Modular I/O Reasoning in DimSum

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Modular I/O Reasoning

```
int echo () :=
  let c := getc();
  putc(c);
  return 0;
```

reads from increasing sequence

{…}
echo
{…}

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reads from increasing sequence

$$\{\lambda\ \mathrm{es},\ \ulcorner \mathrm{es} = [\,]\urcorner\}$$
$$\mathtt{echo}$$
$$\{\lambda\ \mathrm{v},\ \ulcorner \mathrm{v} = 0\urcorner\}$$

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reads from increasing sequence

$$\left\{\lambda\ \mathrm{es},\ \ulcorner \mathrm{es} = [\,]\urcorner * \{\lambda\ \mathrm{es},\ \ulcorner \mathrm{es} = [\,]\urcorner\}\mathtt{getc}\{\lambda\ \mathrm{v},\ \{\lambda\ \mathrm{es},\ \ulcorner \mathrm{es} = \mathrm{v}\urcorner\}\mathtt{putc}\{\_\}\ \}\right\}$$
$$\mathtt{echo}$$
$$\left\{\lambda\ \mathrm{v},\ \ulcorner \mathrm{v} = 0\urcorner\right\}$$

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$$\{\lambda\ \mathrm{es},\ \ulcorner \mathrm{es} = [\,]\urcorner * \exists\ \mathrm{v},\ \mathrm{P}\ \mathrm{v} * (\texttt{getc\_spec}\ \mathrm{P}) * (\texttt{putc\_spec}\ \mathrm{P})\}$$
$$\texttt{echo}$$
$$\{\lambda\ \mathrm{v},\ \ulcorner \mathrm{v} = 0\urcorner\}$$

Modular I/O Reasoning

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int echo () :=
  let c := getc();
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reads from increasing sequence

$$\{\lambda\ es, \ulcorner es = [\,]\urcorner * \exists\ v,\ P\ v\}\ \texttt{getc}\ \{\lambda\ ret, \ulcorner ret = v\urcorner * P\ (v + 1)\}$$

$$\{\lambda\ es, \exists\ v, \ulcorner es = v\urcorner * P\ (v + 1)\}\ \texttt{putc}\ \{\lambda\ ret, P\ (v + 1)\}$$

$$\{\lambda\ es, \ulcorner es = [\,]\urcorner * \exists\ v,\ P\ v * (\texttt{getc\_spec}\ P) * (\texttt{putc\_spec}\ P)\}$$
$$\texttt{echo}$$
$$\{\lambda\ v, \ulcorner v = 0\urcorner\}$$

DimSum

- Decentralized/language-agnostic multi-language semantics
  - No fixed source
  - No fixed set of languages
  - No fixed memory model
  - No fixed notion of linking
- Notion of semantic linking: $\oplus$
  - Link semantic components (modules) rather than syntactic
  - Link programs with specifications (abstract program)
- Program semantics as LTS, interaction via synchronization
- Reason locally in terms of interaction of two modules

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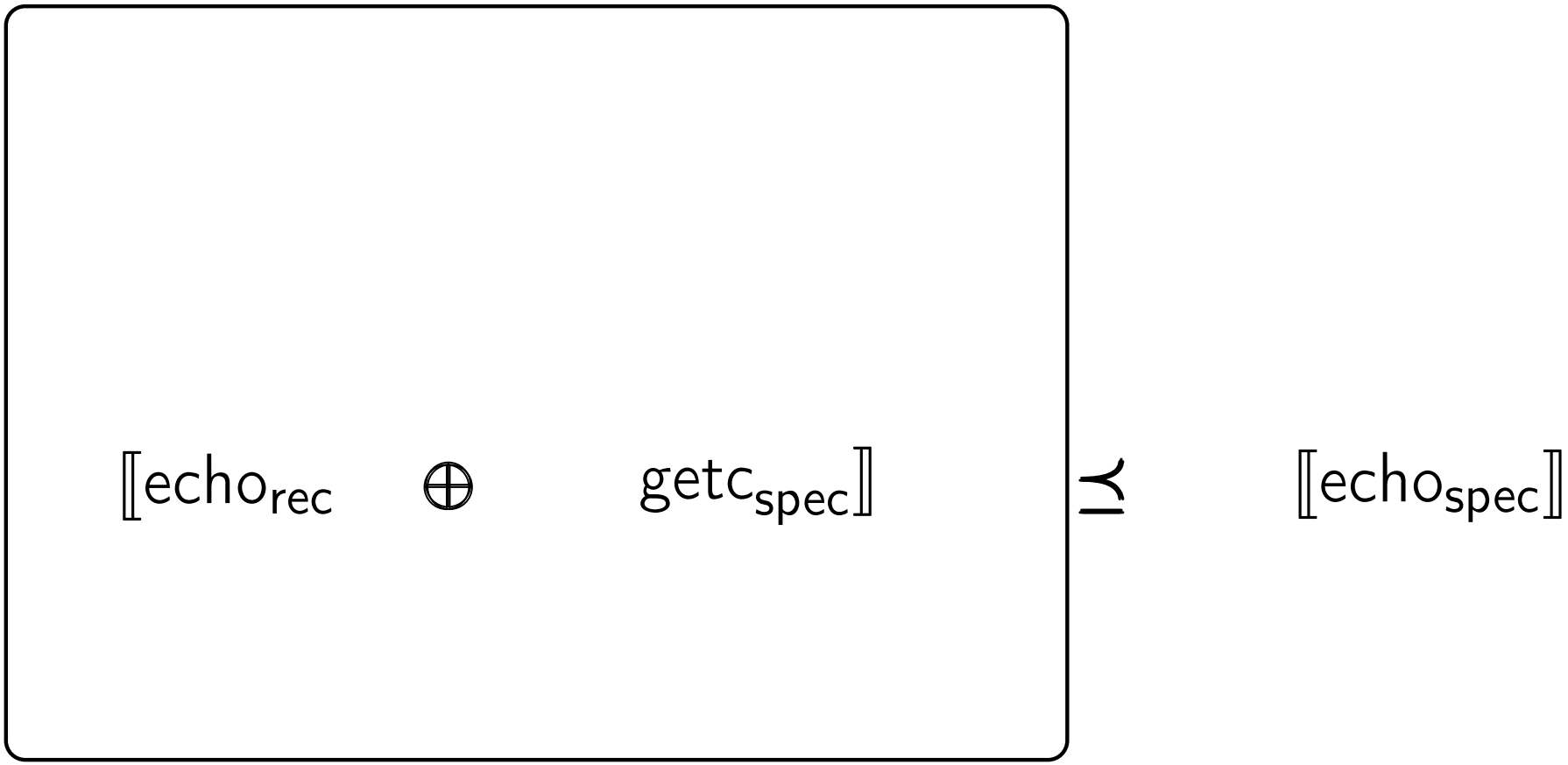
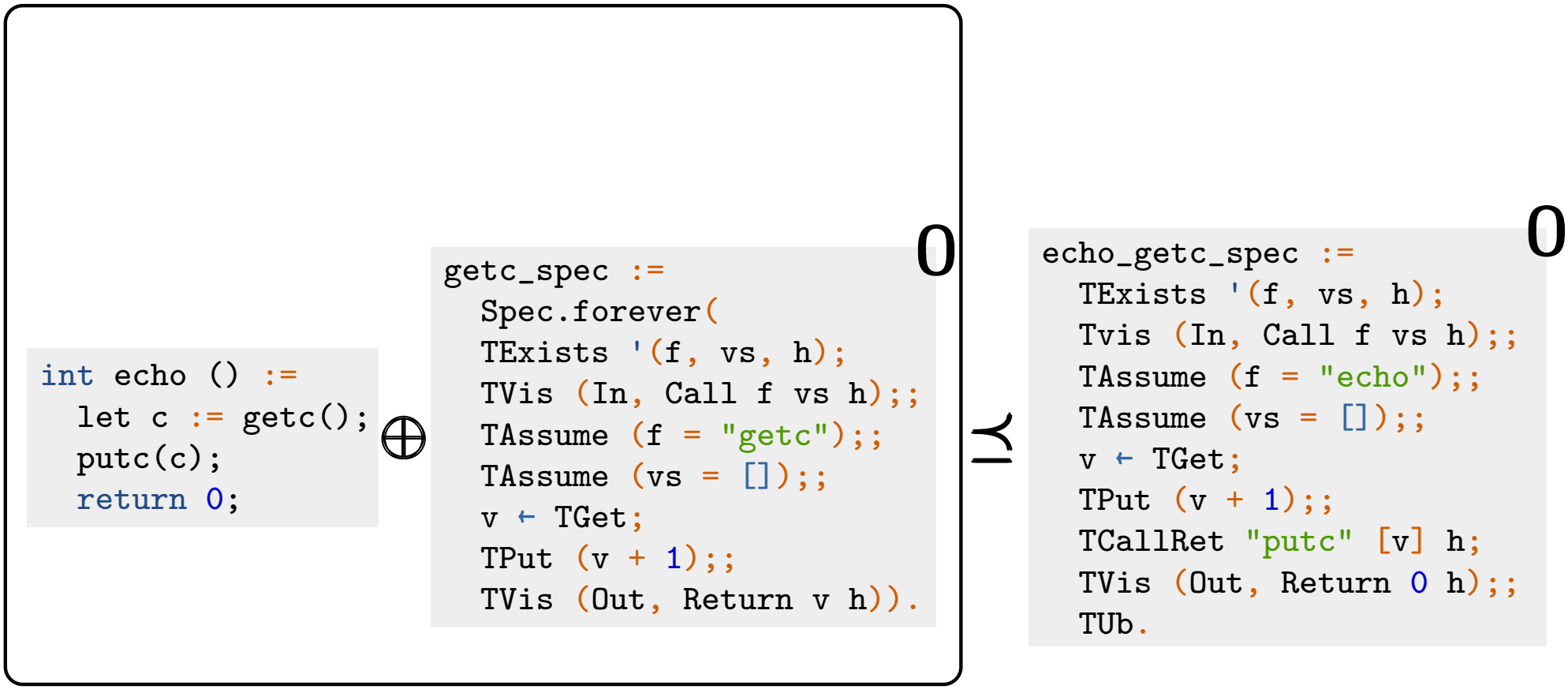
Proofs in DimSum

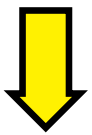


Proofs in DimSum



Proofs in DimSum

(Call f vs h)



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⊕

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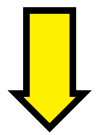

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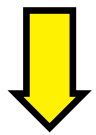

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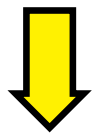

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Proofs in DimSum

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Proofs in DimSum

(Call "echo" [] h)

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$\succcurlyeq_{\Gamma}$

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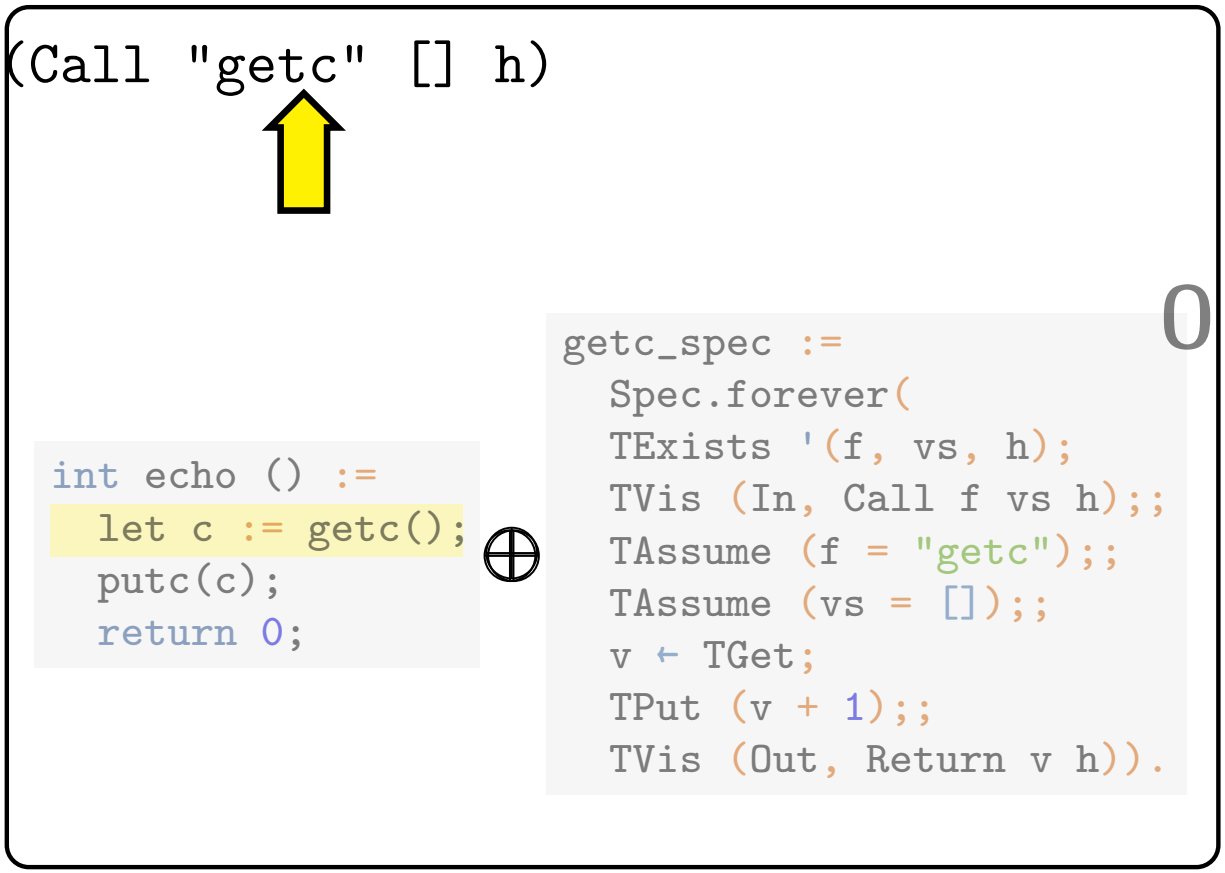
Proofs in DimSum



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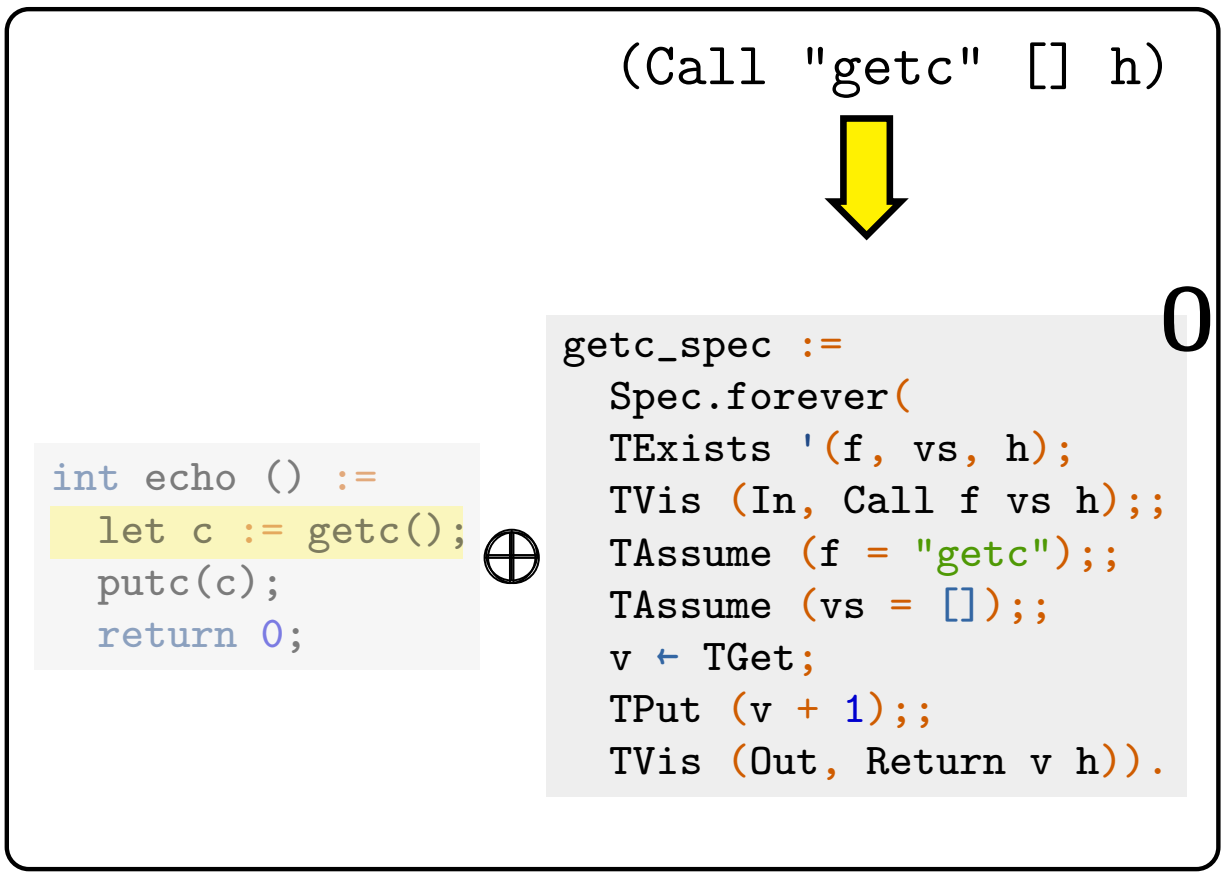

Proofs in DimSum

(Call "getc" [] h)

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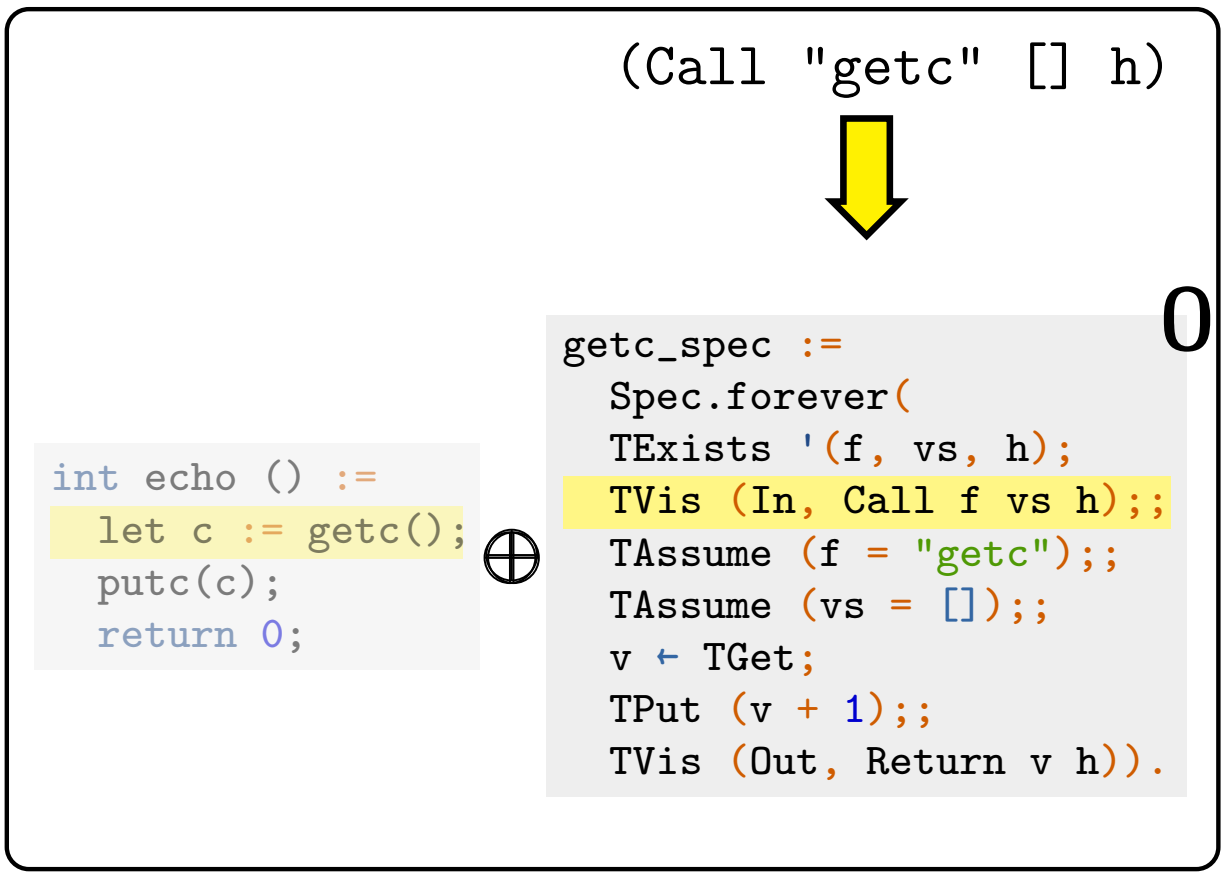

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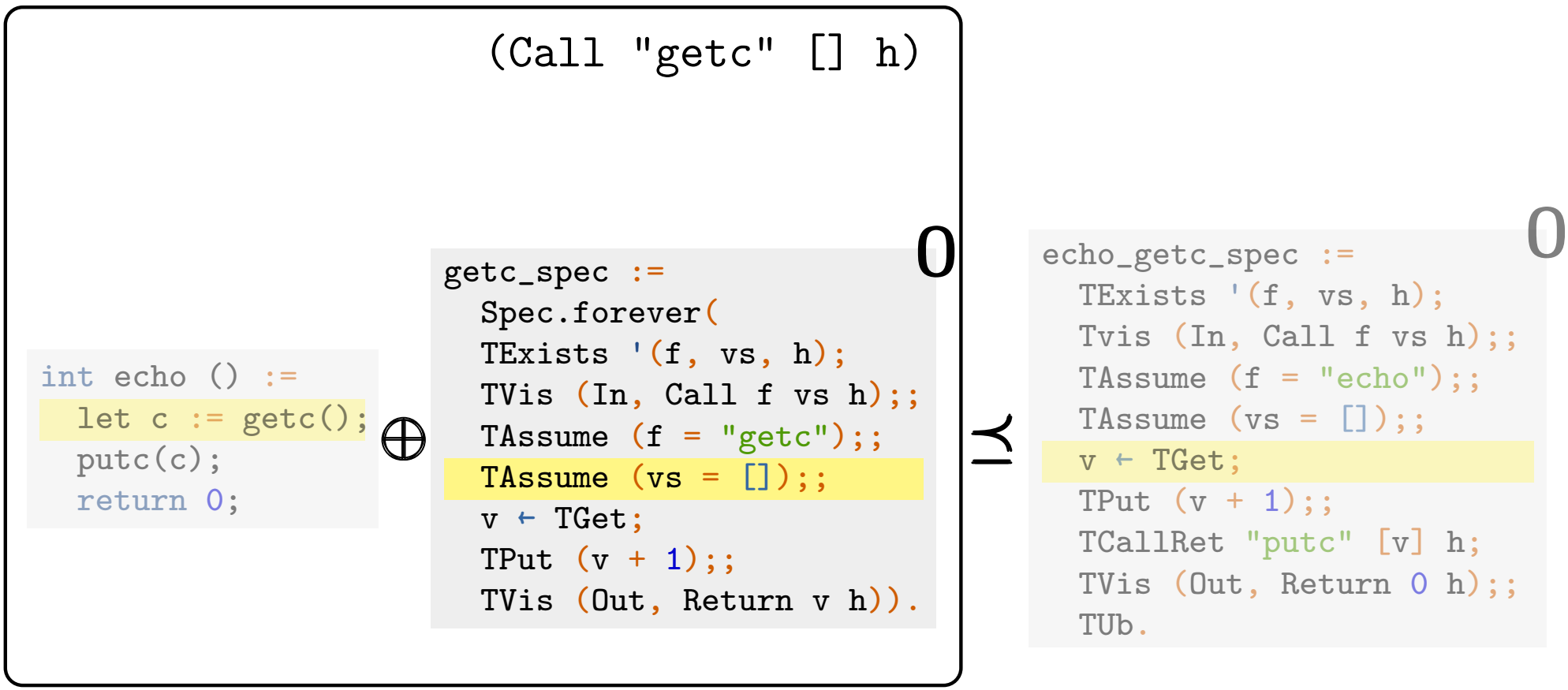

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1

≺1

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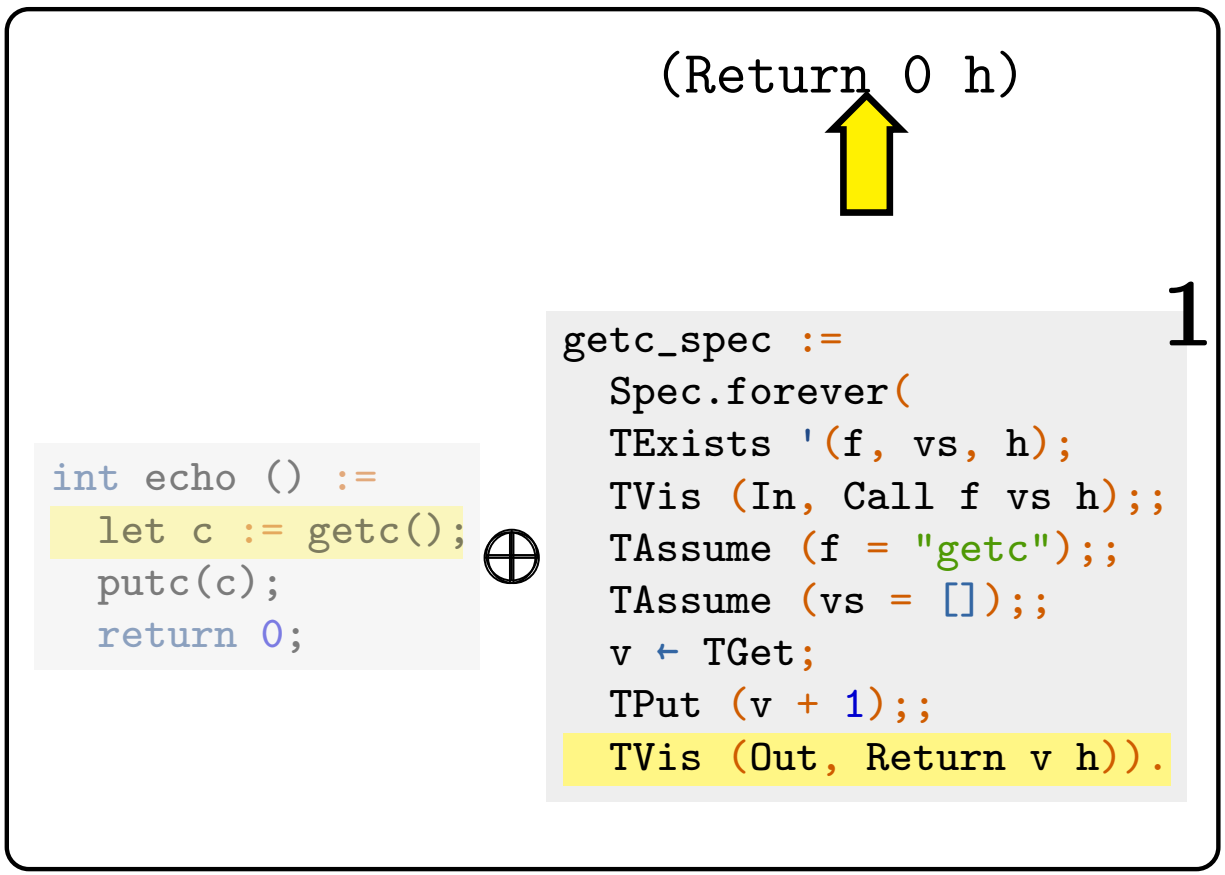
Proofs in DimSum

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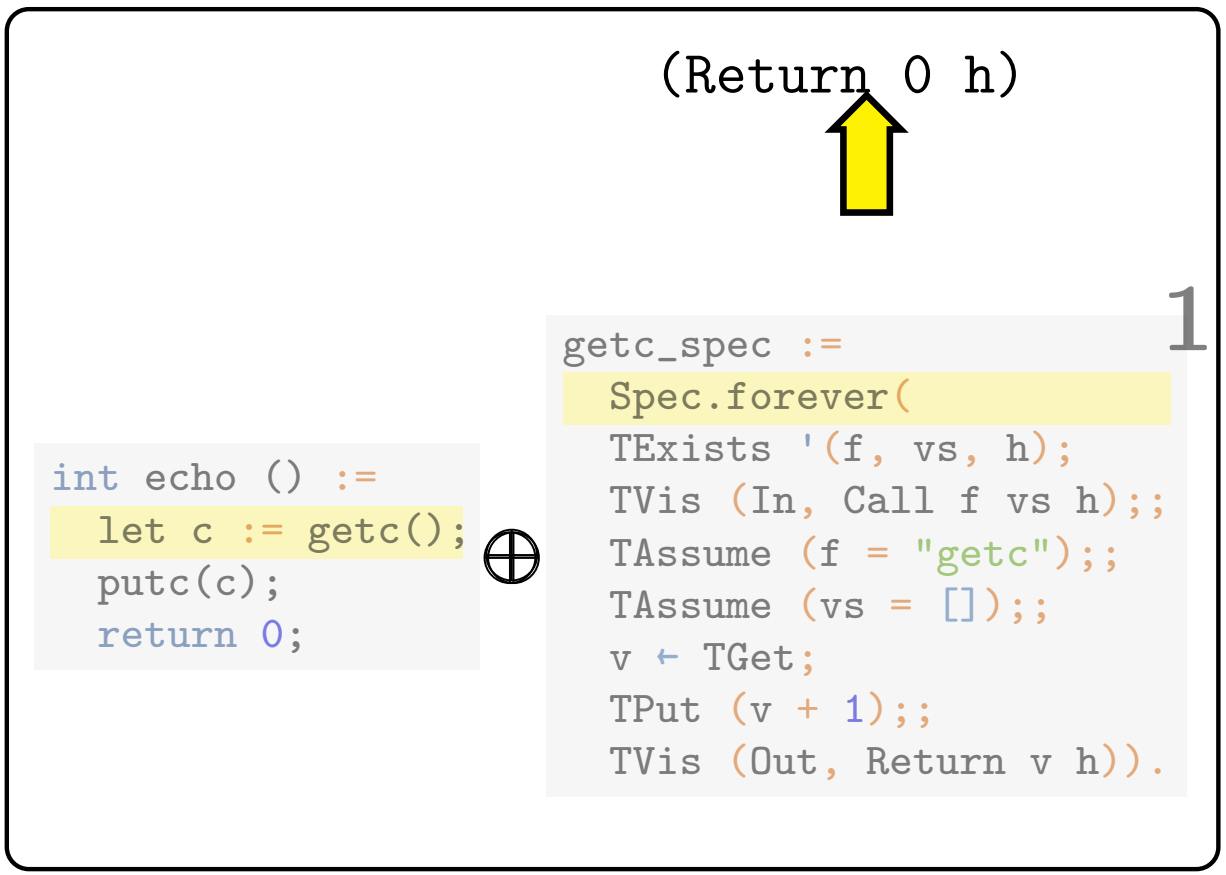

Proofs in DimSum

(Return 0 h)


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1

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  TVis (Out, Return 0 h);;
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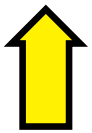
```

0

Proofs in DimSum

```
(Call "putc" 0 h)
```



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int echo () :=
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⊕

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Proofs in DimSum

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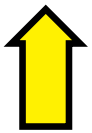

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Proofs in DimSum

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1

⊸

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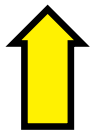

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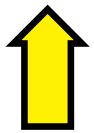

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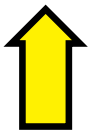

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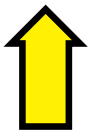

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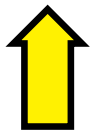

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1

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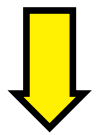
1

≤

(Return v h)



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1

Proofs in DimSum

(Return v h)

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1

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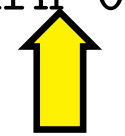
1

Proofs in DimSum

(Return 0 h)



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$\preceq_{\Upsilon}$

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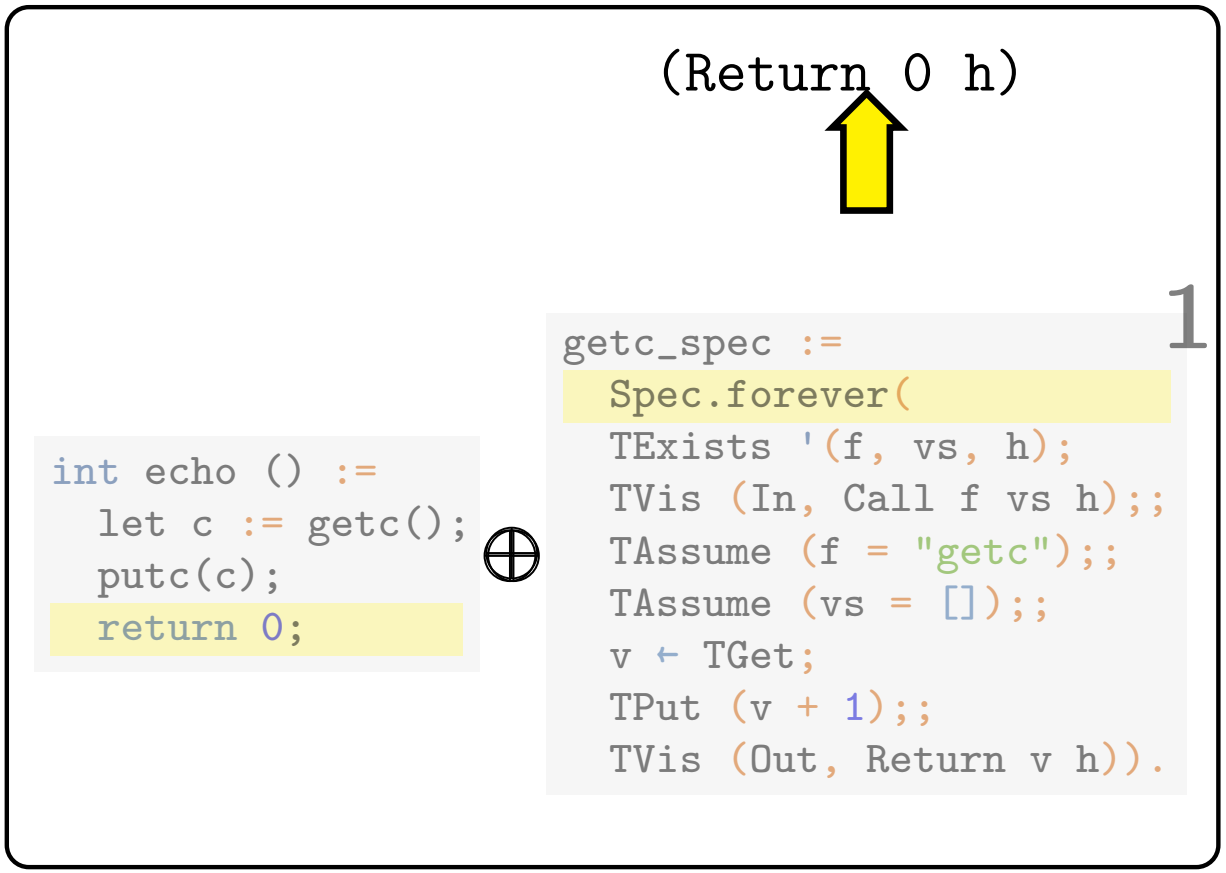
Proofs in DimSum



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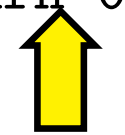

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1

Towards Hoare-style Reasoning

$[\![\mathsf{echo}_{\mathsf{rec}} \oplus \mathsf{getc}_{\mathsf{spec}}]\!]$ $\preceq$ $[\![\mathsf{echo}_{\mathsf{spec}}]\!]$

Towards Hoare-style Reasoning

$$[\![\mathsf{echo}_{\mathsf{rec}} \oplus \mathsf{getc}_{\mathsf{spec}}]\!] \approx\!> (\boldsymbol{\lambda} \kappa_t \sigma_t,$$

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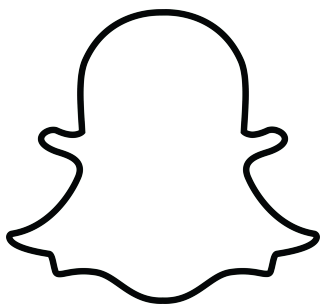

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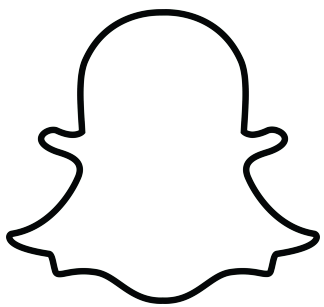

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$$[\![\mathsf{echo}_{\mathsf{rec}}]\!] \approx\!> \Pi_{\oplus}\left(\gamma_{\sigma_1}, \gamma_{\sigma_2}, \gamma_{\sigma_\oplus}, \Pi_s(\gamma_{\sigma_{spec}})\right)$$

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TGT Call "echo" es @ Π $\{\{\Phi\}\}$

Towards Hoare-style Reasoning

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$$\gamma_{\sigma_1} \rightsquigarrow \sigma_1, \gamma_{\sigma_2} \rightsquigarrow \sigma_2, \gamma_{\sigma_\oplus} \rightsquigarrow \sigma_\oplus, \gamma_{\sigma_{spec}} \rightsquigarrow \sigma_{spec}$$

Rotation Project

- Get familiar with DimSum (and Iris)
- Experiment with new reasoning style
- Proof refinements for multiple example programs

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```
int echo () :=
  let c := getc();
  putc(c);
  return 0;
```

```
int getc (l) :=
  let _ := read(l);
  return *l;
```

```
void echo () :=
  let c := getc();
  putc(c);
  echo ();
```

```
global pos = 0;
read (l, c) :=
  if (c <= 0) {
    return 0;
  } else {
    l <- *pos;
    pos <- *pos + 1;
    ret = read(l + 1, c -1);
    return ret + 1;
  }
```

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int echo () :=
  let c := getc();
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(Modular) Hoare-style Reasoning

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TGT Call "echo" es @ Π
  PRE |-*: es POST_e, ⌜es = []⌝ *
    TGT Call "getc" es @ Π
      PRE |-*: es POST, ⌜es = []⌝ *
      POST |*: ret,
        TGT Call "putc" es @ Π
          PRE |-*: es POST, ⌜es = [v]⌝ *
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Example 1

$$[\![\mathrm{echo}_{\mathrm{rec}} \oplus \mathrm{getc}_{\mathrm{spec}}]\!] \preceq [\![\mathrm{echo}_{\mathrm{spec}}]\!]$$

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getc_spec :=
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  TPut (v + 1);;
  TVis (Out, Return v h)).
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Lemma sim_getc_spec `{!specGS} Π Φ :
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Lemma sim_getc fns Π_l Π_r PL σi :
  "getc" ↪ None -∗
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  □ switch_linked_fixed Tgt Π_l Π_r
      PRE |-∗: σ_l POST, ∃ h v σg, PL σg ∗
      POST (ERCall "getc" [] h) σg |∗: σr Π_r',
    switch_link Tgt Π_r'
      Pre |-∗: σ_r' POST, ∃ h'
      POST (ERReturn (ValNum v) h') _ σ_l |∗: _ Π_l',
        ⌜Π_l' = Π_l⌝ ∗ PL σ_r' ==∗
  ∃ P, P 0 ∗ □ rec_fn_spec_hoare Tgt Π_l "getc" (getc_fn_spec P).
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  □ switch Π_l
      PRE |-∗: κ σ0 POST, ∃ h v σg, PL σg ∗
      POST Tgt _ _ |∗:  σi0 Πi, ⌜σi0 = σg⌝ ∗ ⌜Πi = Π_r⌝ ∗
    switch Πi
      PRE |-∗: κ' σ POST0, ∃ e' : rec_ev, ⌜κ' = Some (Incoming, e')⌝ ∗
      POST0 Tgt _ _ |∗: σr Πr, ⌜σr = σ⌝ ∗ ⌜e' = ERCall "getc" [] h⌝ ∗
    switch Πr
      PRE |-∗: κ0 σ1 POST1, ∃ h', ⌜κ0 = Some (Outgoing, ERReturn v h')⌝ ∗
      POST1 Tgt _ _ |∗: σi1 Πi0, ⌜σi1 = σ0⌝ ∗
    switch Πi0
      PRE |-∗: κ'0 σ2 POST2, ∃ e'0, ⌜κ'0 = Some (Incoming, e'0)⌝ ∗
      POST2 Tgt _ _ |∗: σr0 Πr0,
        ⌜σr0 = σ2⌝ ∗ ⌜e'0 = ERReturn v h'⌝ ∗ ⌜Πr0 = Π_l⌝ ∗ PL σ1 ==∗
  ∃ P, P 0 ∗ □ rec_fn_spec_hoare Tgt Π_l "getc" (getc_fn_spec P).
```

Outcome & Takeaways

- Lemma for `TCallRet`
- Keep Πs the same - new lemmas for linking
- Balance between Abstraction and Information
- Balance between Hacking and Thinking