Assemblages: Modules with Interfaces for Dynamic Linking and Communication

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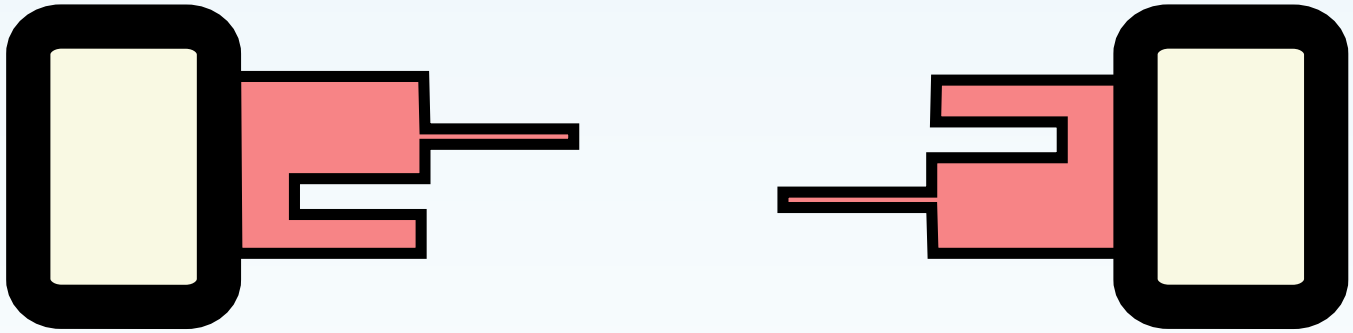
The Main Design Principle

Every form of interaction of code with the environment should be supported by explicit, declared interfaces.

A Typical Module

Examples: Functors, Mixins



Modern Language Interactions

Main forms of interaction include

- Code-code interaction via static linking
- Code-runtime interaction via dynamic linking
- Runtime-runtime interaction via distributed messaging

Our Approach: Assemblages

- A module-centric approach to interfaces for all three
- Static linking of assemblages—mostly standard stuff
- Main contributions:
  - Module-centric view of dynamic extensibility and distributed messaging
  - Unified treatment of all three, using related notions of interface

Code and Runtime

- *Assemblages* are code units—modules
- *Assemblage runtimes* are loaded assemblages

Static Linking Illustrated

Assemblages with static linkers being linked together:

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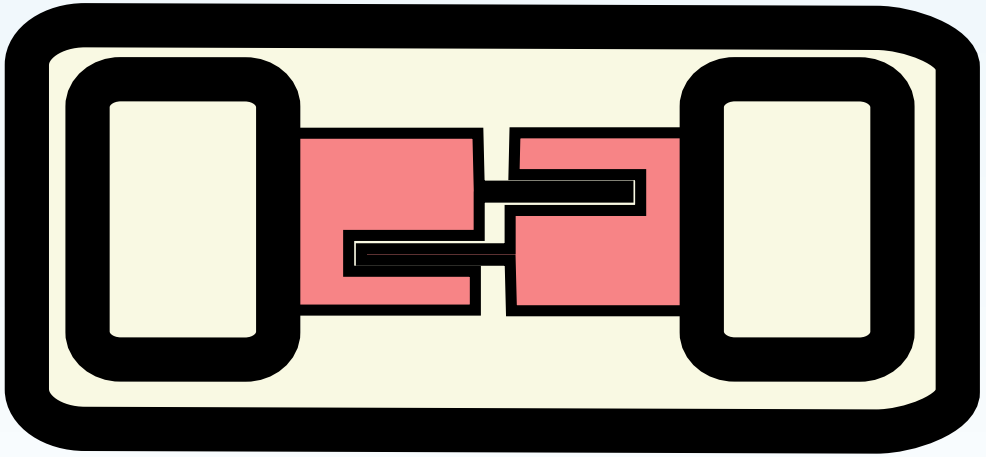

Static Linking Illustrated

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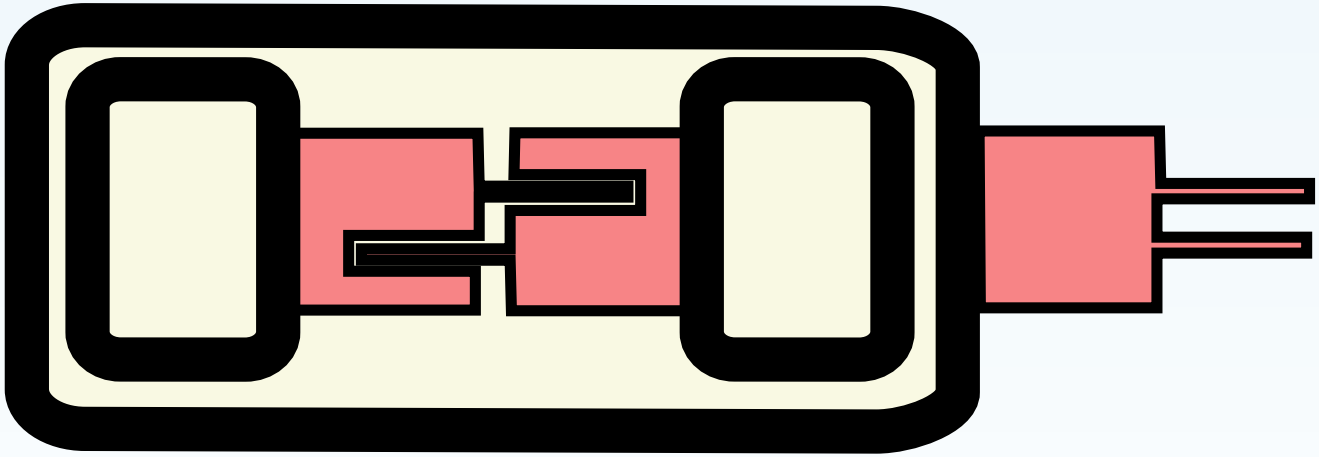
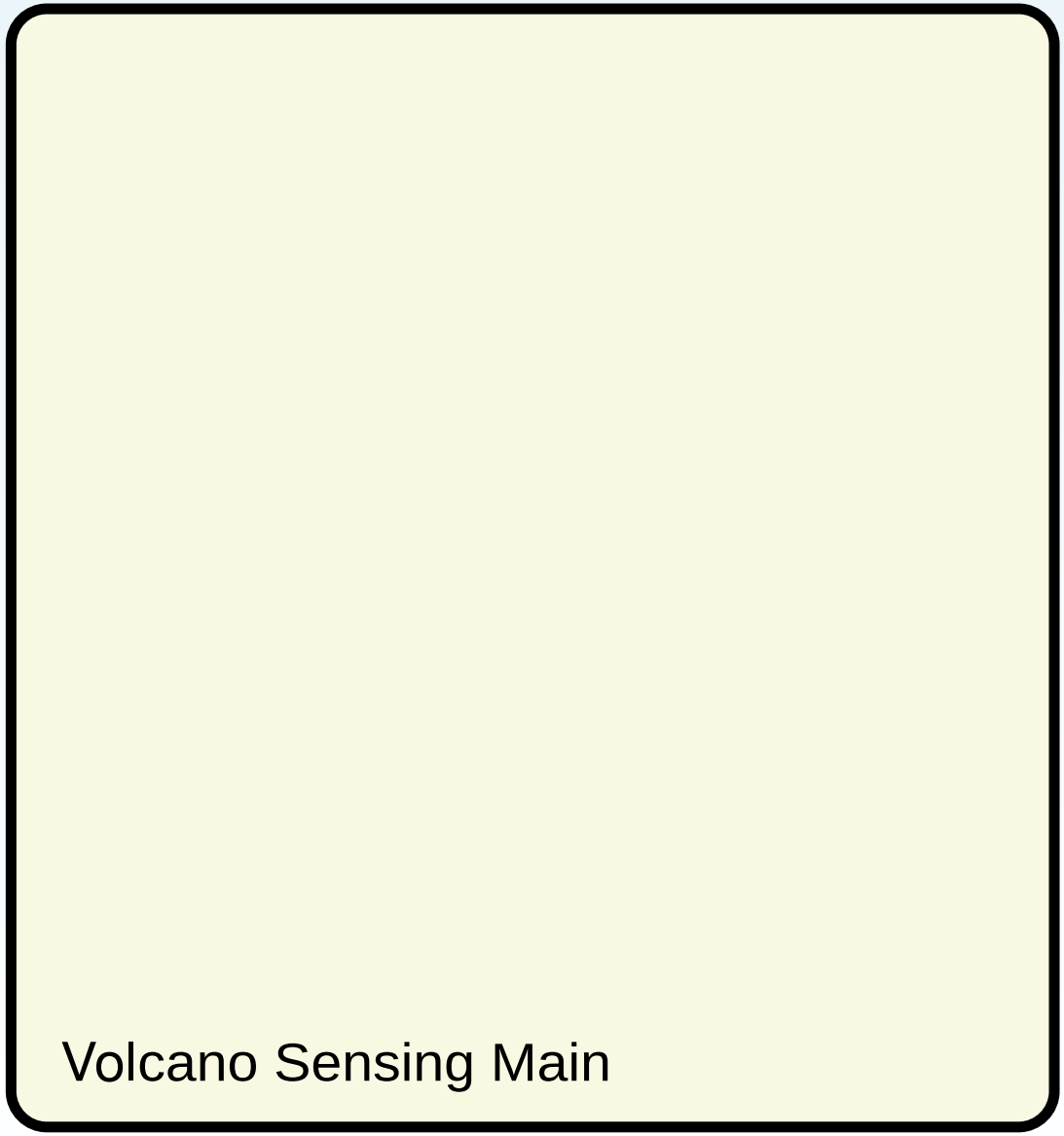
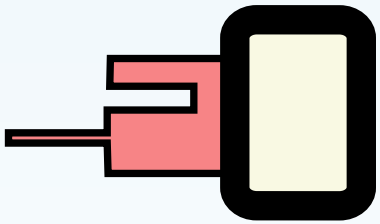


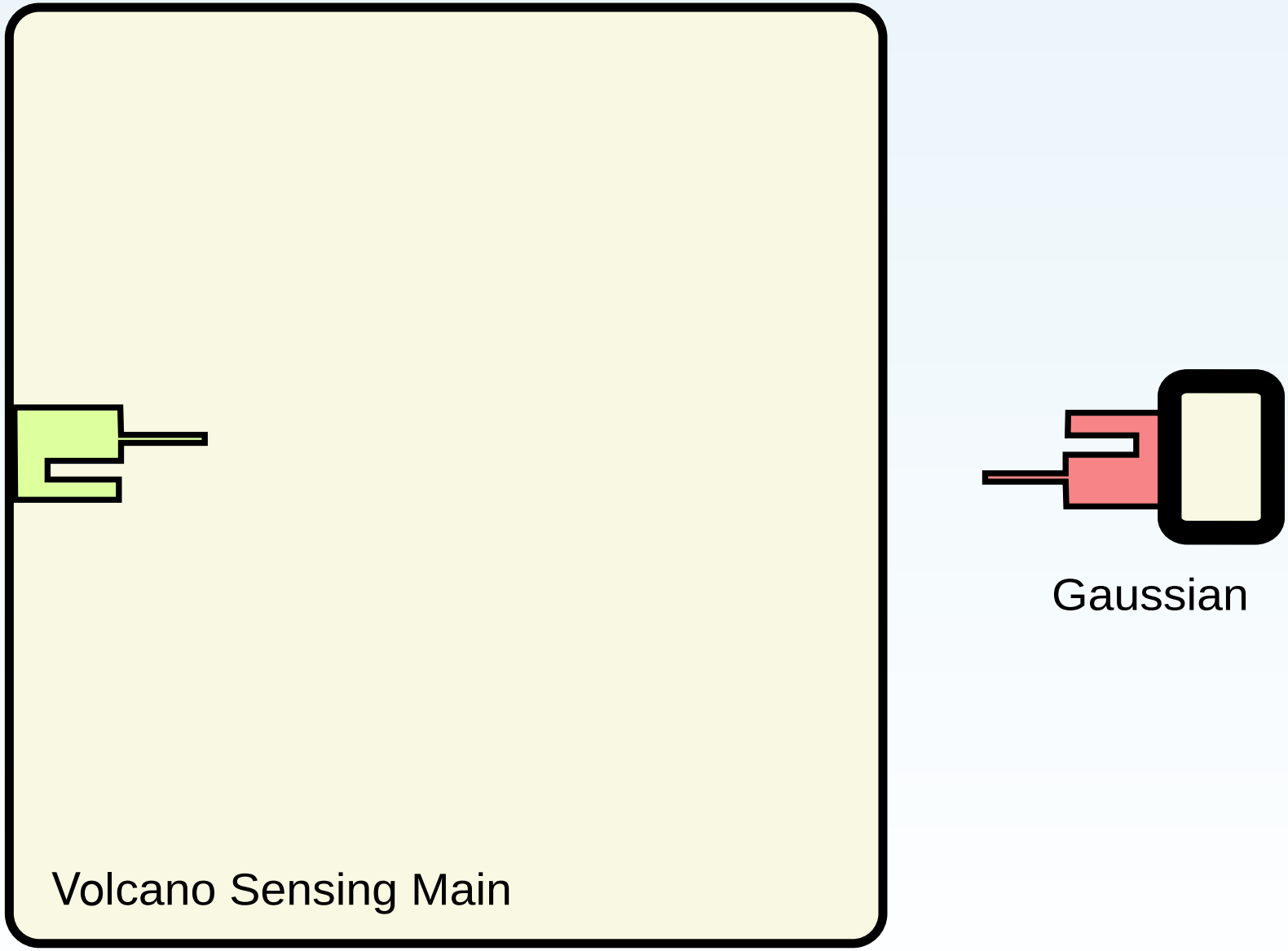
Dynamic Linking





Gaussian

Dynamic Linking



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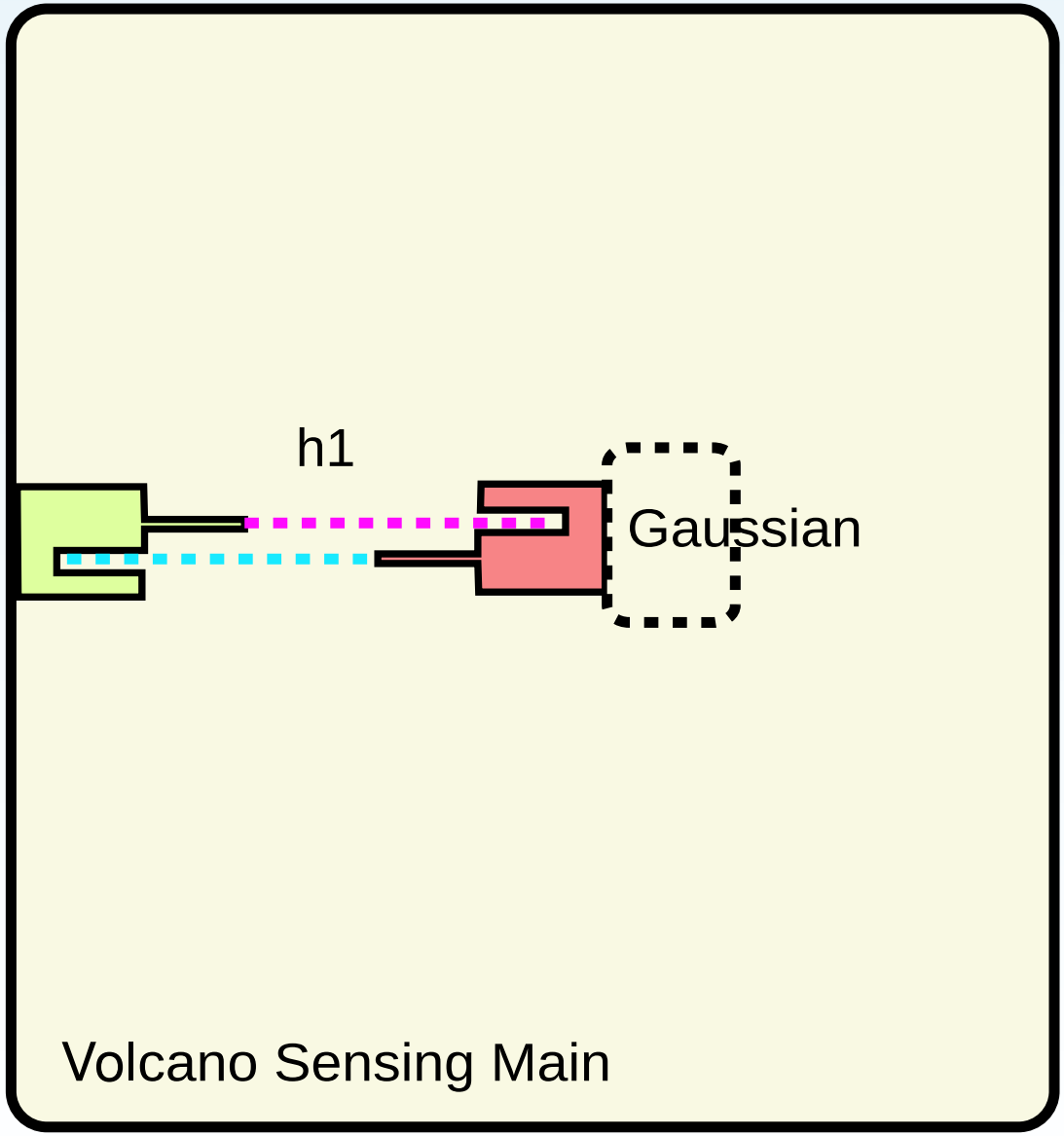
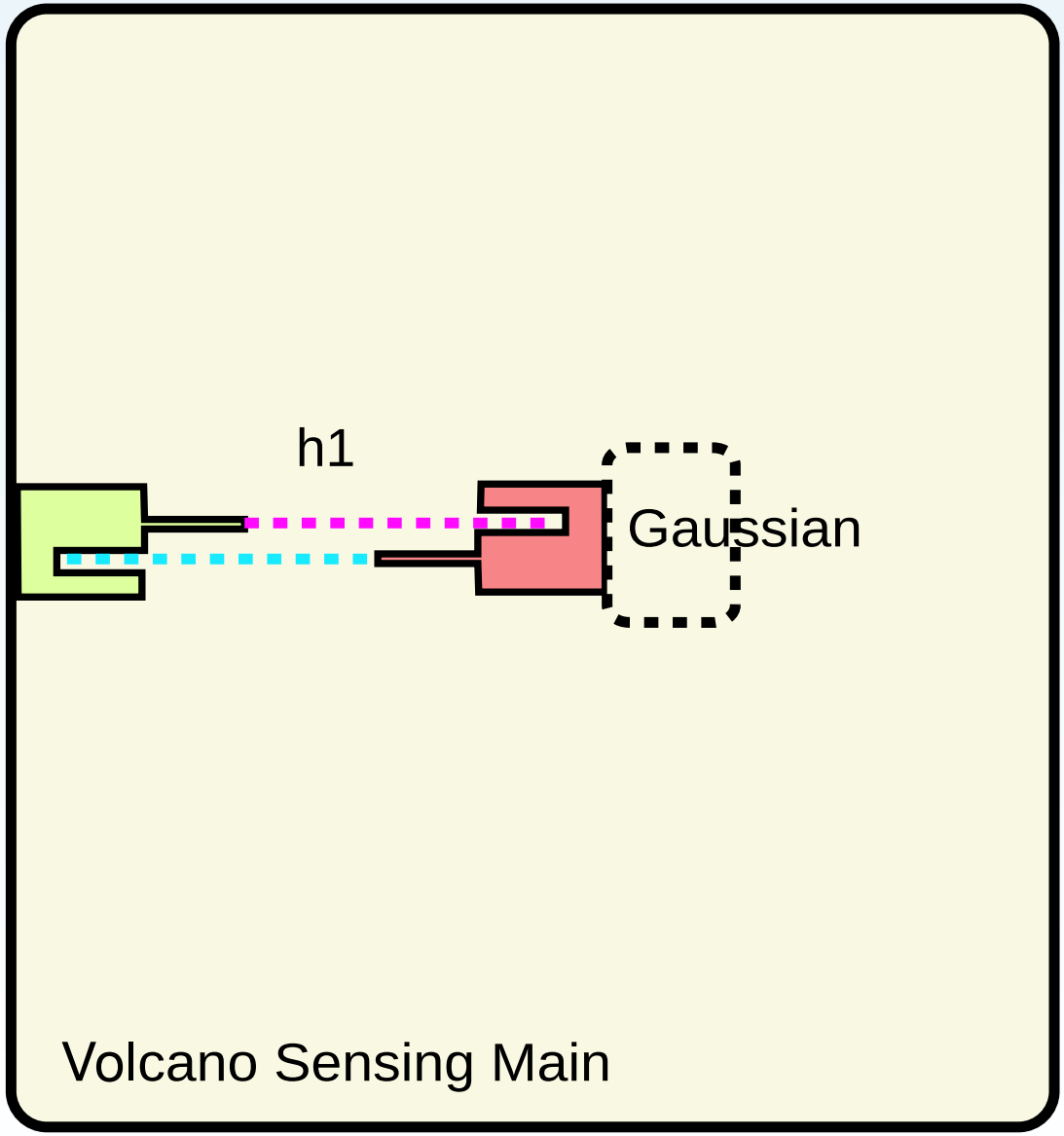


Rebindability of Dynamic Linkers

- Problem: The need to allow *arbitrary* code extension
  vs
  Fact that only a *fixed* number of dynamic linkers can be on an assemblage

- Solution:
  - Allow *multiple simultaneous* linkings on a single dynamic linker
  - Get a different name ("handle") to access each one
  - Unlinking is implicit via garbage collection when handle is unreachable
  - Use of handles also avoids an “unlinked” error – if you have a handle, it references a real plugin

Rebindability illustrated



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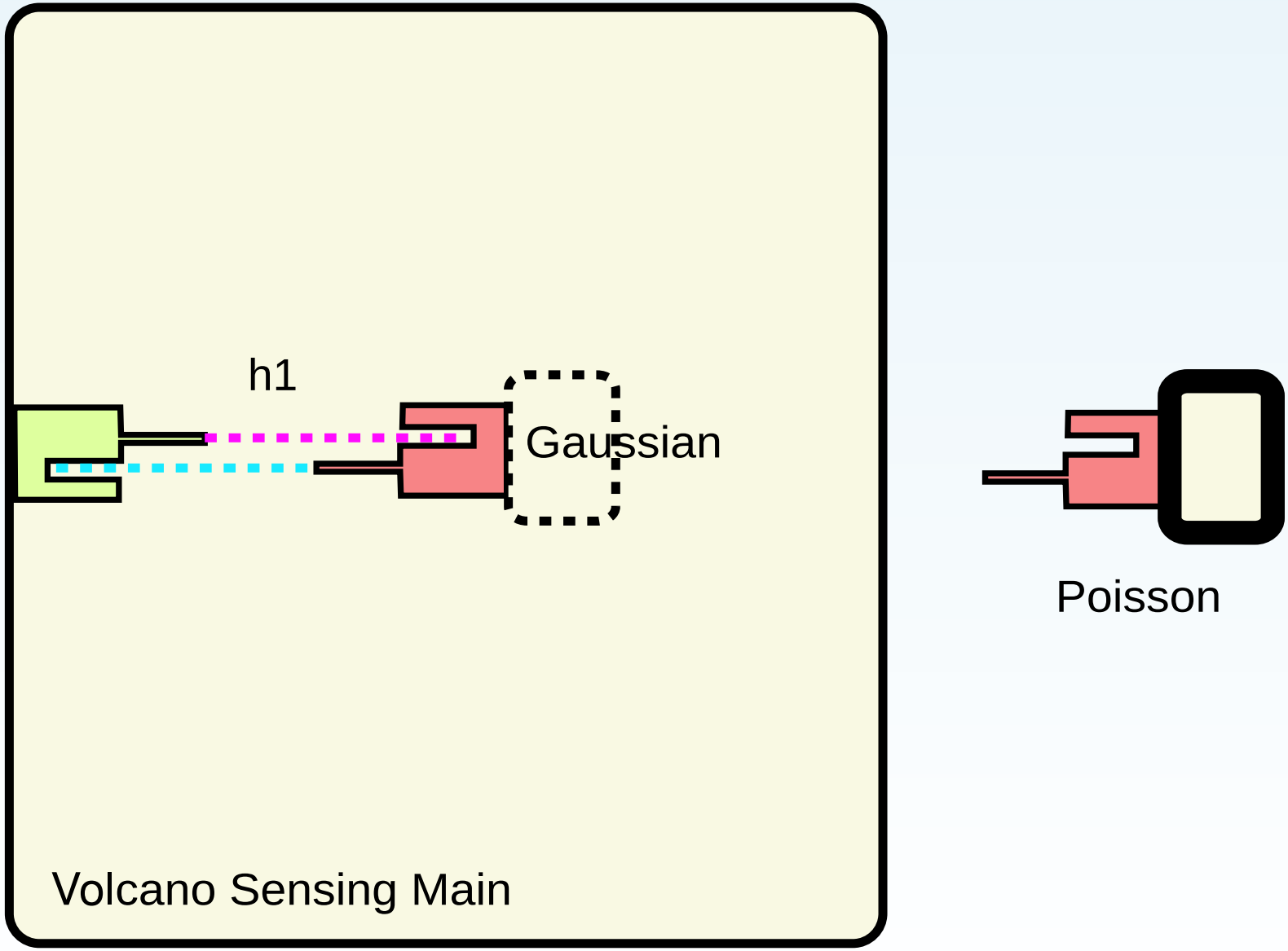

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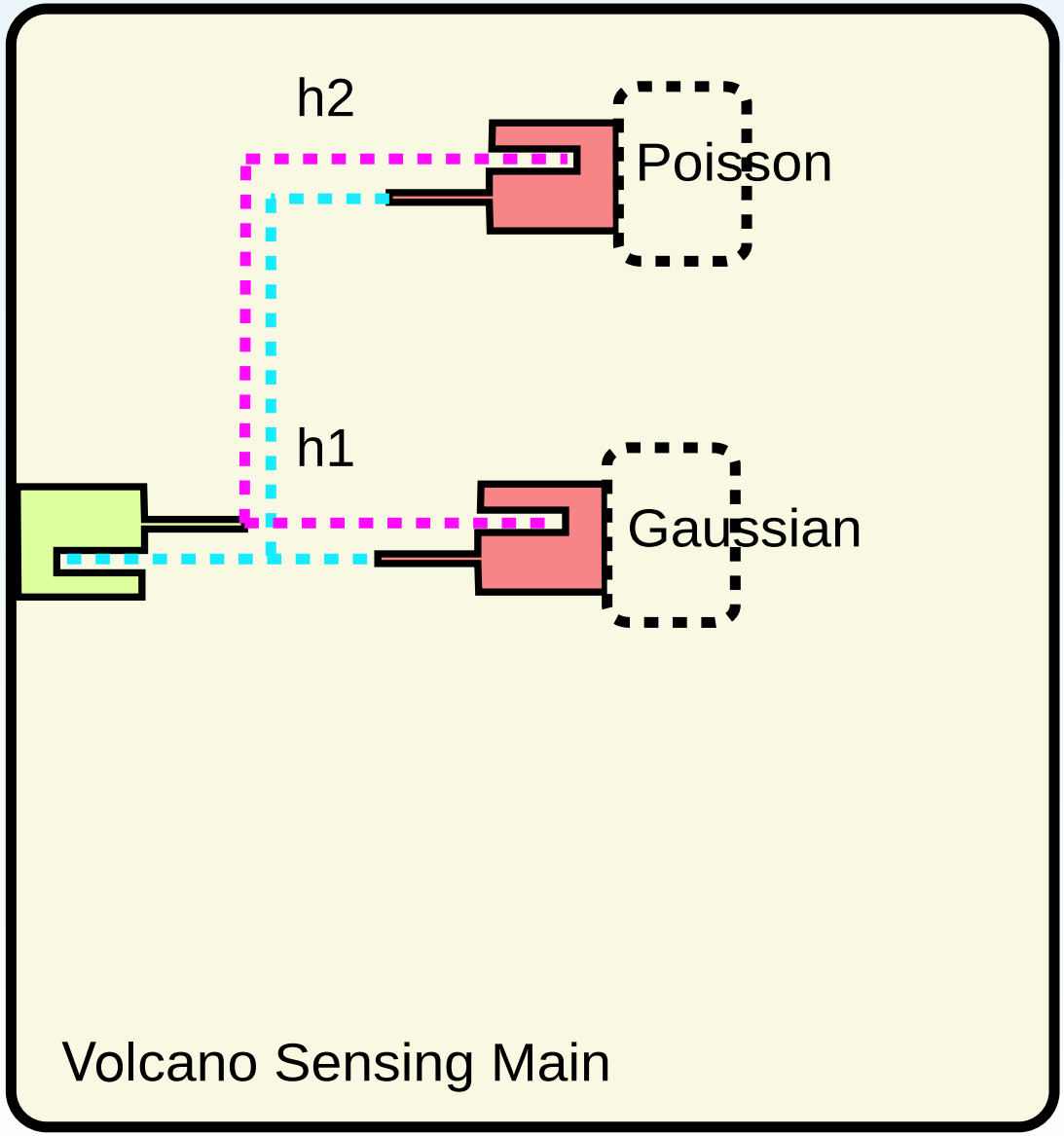

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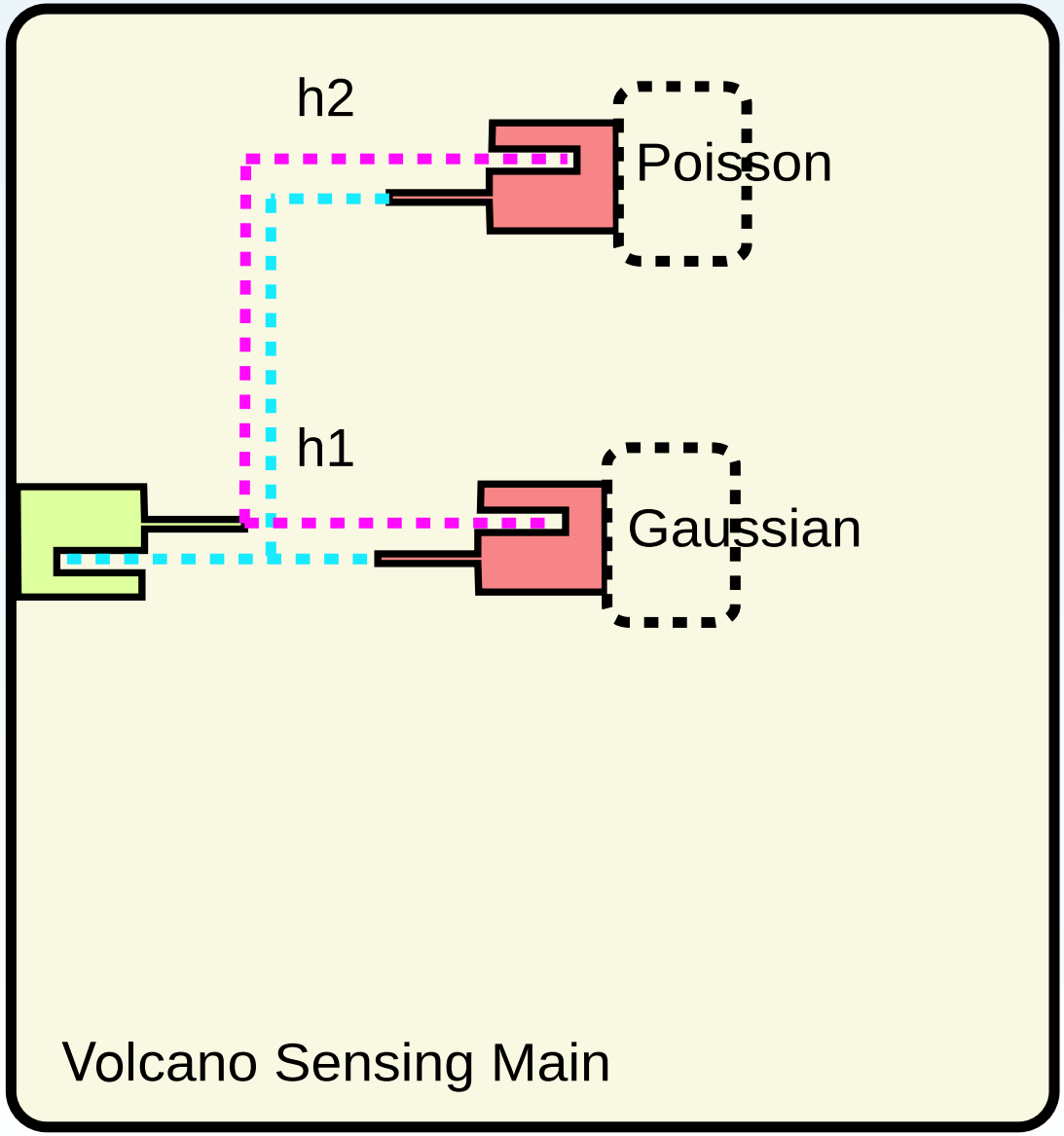
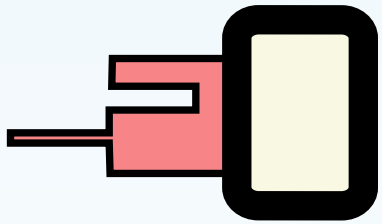
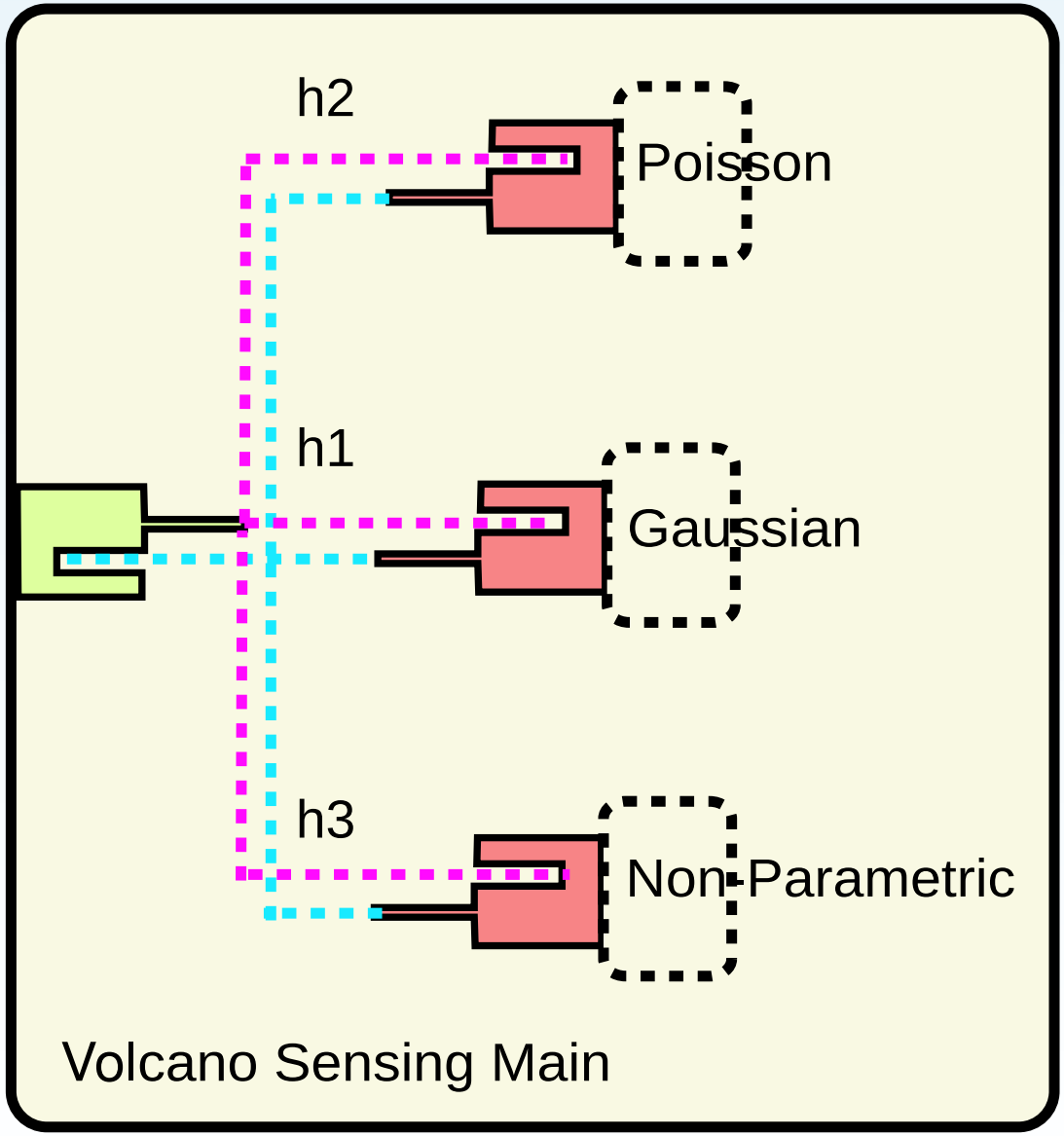


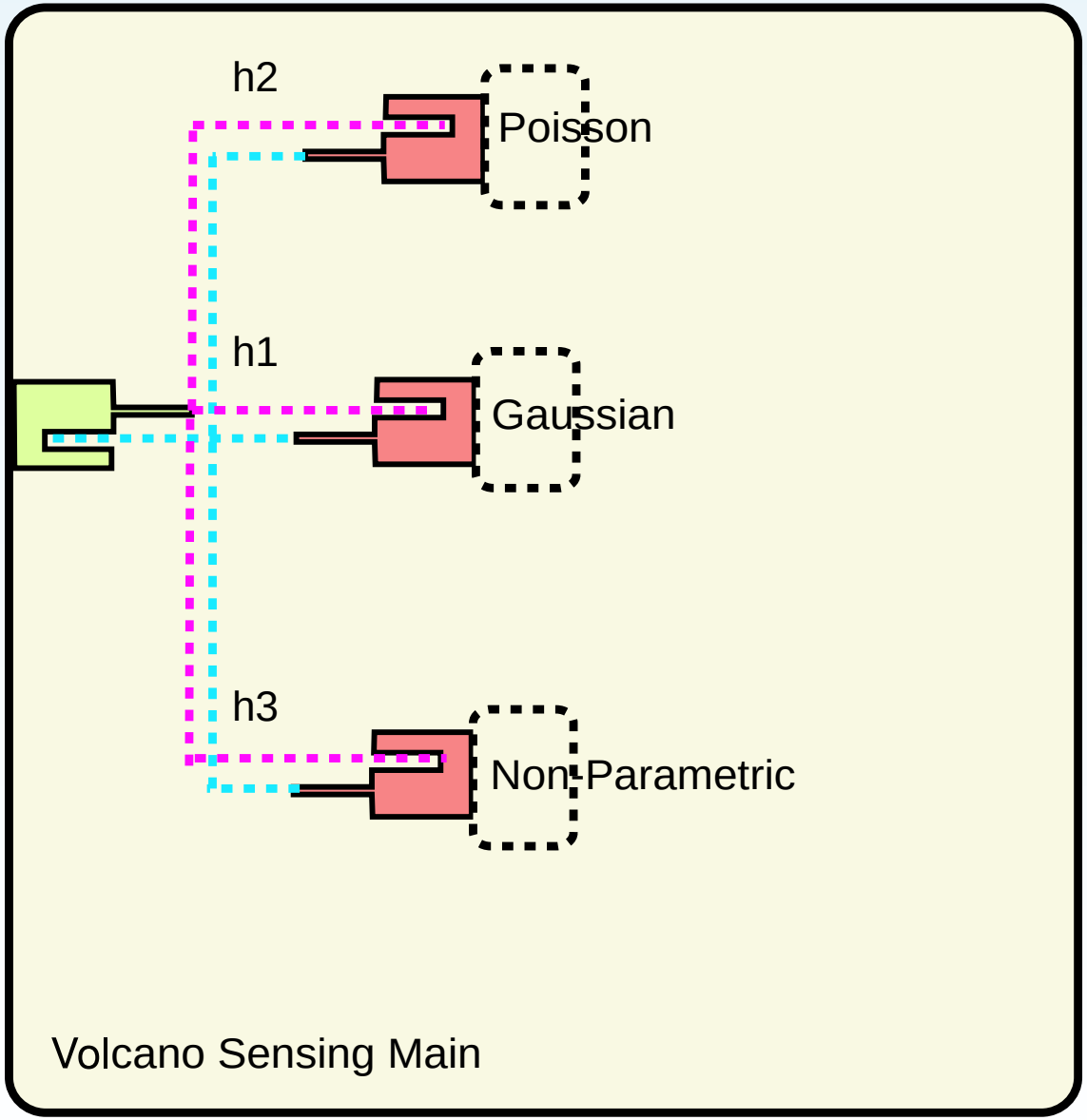


Non-Parametric

Rebindability illustrated



Dynamic Linking Tree



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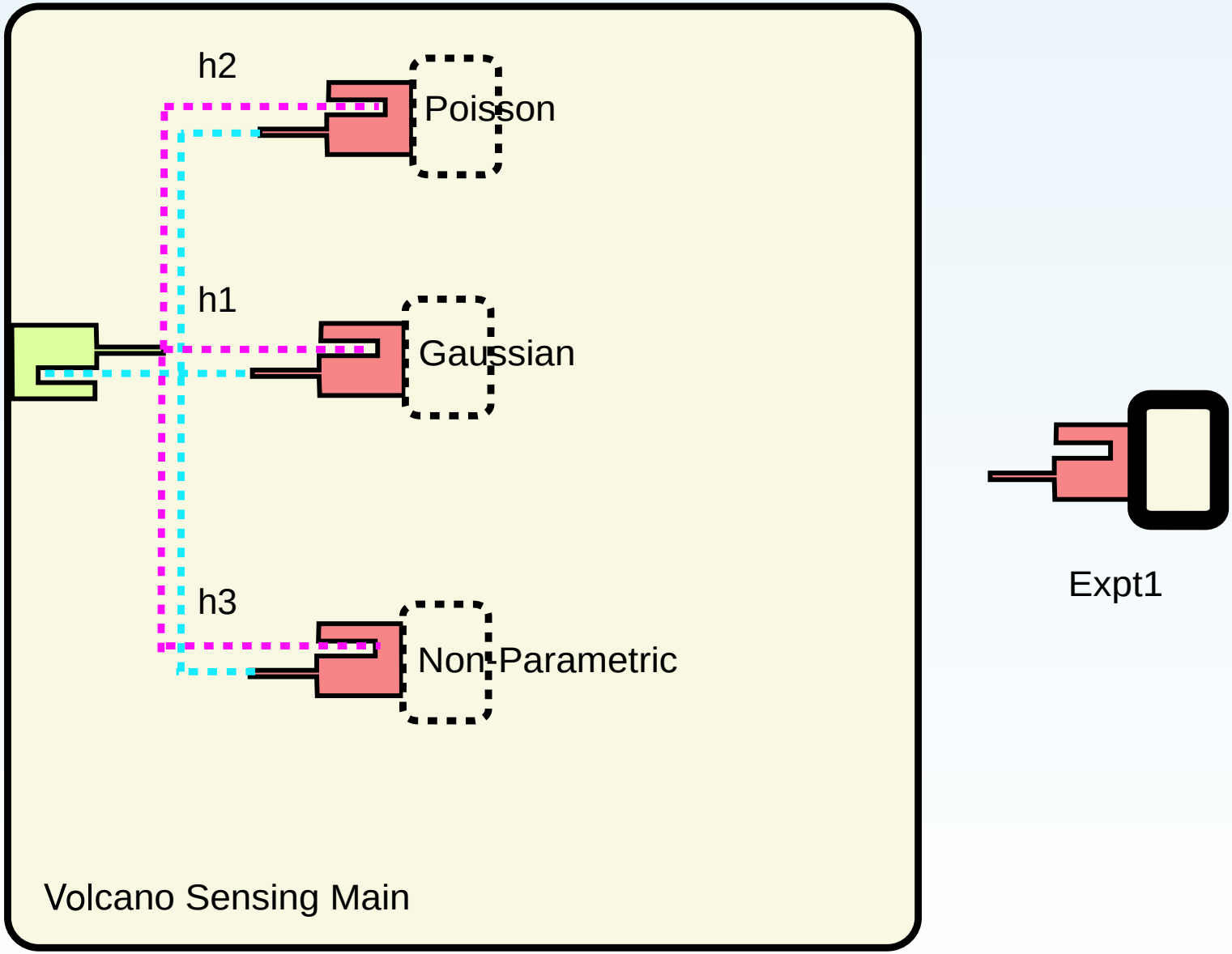

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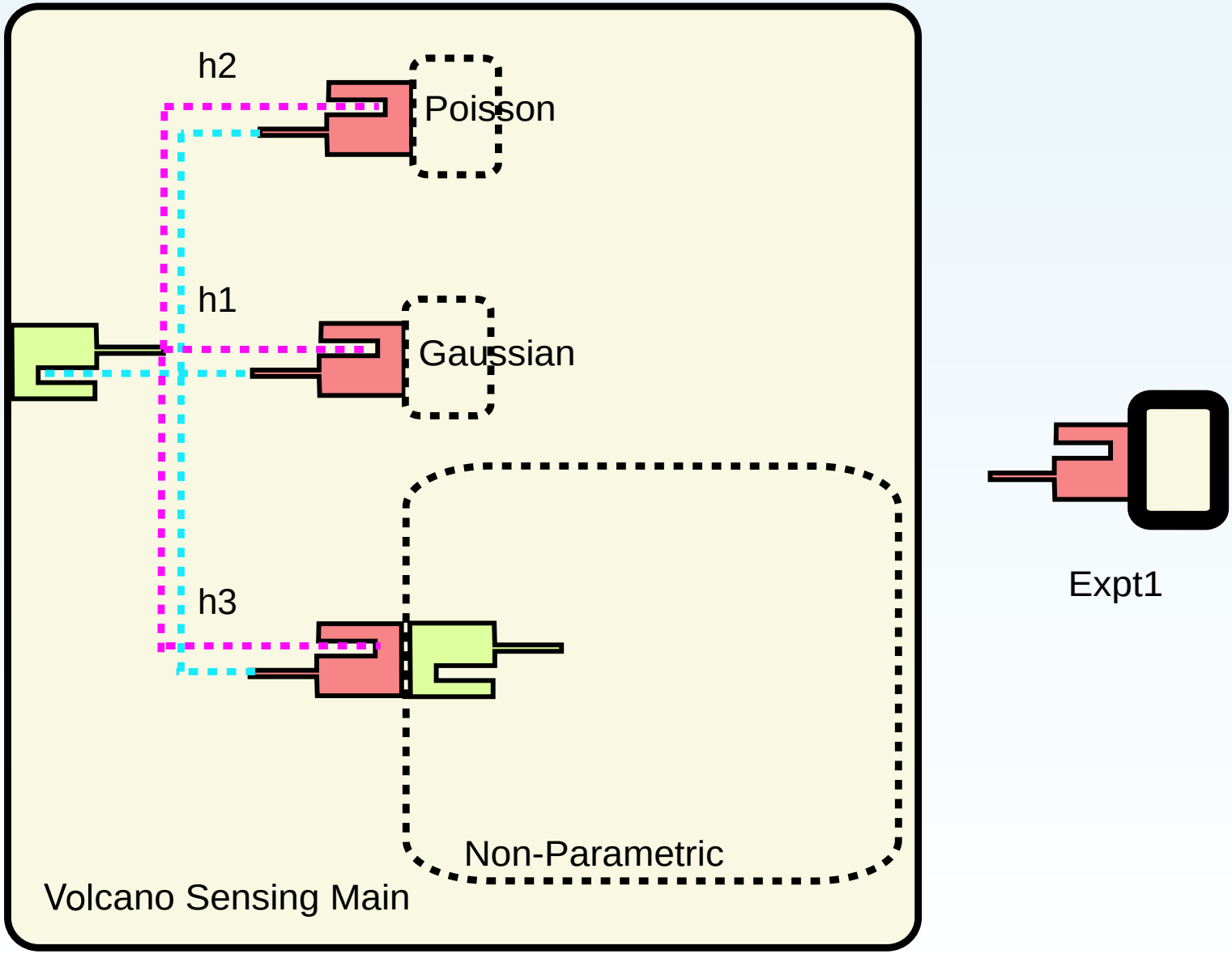

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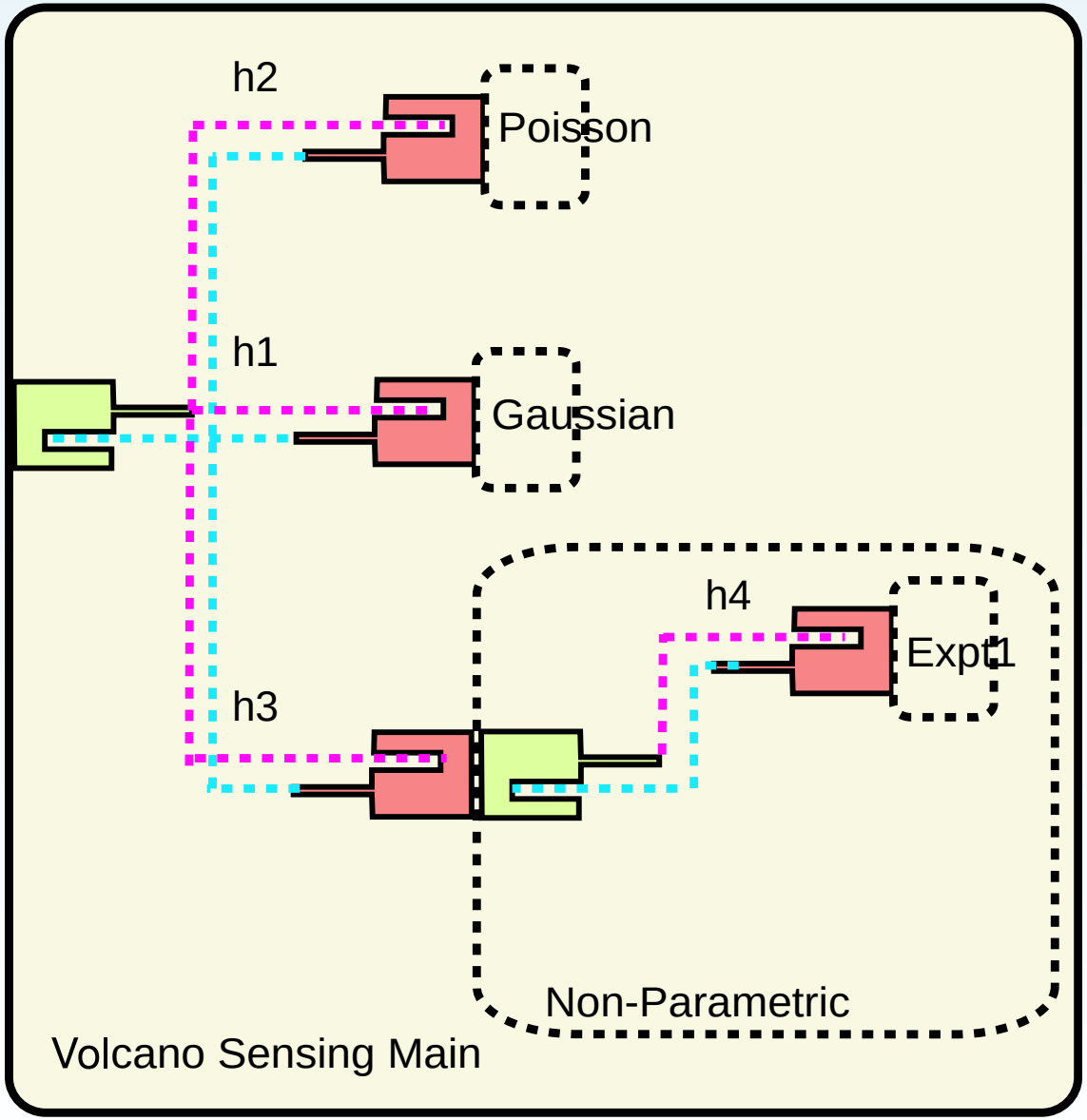

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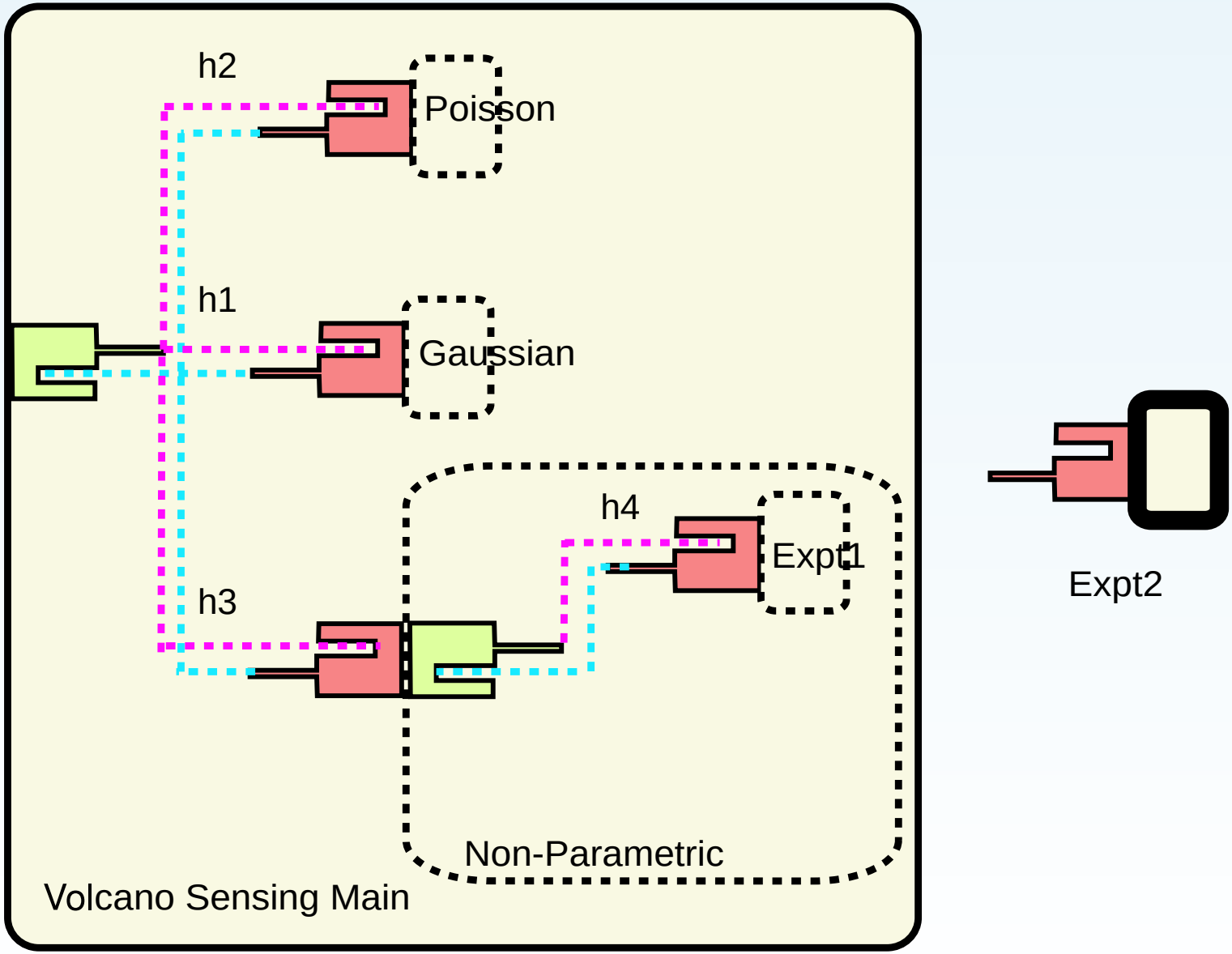

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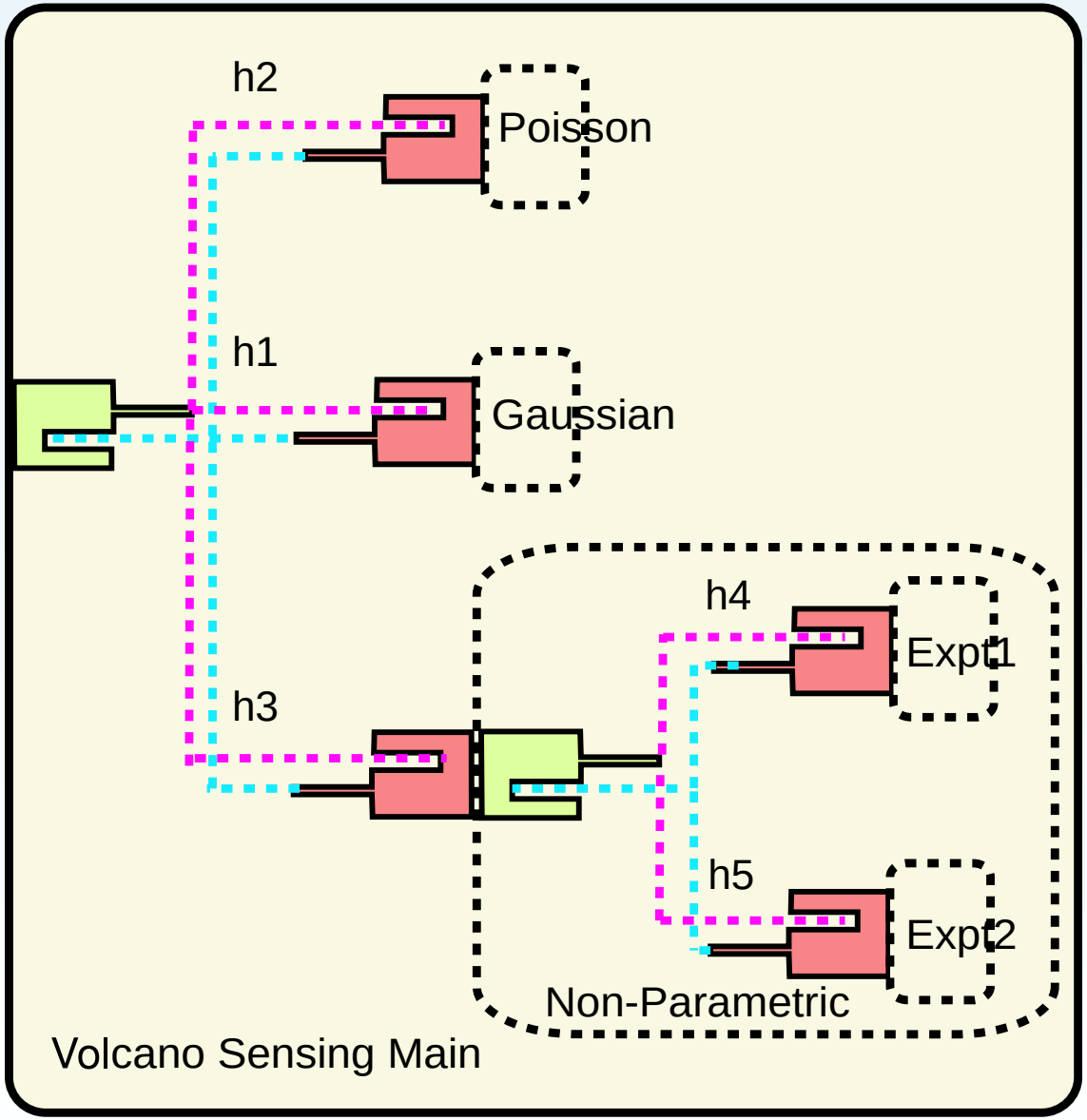

Connectors for Messaging

- Connectors allow different assemblage runtimes to interact
- Aim is a cleaner notion to replace RMI/RPC
  – RMI/RPC lacks a declared interface of interaction
- Connectors in programming languages are not completely new
  - Previously used in e.g. Cells and ArchJava and Darwin

Distributed Messaging Illustrated

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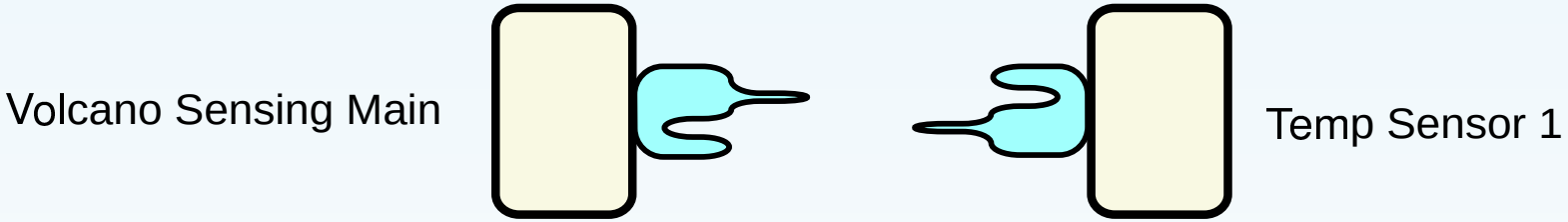
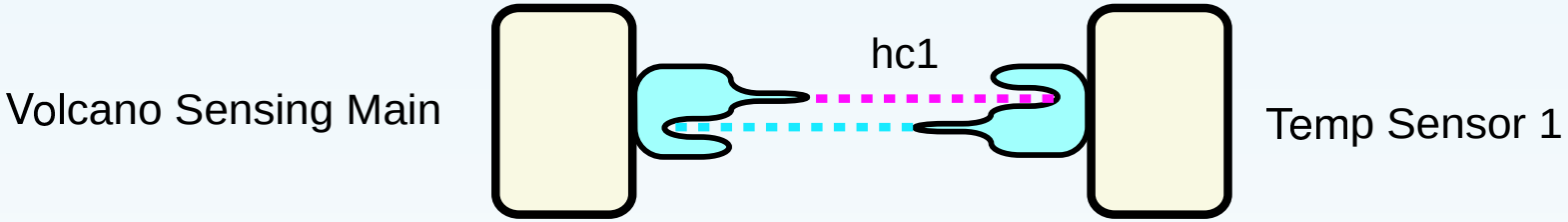


Distributed Messaging Illustrated



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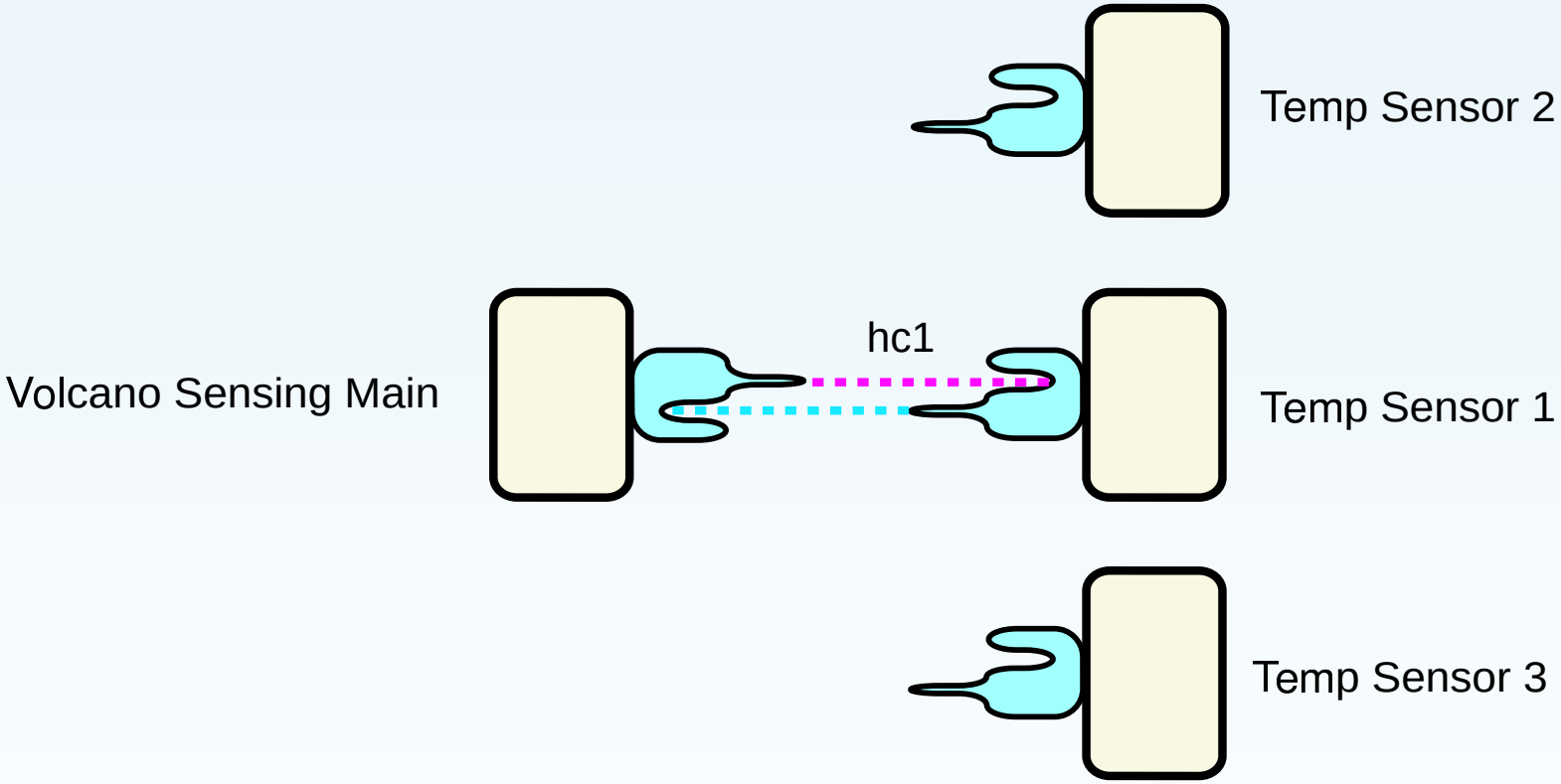

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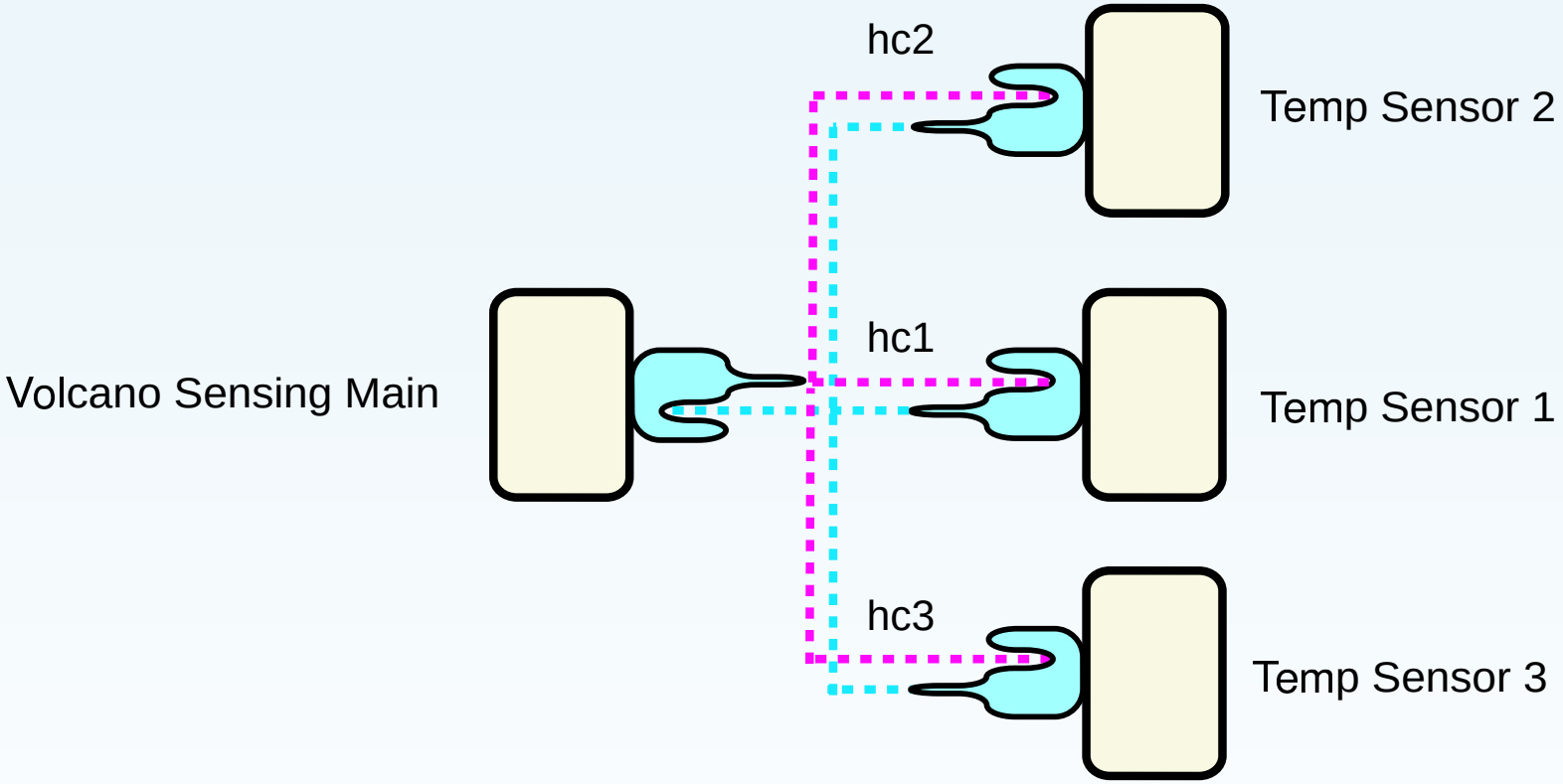


Data Encapsulation

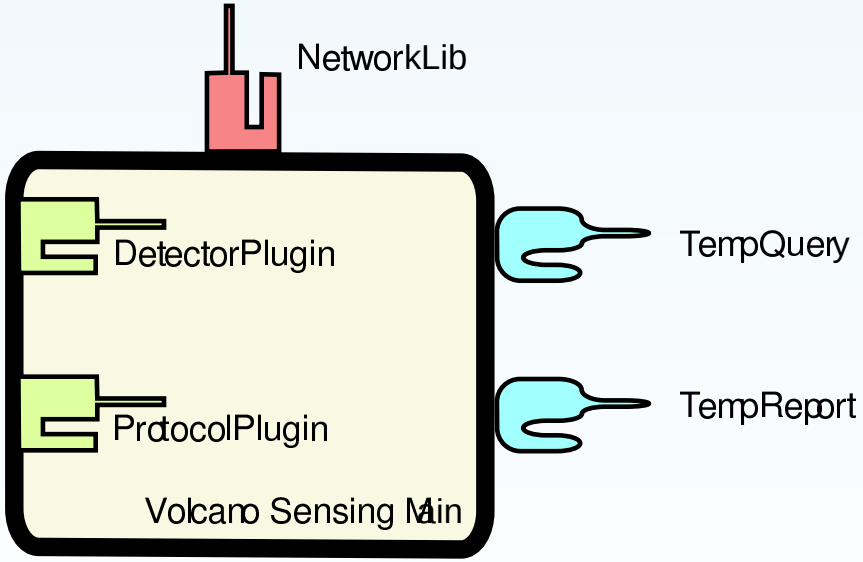
Goal: maintain sanctity of the runtime interfaces

- Only access internals of a runtime through its interfaces
- RMI/RPC violate the sanctity of interfaces
  - Object references can be passed around
  - No external interface on modules for potential RMI interactions

Thus we enforce the following

- No passing of object references across the network
- Objects can be copied, but *only* if their code is already plugged in on the other side
- Runtime references can be passed

The Unification



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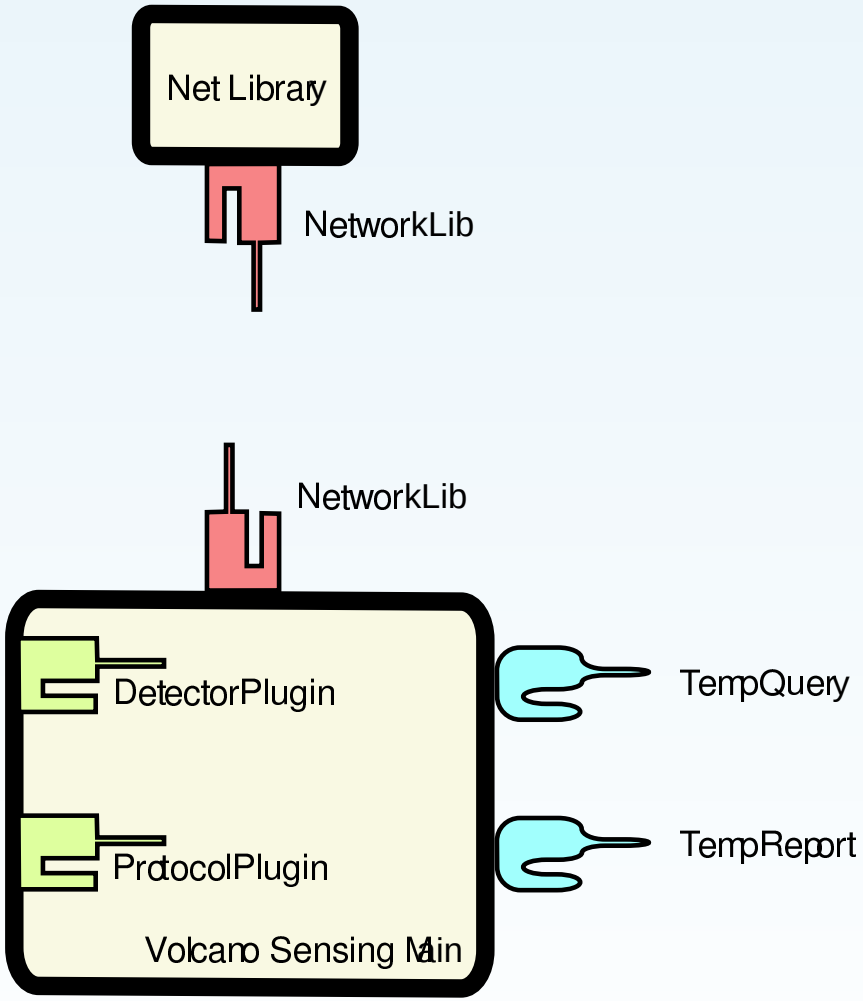

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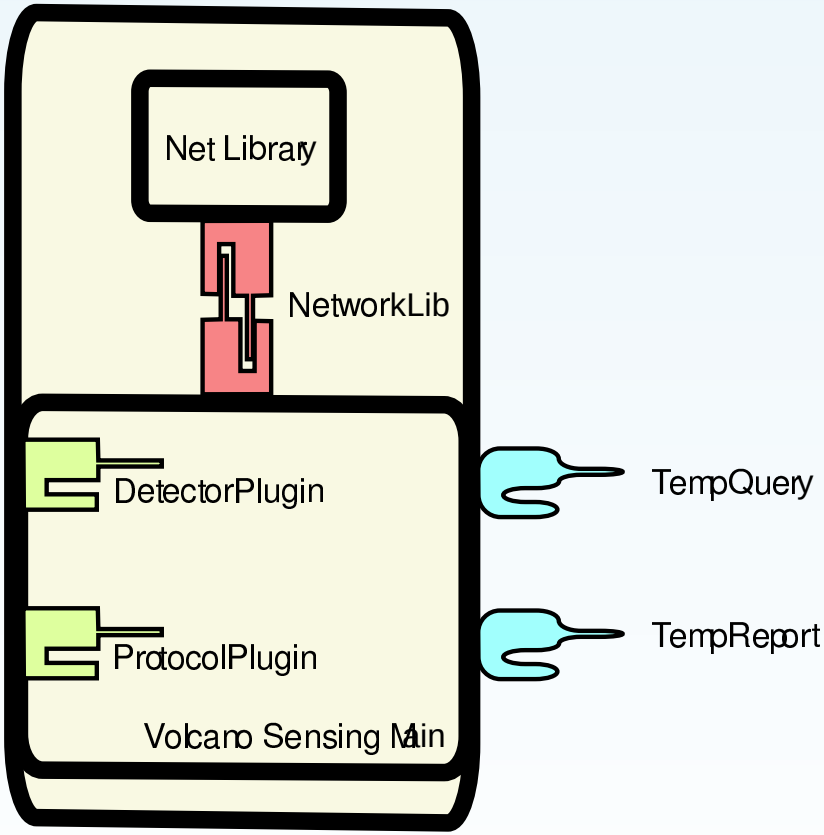

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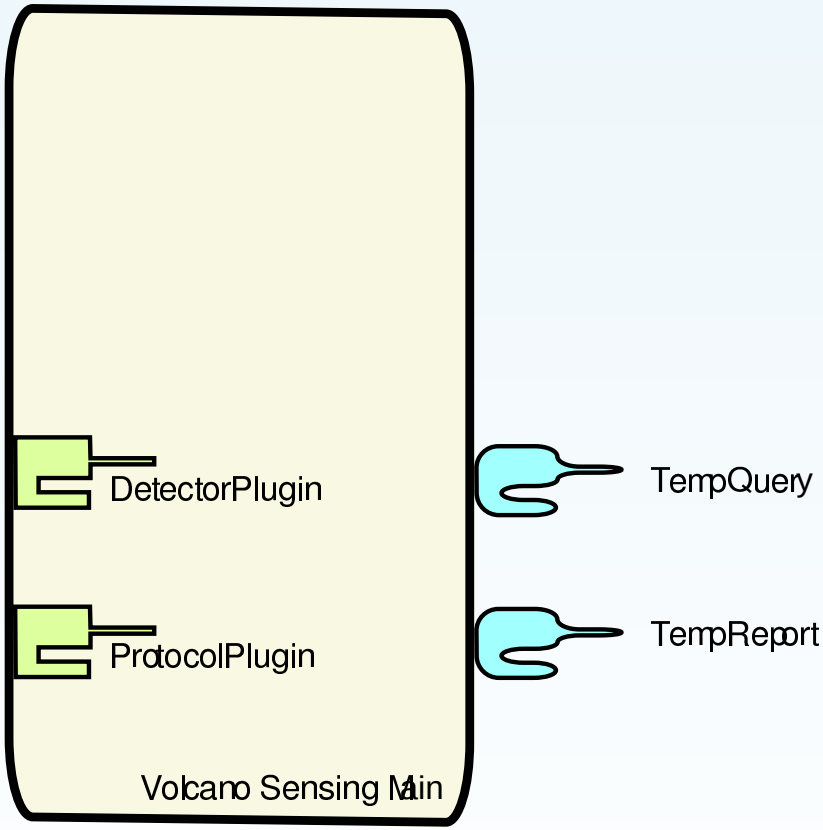

The Code

VolcanoMain $=$ // Volcano sensor example

assemblage {

static linker NetLib {... statically linking some network library ...}

dynamic linker DetectorPlugin {

import detectMethod()

export getEnv $==$ ... get current environment snapshot ...}

connector CodeUpdate {

import getDetectCode();

export check($condition$) $==$ ... check applicability of detect model ...}

... // local feature implementation

updateDetector $== \lambda x.($ **let** $cb =$ **connect**$_{\text{CodeUpdate}\mapsto\text{Code}}$ x **in**

let $code = cb \triangleright$ getDetectCode $\leftarrow ()$ **in**

let $comp =$ **plugin**$_{\text{DetectorPlugin}\mapsto\text{Detect}}$ $code$ **in**

$comp$.detectMethod()))

...}

The Type System

- Static linkers, dynamic linkers, and connectors are typed
- Each import/export is typed
- There may be more exports than imports (subtyping)
- Assemblage runtime types are the connector types
- First-class assemblage types are static/dynamic linkers and connector types

Technical Accomplishments

- Formal operational semantics
- Type system
- Soundness via a subject reduction argument
  - Significant extra complication here due to multiple runtimes, modules as first-class values etc
- Extension to have types as features on linkers (not proved sound)

Related Work

Explicit interfaces are there to some degree

- Static linking
  - “solved” in many module systems/calculus.
- Dynamic linking
  - Java classloaders: not explicit; very fine-grained
  - Units, Argus, MJ, *etc* have partial interface support on code being linked, but not on the runtime
- Distributed langauge-based messaging
  - Existing protocols bury interactions in the code
  - RPC/RMI: When remote objects are passed between JVM’s, you don’t even know who you are talking to
  - Connectors

Future Work

- Implementation
- Ensemble: A connector-based Sensornet language
- MVM: a Microkernel Virtual Machine
- Extensions
  - Inference of signatures from assemblages
  - Linker- and connector-based security
  - Version control