# Melocoton

## A Program Logic for Verified Interoperability Between OCaml and C

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# Multi-Language Programs Are Everywhere


Python

C

Fortran


C++

Rust

JavaScript


C

Bindings for:

- Rust
- Python
- OCaml
- Go
- …

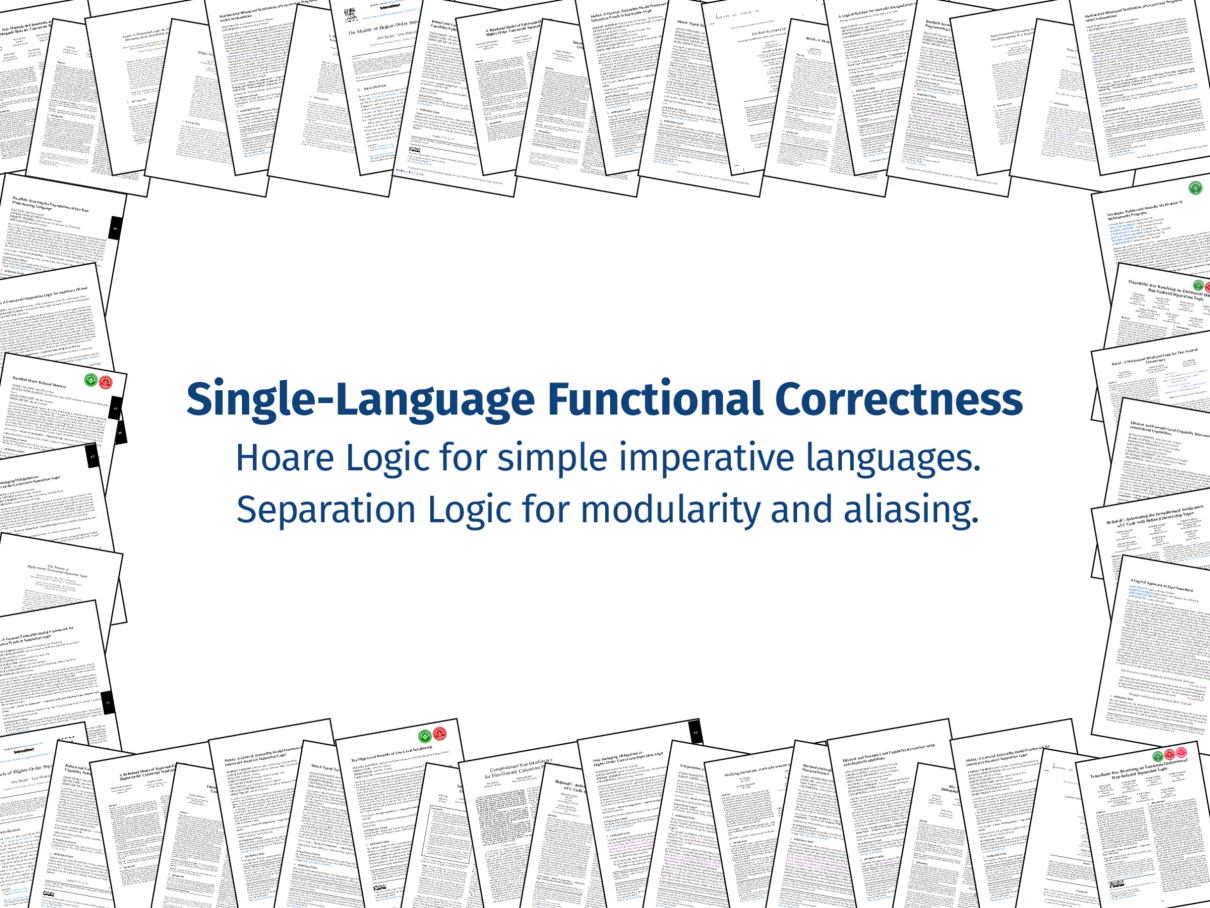
# The Goal: Verifying Multi-Language Programs

How do we

**verify functional correctness**

of programs written in

**different languages**?



# Single-Language Functional Correctness

Hoare Logic for simple imperative languages.
Separation Logic for modularity and aliasing.

# Multi-Language Functional Correctness

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Existing work on Semantics and Logical Relations.
How do we prove functional correctness of
individual, potentially unsafe programs?

# A Multi-Language Program in OCaml and C

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## C business logic

```
void hash_ptr(int * x) {
    // Implemented in OpenSSL
    // tedious to port to OCaml
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# A Multi-Language Program in OCaml and C

**OCaml** business logic

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let main () =
  let r = ref 42 in
  hash_ref r; (*written in C*)
  print_int !r
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## **C** glue code

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value caml_hash_ref(value r) {
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    hash_ptr(&x);
    Store_field(r, 0, Val_int(x));
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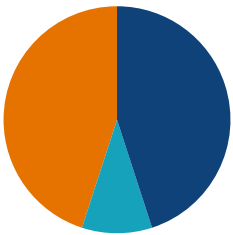
# A Schematic Multi-Language Program

Most multi-language programs look like this:

**OCaml** business logic
oblivious of C



**C** business logic
oblivious of OCaml

**glue code**
where the languages actually interact

**We Need to Reason Language-Locally!**

# Our Contribution: Melocoton


**Common Approach:** program logic on top of semantics, **but**

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# Language Interaction: Different Views of the Same Data

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High-level **OCaml** values are accessed..
..through a low-level **block** representation.

# Language Interaction: Semantics

High-level **OCaml** value $\sim_{\texttt{ML}}$ Low-level **block** representation

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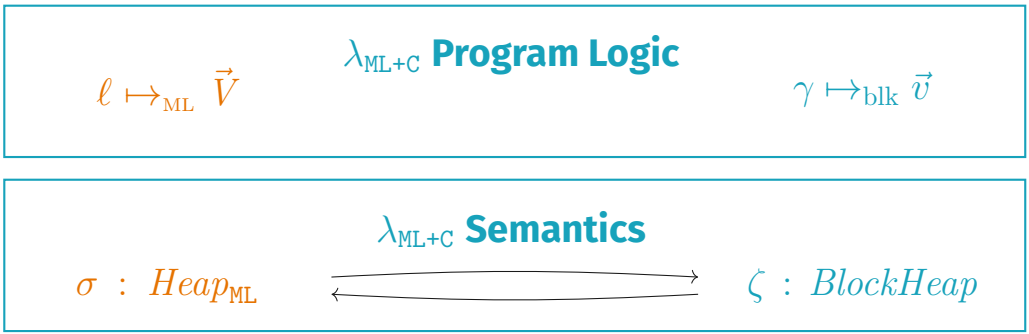

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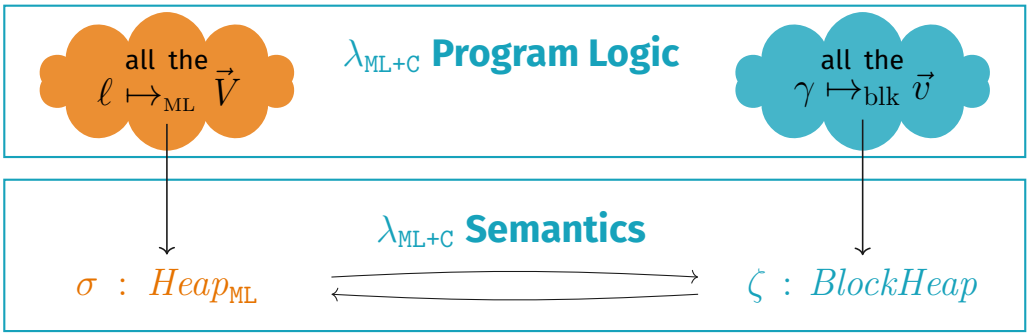

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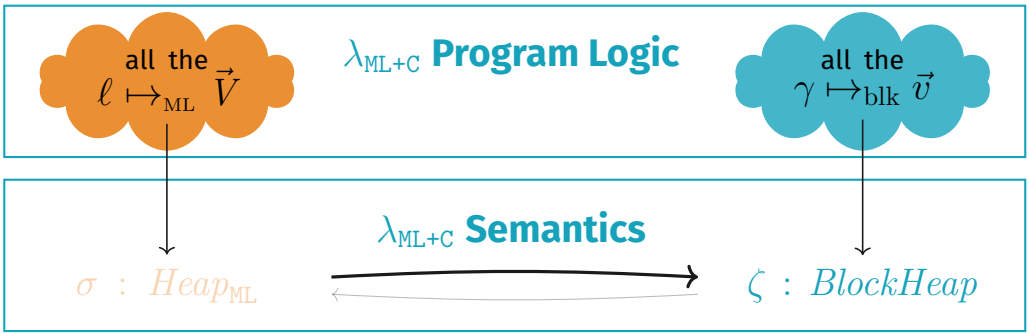

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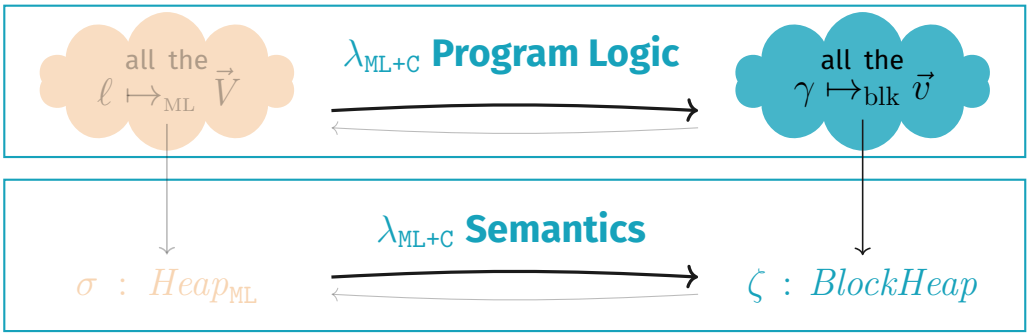

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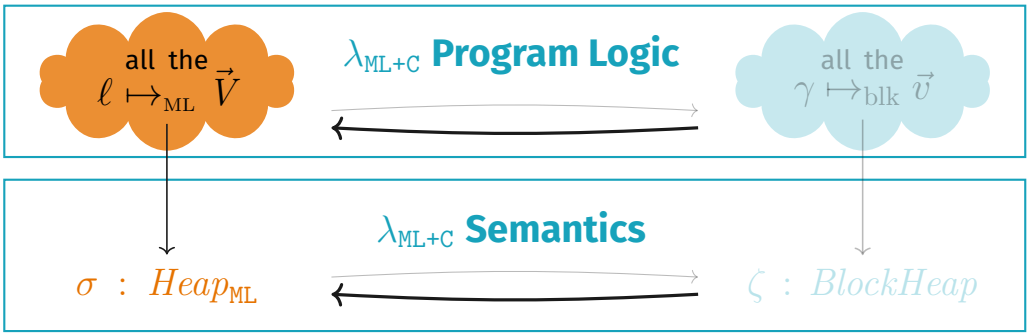

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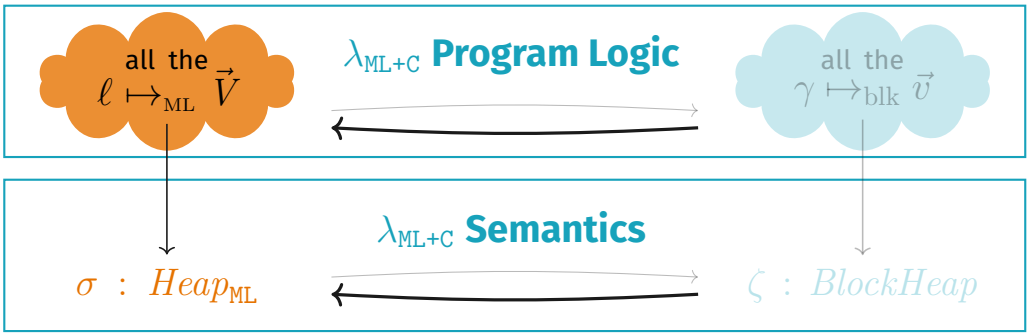


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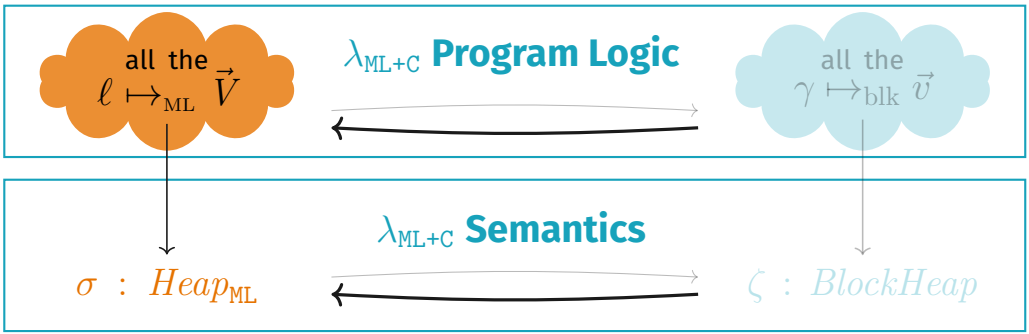


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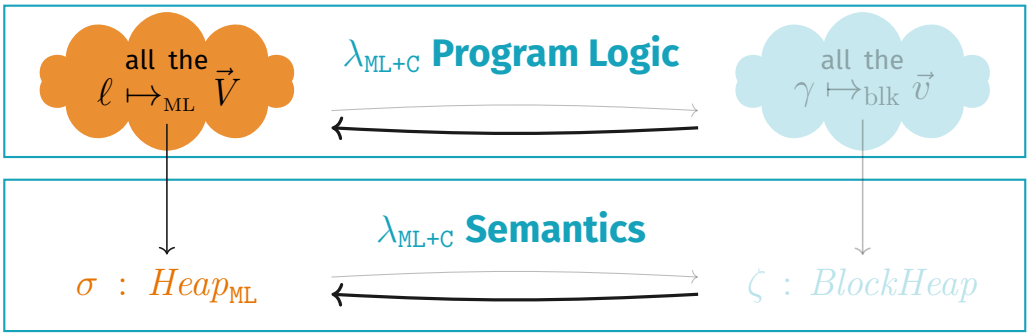


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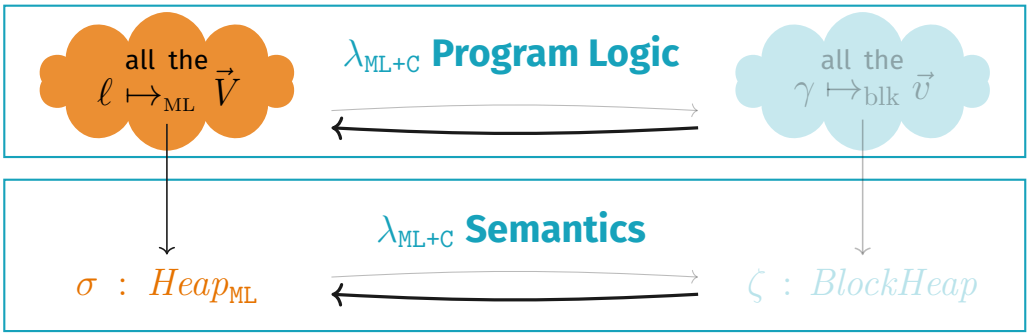


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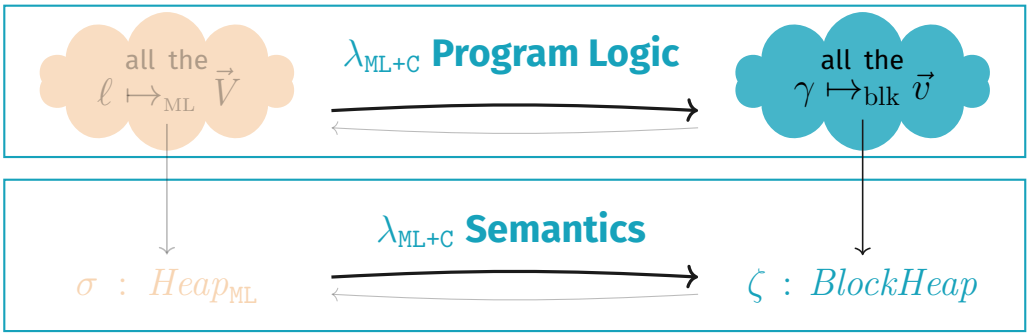


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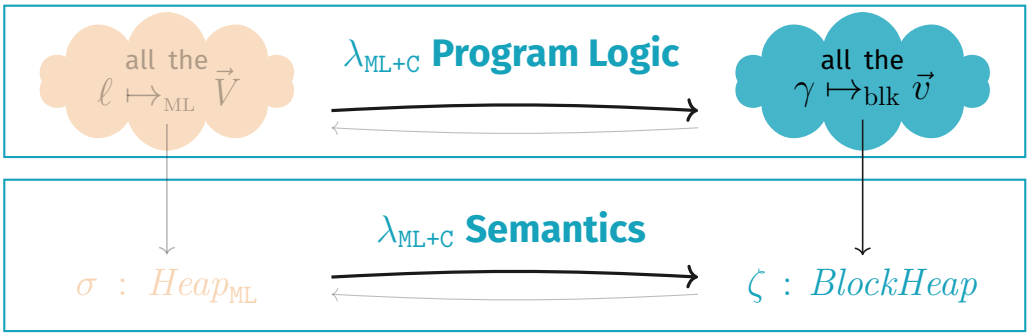


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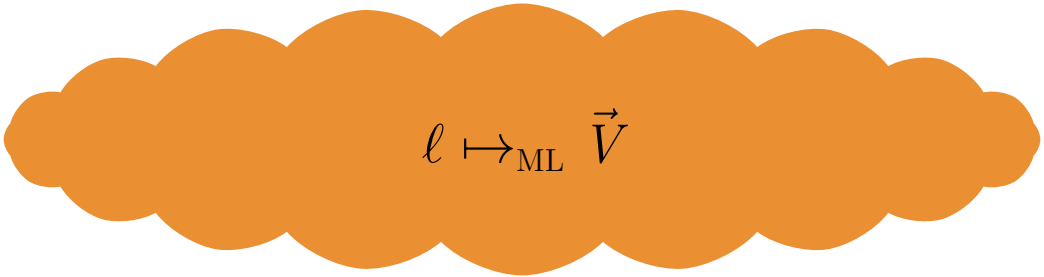

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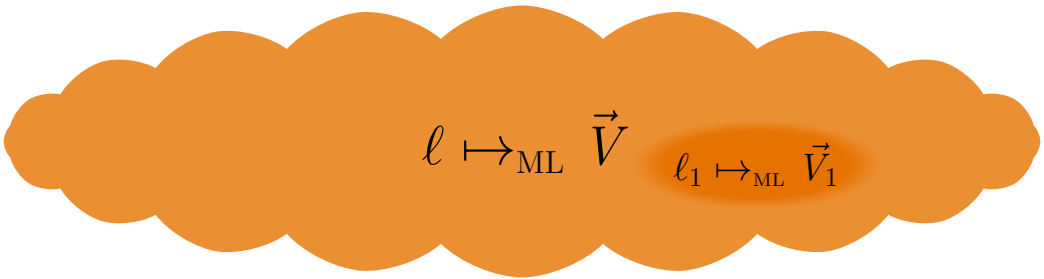

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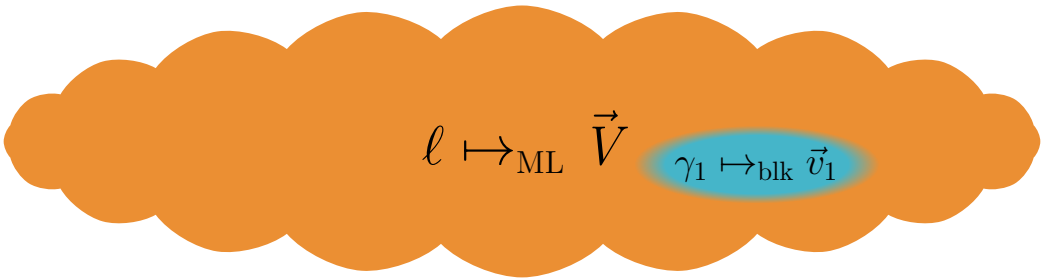

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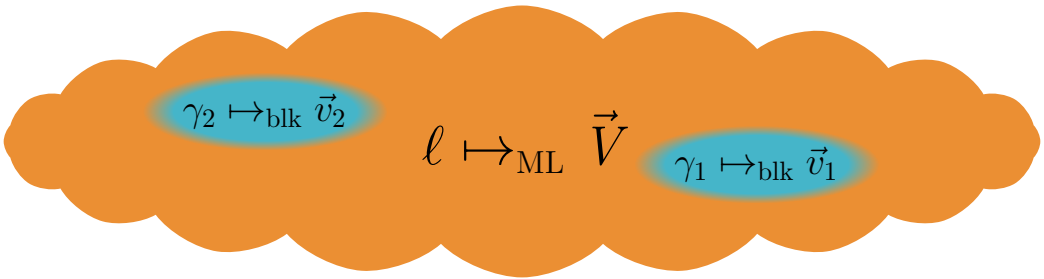

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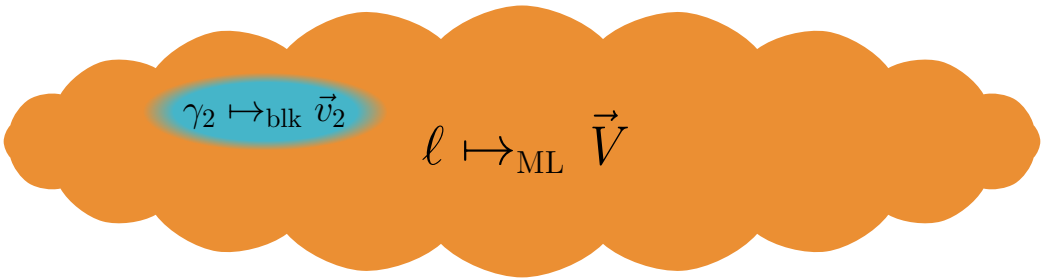

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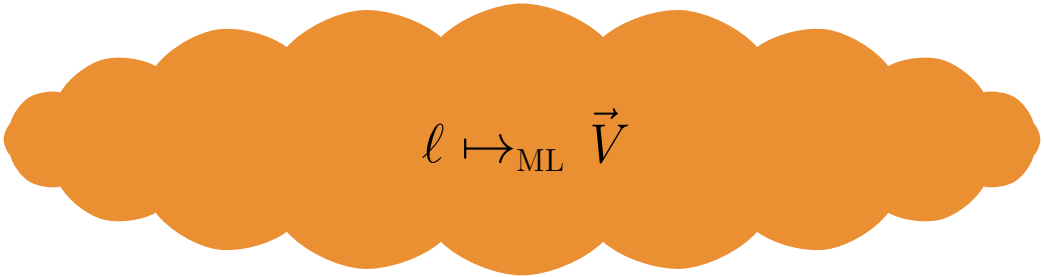

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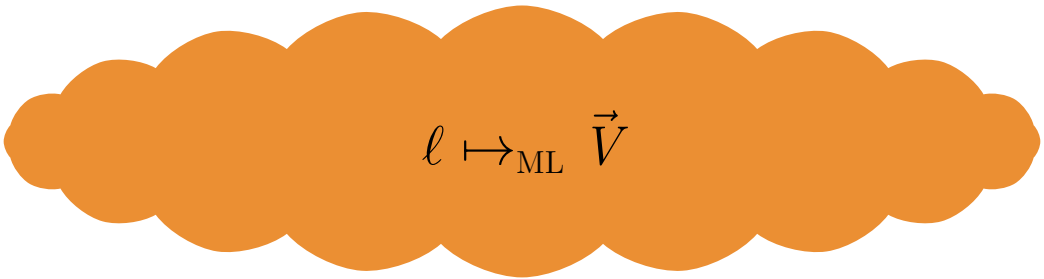


**View Reconciliation Rules for Converting On-Demand:**

$$\ell \mapsto_{\mathrm{ML}} \vec{V} \Rrightarrow \exists \gamma \vec{v}.\, \gamma \mapsto_{\mathrm{blk}} \vec{v} * \ell \sim_{\mathtt{ML}} \gamma * \vec{V} \sim_{\mathtt{ML}} \vec{v}$$

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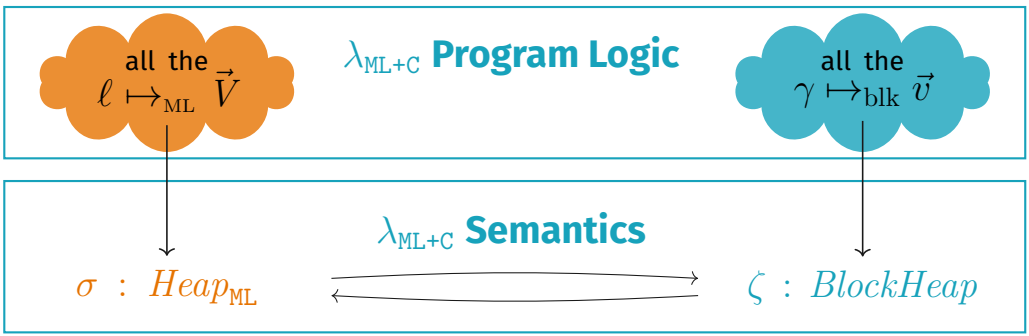

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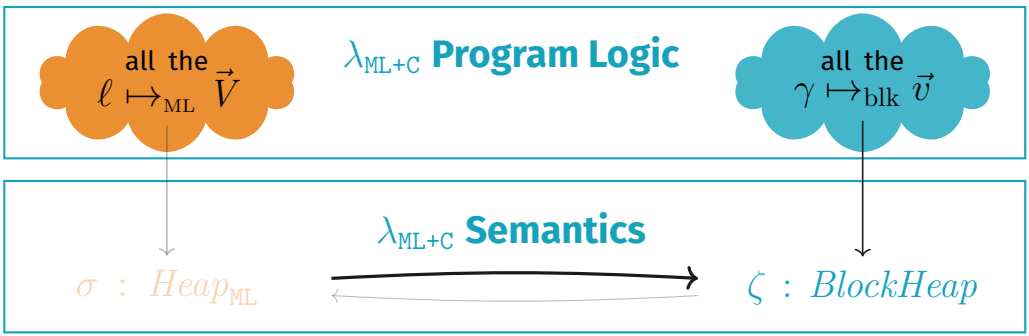

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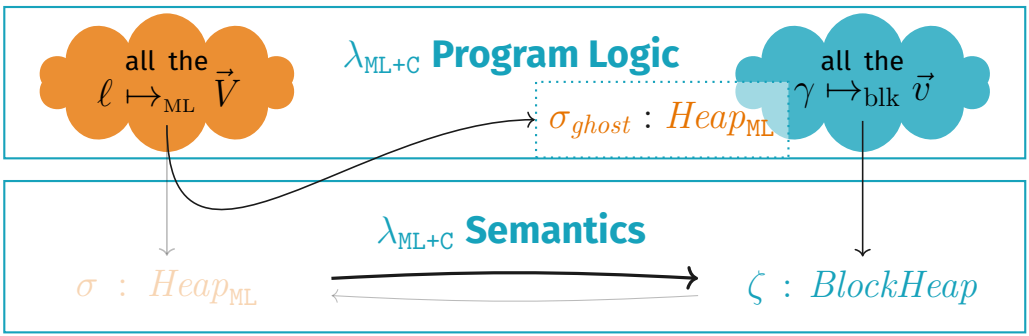

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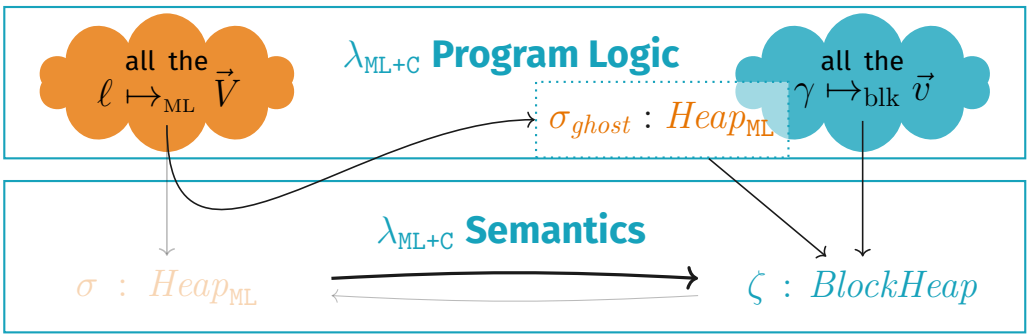
$$\vec{V} \sim_{\mathtt{ML}} \vec{v} * \gamma \mapsto_{\mathtt{blk}} \vec{v} \;\; \text{-}\!\!\ast\!\!\ast \;\; \exists \ell \;\; .\, \ell \mapsto_{\mathtt{ML}} \vec{V} * \ell \sim_{\mathtt{ML}} \gamma$$

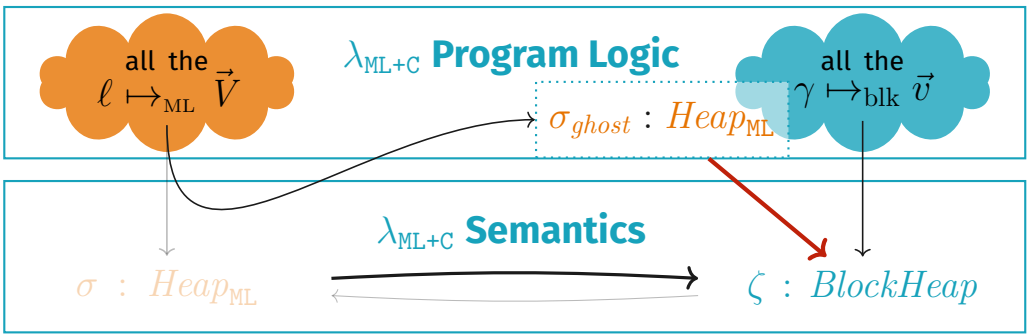


# Language Interaction: View Reconciliation

## View Reconciliation Rules

$$\ell \mapsto_{\mathtt{ML}} \vec{V} \;\; \text{-}\!\!\ast \;\; \exists \gamma \vec{v}.\, \gamma \mapsto_{\mathrm{blk}} \vec{v} * \ell \sim_{\mathtt{ML}} \gamma * \vec{V} \sim_{\mathtt{ML}} \vec{v}$$

$$\vec{V} \sim_{\mathtt{ML}} \vec{v} * \gamma \mapsto_{\mathrm{blk}} \vec{v} \;\; \text{-}\!\!\ast \;\; \exists \ell \;\; .\, \ell \mapsto_{\mathtt{ML}} \vec{V} * \ell \sim_{\mathtt{ML}} \gamma$$



# More in the paper …

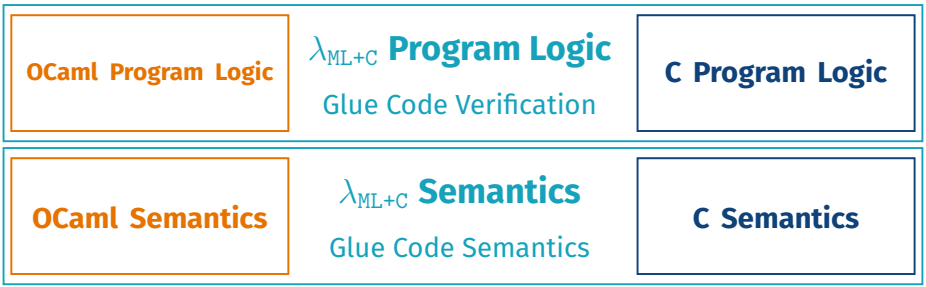
- Language-local reasoning for **external calls**.
- Additional **OCaml FFI features**: garbage collection, registering roots, custom blocks, callbacks, etc.
- **Case studies** utilising all of these features.
- **Step-indexed logical relation** to prove OCaml type safety of external C functions.

Transfinite

Iris

# Our Contribution: Melocoton

## Language Locality: Embed Existing Languages




## Language Interaction: View Reconciliation Rules

$$\ell \mapsto_{\text{ML}} \vec{V} \;\Rrightarrow\; \exists \gamma \vec{v}.\, \gamma \mapsto_{\text{blk}} \vec{v} * \ell \sim_{\text{ML}} \gamma * \vec{V} \sim_{\text{ML}} \vec{v}$$

$$\vec{V} \sim_{\text{ML}} \vec{v} * \gamma \mapsto_{\text{blk}} \vec{v} \;\Rrightarrow\; \exists \ell \;.\, \ell \mapsto_{\text{ML}} \vec{V} * \ell \sim_{\text{ML}} \gamma$$

https://melocoton-project.github.io