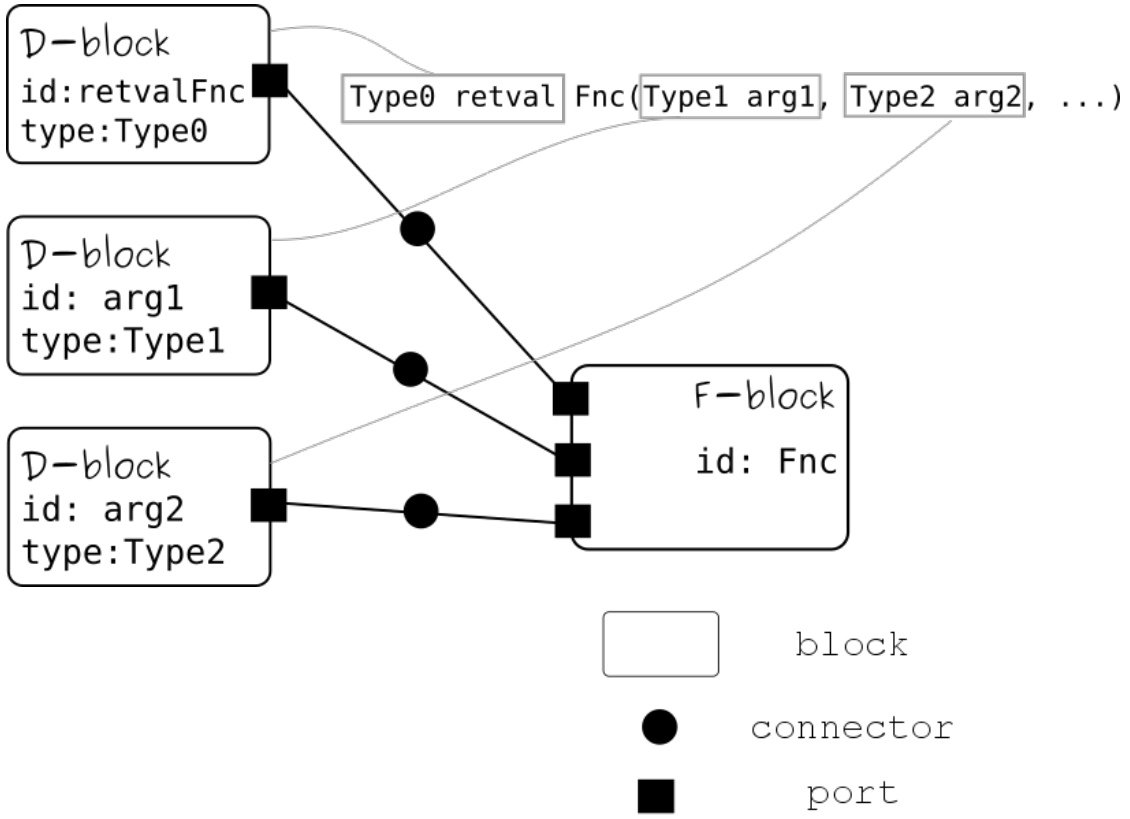
Entities and Relationships:

- D-block: (digital) **data** (representation)
- F-block: pure **function** (no side effects)
- S-block: scheduling (or **control flow**)
- C-block: **composition** of the above

Note: this is not robotics specific (hence, “meta meta”), but useful in motion, perception, and world model



Integration algorithms-components

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Algorithm:

- **Synchronous, no side effects**
- Processes motion, perception, world and task data, at **all** levels of abstraction
- Composes different levels of abstraction: mereology, topology, geometry, dynamics, …

Component:

- **Asynchronous, side effects**
- Responsive to real-time queries
- Composability: view and levels of abstraction in data streams
- Distributed
- Life Cycle, history, logs

Synchronous, concurrent, distributed programming is tough

Concurrency relevant for algorithms *and* components

Integration algorithms-components (2)

Composition pattern: *"event loop"*

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```
when triggered    // = scheduling by OS, i.e., asynchronous side effect
 do {             // = the Composition structure of the event loop
  communicate()   // get "message" with events & data that have been filled
                  // in by other asynchronous activities since last execution
  coordinate()    // handle the events, and decide which ones to react to
  configure()     // realise reconfiguration of local Computations
                  // whenever this is required by the events

  schedule()      // execute your algorithms' side effect-free Computations

  coordinate()    // this execution could trigger new events,
                  // both internally and externally
  communicate()   // the execution could generate data that other
                  // asynchronous activities must know about
  log()           // remember what happened
 }
```

`communicate()`: takes place via "Ports" of containing Component.
`coordinate()`, `configure()`, `schedule()`, `compute()`: take place via "Ports" of Algorithms