μse: programming multi-party sessions for SOC

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Joint work with

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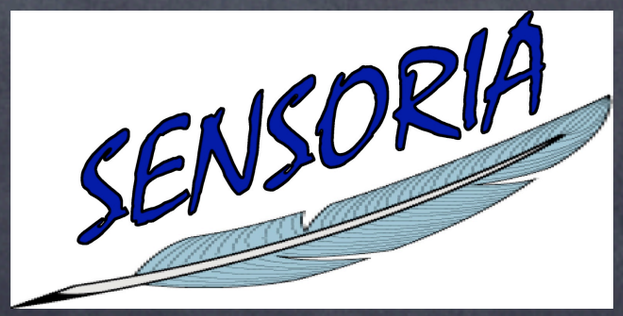
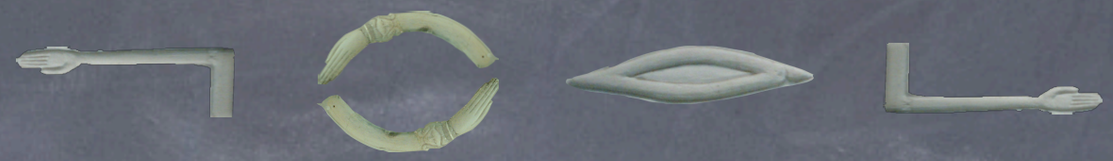
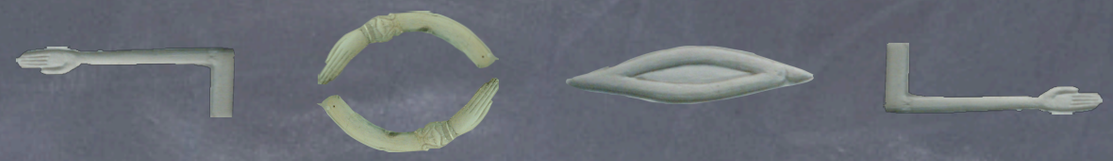


The problem



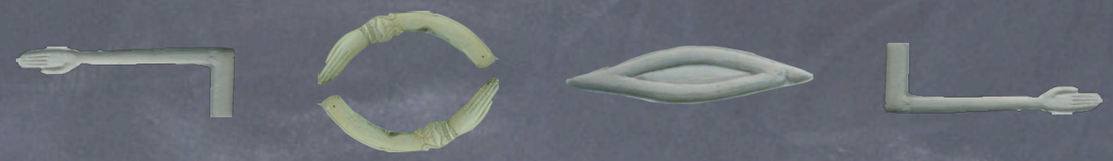
- SOC envisages systems as a combination of services $a_1 \Rightarrow P_1 \mid \ldots \mid a_n \Rightarrow P_n$
- many invocations to each $a_i \Rightarrow P_i$
- each invocation triggers a "new" instance of P_i
- different instances "should not interfere"

Some solutions



- Standards (WS-BPEL & WS-CDL) use correlation sets
  - too low level and not formally defined
  - reasoning on systems is hard (value-driven interactions)
  - interferences (different instances may use "right" values)
- "Fresh" sessions
  - More formal
  - abstract mechanism for scoping interactions
  - 2-parties

Multiparty



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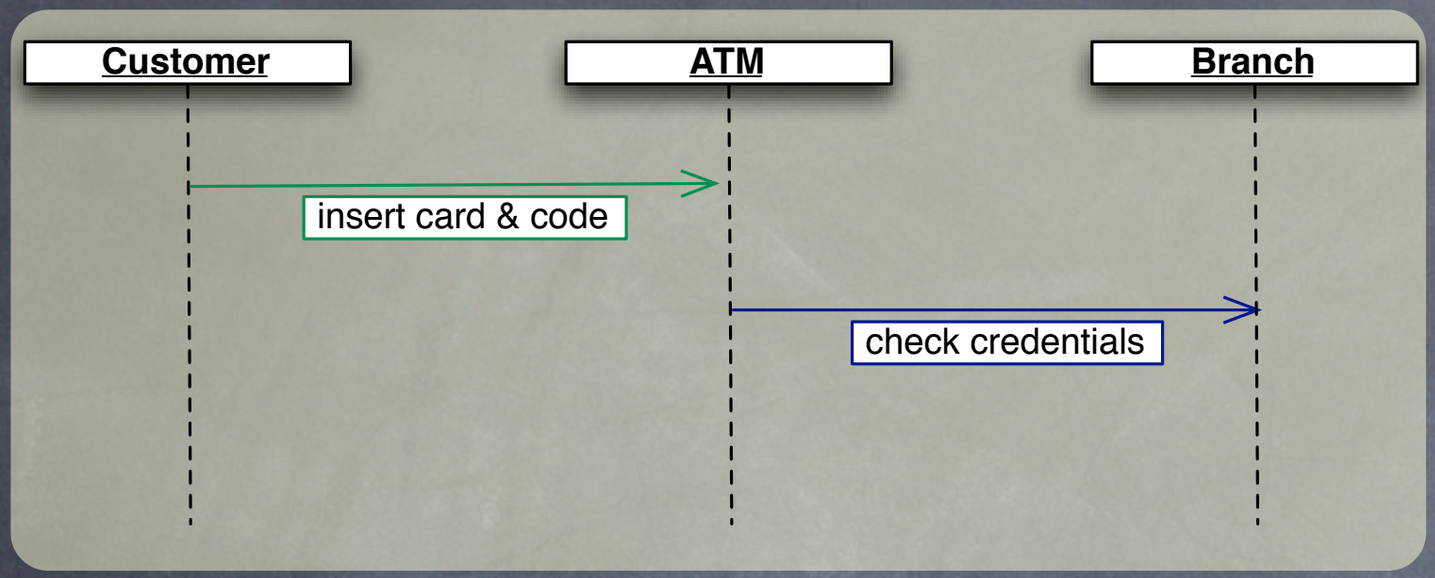

- designed as a 3-party session
- implemented with two 2-party sessions
  - a new session starts between ATM & Branch

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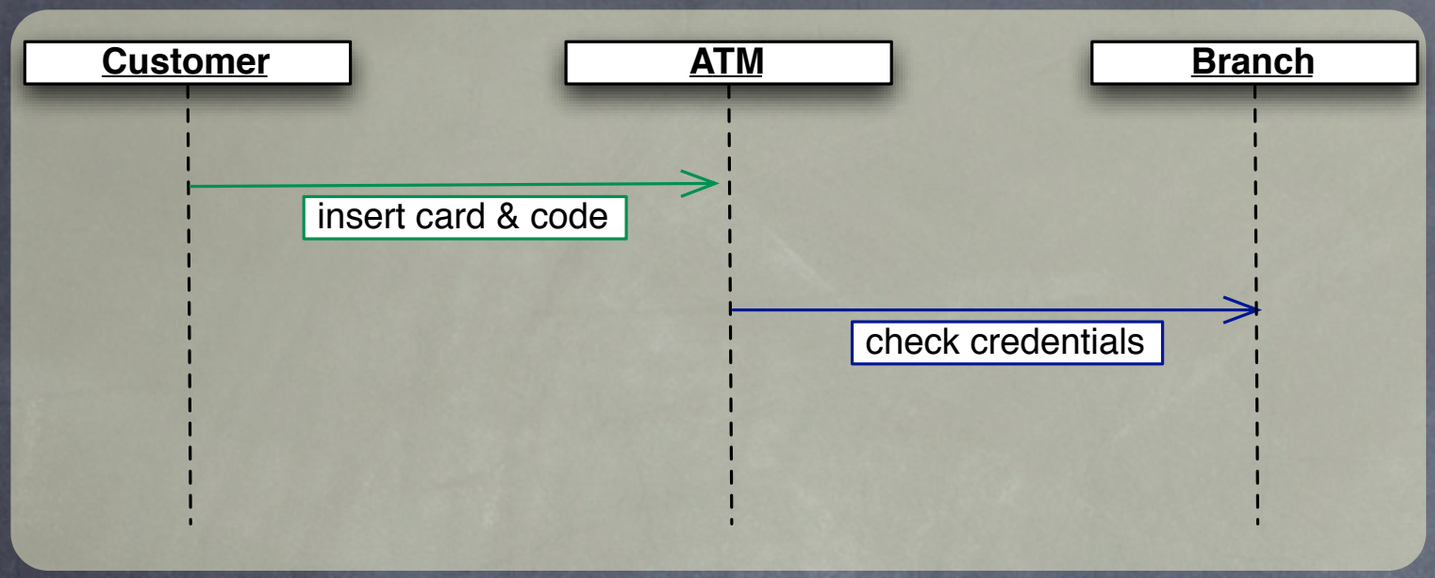
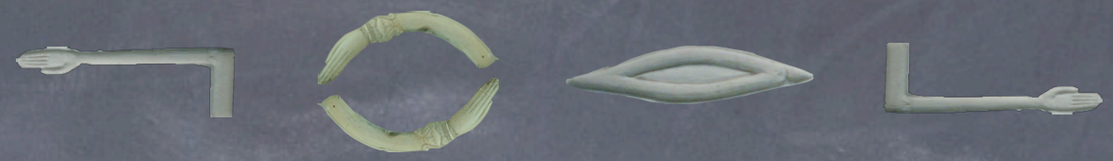


- designed as a 3-party session
- implemented with two 2-party sessions
  - a new session starts between ATM & Branch

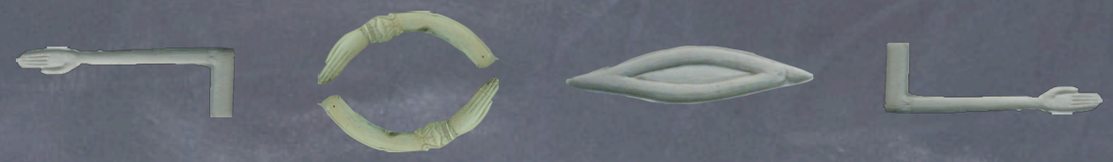
- 1st invoker has to wait
- many gamblers can join (and interact)
  - implemented with two 2-party sessions
    - 55 (?=>!) 2-party sessions

Plan



- μse design principles
- Syntax & SOS semantics
- A few interesting (?) examples
- Considerations on μse's observational semantics
- Concluding remarks

μse design



- Sessions unit of conversations among endpoints s▷P
  - session transparency
  - session merging through entry points merge e.Q
- Services a => P
  - invocation≠communication invoke a.Q
  - ephemeral s▷invoke a.Q | a => P ➠ s▷Q | P
  - communications (π-like)
    - intra- & extra-sessions
    - locations l::P delimit extra-session communications

µse syntax

S, T	$::=$	$l :: a \Rightarrow P$	Service definition
	$\mid$	$l :: P$	Located process
	$\mid$	$S \mid T$	Composition of systems
	$\mid$	$(\nu n)S$	New name
P, Q	$::=$	$\mathbf{0}$	Empty process
	$\mid$	$\overline{x}w.P$	Intra-session output
	$\mid$	$x(y).P$	Intra-session input
	$\mid$	$x!w.P$	Intra-site output
	$\mid$	$x?(y).P$	Intra-site input
	$\mid$	$\mathsf{install}[a \Rightarrow P].Q$	Service installation
	$\mid$	$\mathsf{invoke}\ a.P$	Service invocation
	$\mid$	$\mathsf{merge}\ e.P$	Entry point
	$\mid$	$r \triangleright P$	Endpoint
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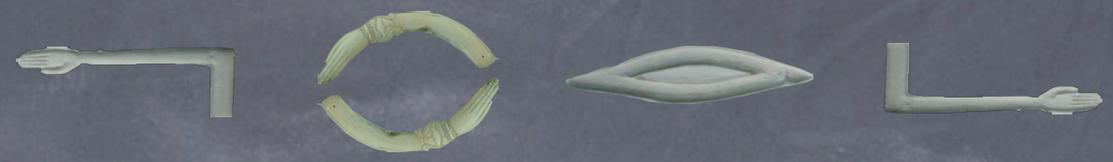

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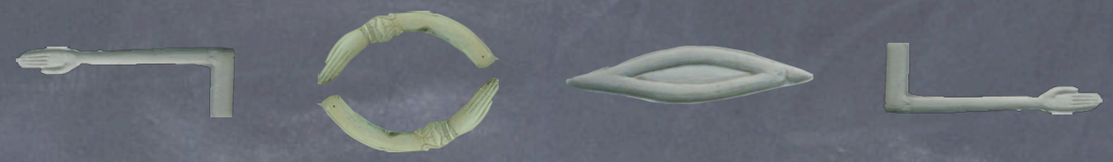
Names around in µse

- ✓services
- ✓sessions
- ✓entry points
- ✓locations
- ✓channels

Channels, services and entry points are communicable values

Usual structural congruence

µse syntax



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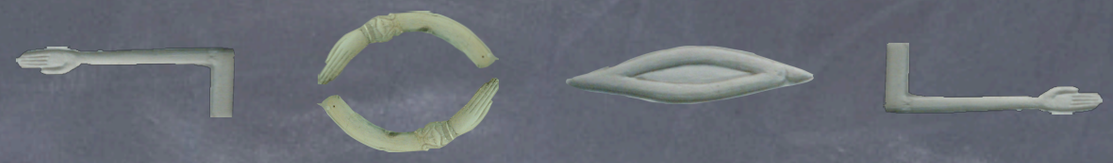
Intra-session

μse syntax



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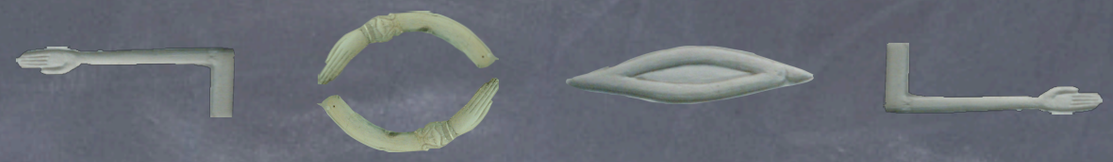
Extra-session

μse semantics (1)



$$\overline{x}v.P \xrightarrow{\overline{x}v} P \qquad x(y).P \xrightarrow{xv} P\{v/y\}$$

$$x!v.P \xrightarrow{x!v} P \qquad x?(y).P \xrightarrow{x?v} P\{v/y\}$$

$$\text{invoke } a.P \xrightarrow{\perp a} P \qquad \text{install}[a \Rightarrow R].P \xrightarrow{a[R]} P$$

$$\text{merge } e.P \xrightarrow{\bowtie e} P$$

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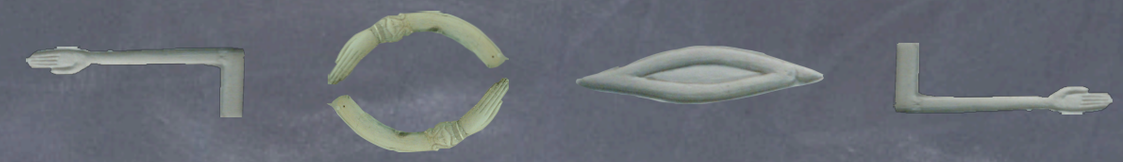

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early-style semantics

μse semantics (1)

$$\overline{x}v.P \xrightarrow{\overline{x}v} P \qquad x(y).P \xrightarrow{xv} P\{v/y\}$$

$$x!v.P \xrightarrow{x!v} P \qquad x?(y).P \xrightarrow{x?v} P\{v/y\}$$

$$\text{invoke } a.P \xrightarrow{\perp a} P \qquad \text{install}[a \Rightarrow R].P \xrightarrow{a[R]} P$$

$$\text{merge } e.P \xrightarrow{\bowtie e} P$$

This is not code mobility;
just services at top level

early-style semantics

μse semantics (2)

$$\frac{P \xrightarrow{\alpha} Q \quad \alpha \in \{\bot a, xv, \overline{x}v, \bowtie e\}}{r \rhd P \xrightarrow{r\ \alpha} r \rhd Q}$$

$$\frac{P \xrightarrow{\alpha} Q \quad \alpha \notin \{\bot a, xv, \overline{x}v, \bowtie e\}}{r \rhd P \xrightarrow{\alpha} r \rhd Q}$$

$$\frac{P \xrightarrow{a[R]} Q}{l :: P \xrightarrow{\tau} l :: Q \,|\, l :: a \Rightarrow R}$$

$$\frac{P \xrightarrow{\alpha} Q \quad \alpha \notin \{a[R], x?(v), x!v\}}{l :: P \xrightarrow{\alpha} l :: Q}$$

$$l :: a \Rightarrow P \xrightarrow{r \top a} l :: r \rhd P$$

$$\frac{P \xrightarrow{x!v} P' \quad Q \xrightarrow{x?v} Q'}{P|Q \xrightarrow{\tau} P'|Q'}$$

$$\frac{\mathcal{A} \xrightarrow{\alpha} \mathcal{A}' \quad \mathrm{bn}(\alpha) \cap \mathrm{fn}(\mathcal{B}) = \emptyset}{\mathcal{A}|\mathcal{B} \xrightarrow{\alpha} \mathcal{A}'|\mathcal{B}}$$

$$\frac{\mathcal{A} \xrightarrow{r\ \overline{x}v} \mathcal{A}' \quad \mathcal{B} \xrightarrow{r\ xv} \mathcal{B}'}{\mathcal{A}|\mathcal{B} \xrightarrow{\tau} \mathcal{A}'|\mathcal{B}'}$$

$$\frac{\mathcal{A} \xrightarrow{r \bowtie e} \mathcal{A}' \quad \mathcal{B} \xrightarrow{s \bowtie e} \mathcal{B}'}{\mathcal{A}|\mathcal{B} \xrightarrow{\tau} \mathcal{A}'|\mathcal{B}'|s \doteq r}$$

$$\frac{S \xrightarrow{r \top a} S' \quad T \xrightarrow{r \bot a} T'}{S|T \xrightarrow{\tau} S'|T'}$$

$$\frac{\mathcal{A} \xrightarrow{\alpha} \mathcal{A}' \quad n \notin \mathrm{n}(\alpha)}{(\nu n)\mathcal{A} \xrightarrow{\alpha} (\nu n)\mathcal{A}'}$$

$$\frac{\mathcal{A} \xrightarrow{\alpha} \mathcal{A}' \quad \alpha \in \{\overline{x}w, x!w, r\ \overline{x}w, r\ x!w\}}{(\nu w)\mathcal{A} \xrightarrow{(w)\alpha} \mathcal{A}'}$$

μse ATM

$$hiw :: r \triangleright C$$

$$|$$

$$(\nu\ check, abort)(hiw :: *atm \Rightarrow A \mid branch :: *bank \Rightarrow B)$$

$$C \quad = \quad \text{invoke } atm.\overline{req}\langle \mathsf{c}, \mathtt{m}\rangle.(cash(x)|sms(y))$$

$$A \quad = \quad req(x,y).\text{invoke } bank.\overline{check}\langle x, y\rangle.(\ check().\overline{cash}\ y + abort().\overline{cash}\ 0\ )$$

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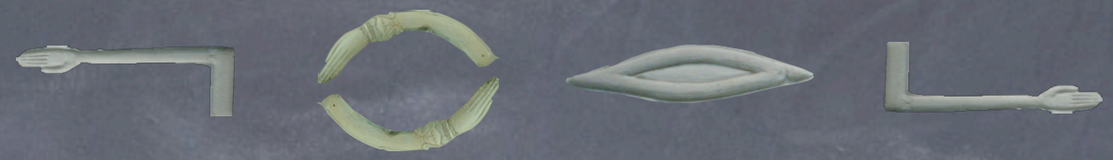

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hiw

branch

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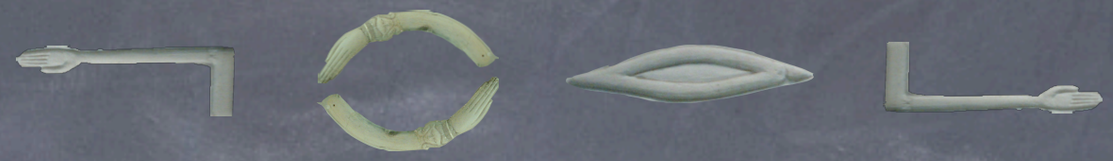

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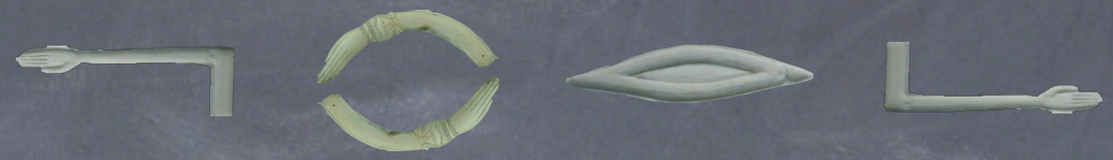

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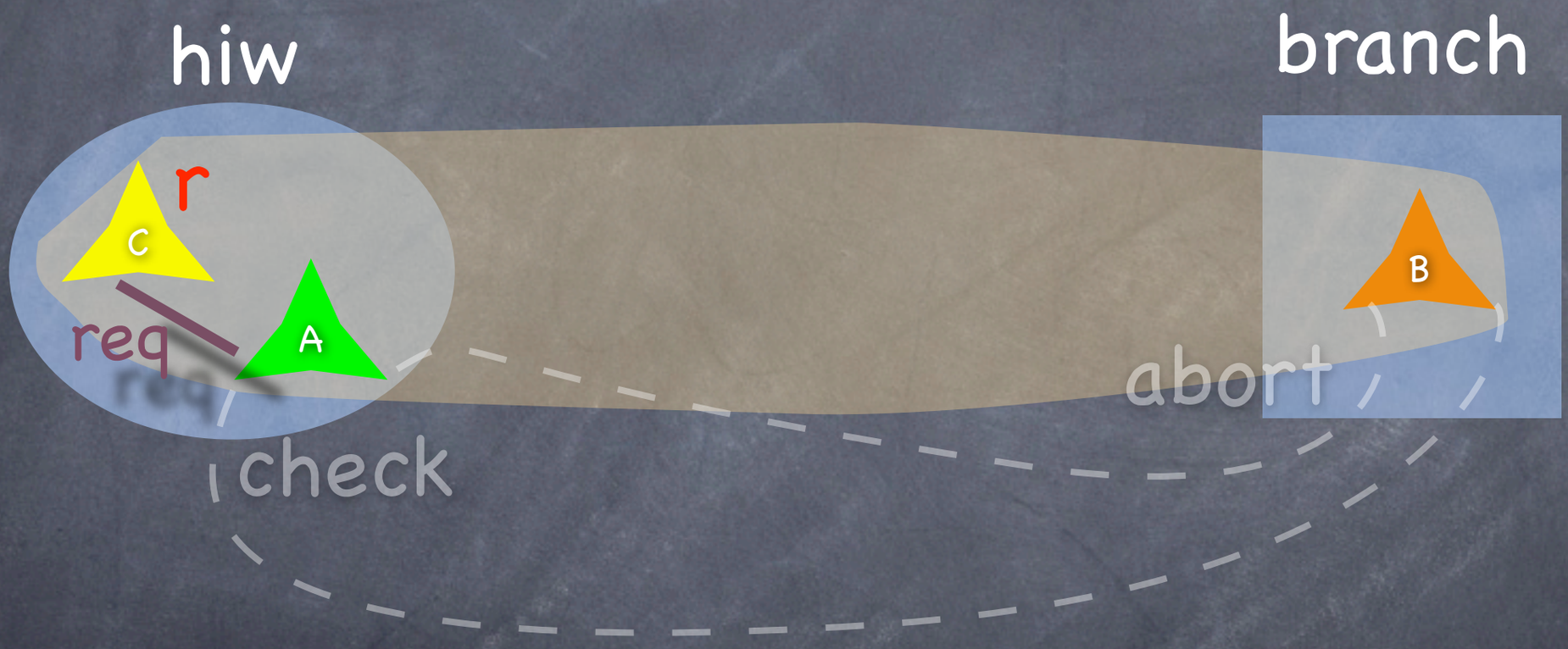

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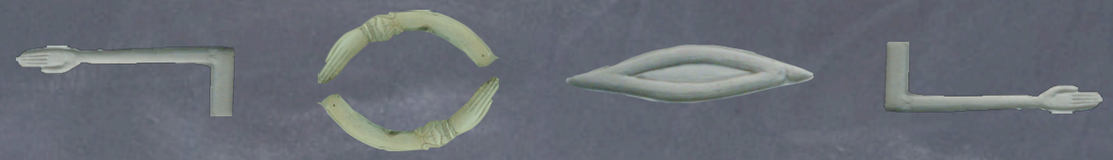

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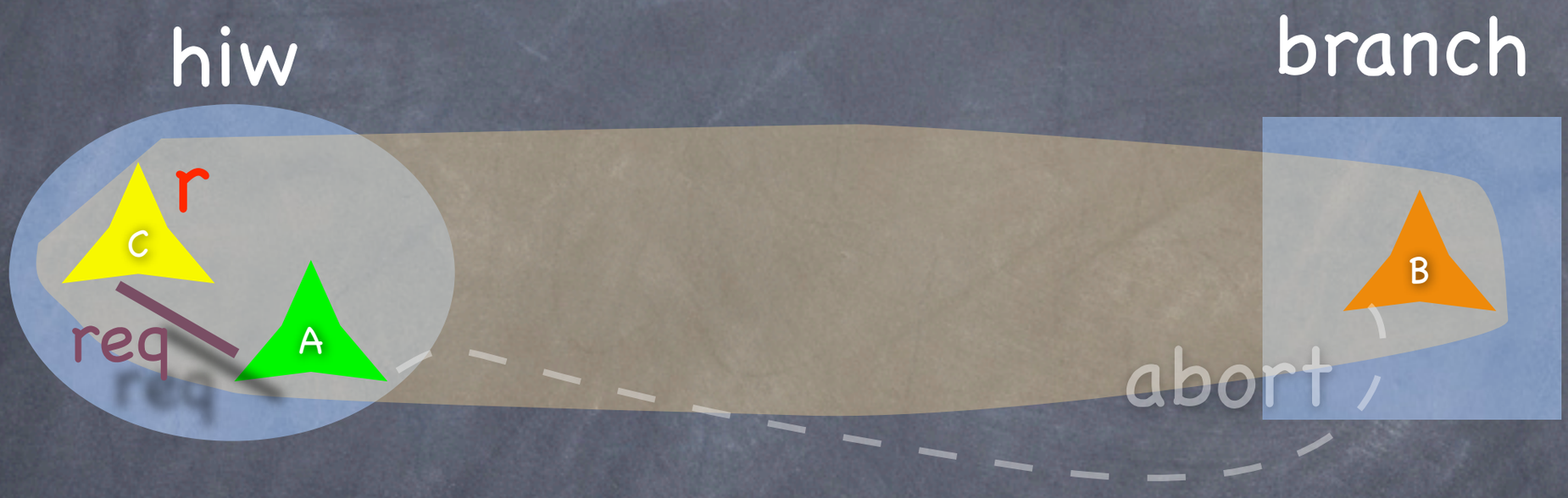

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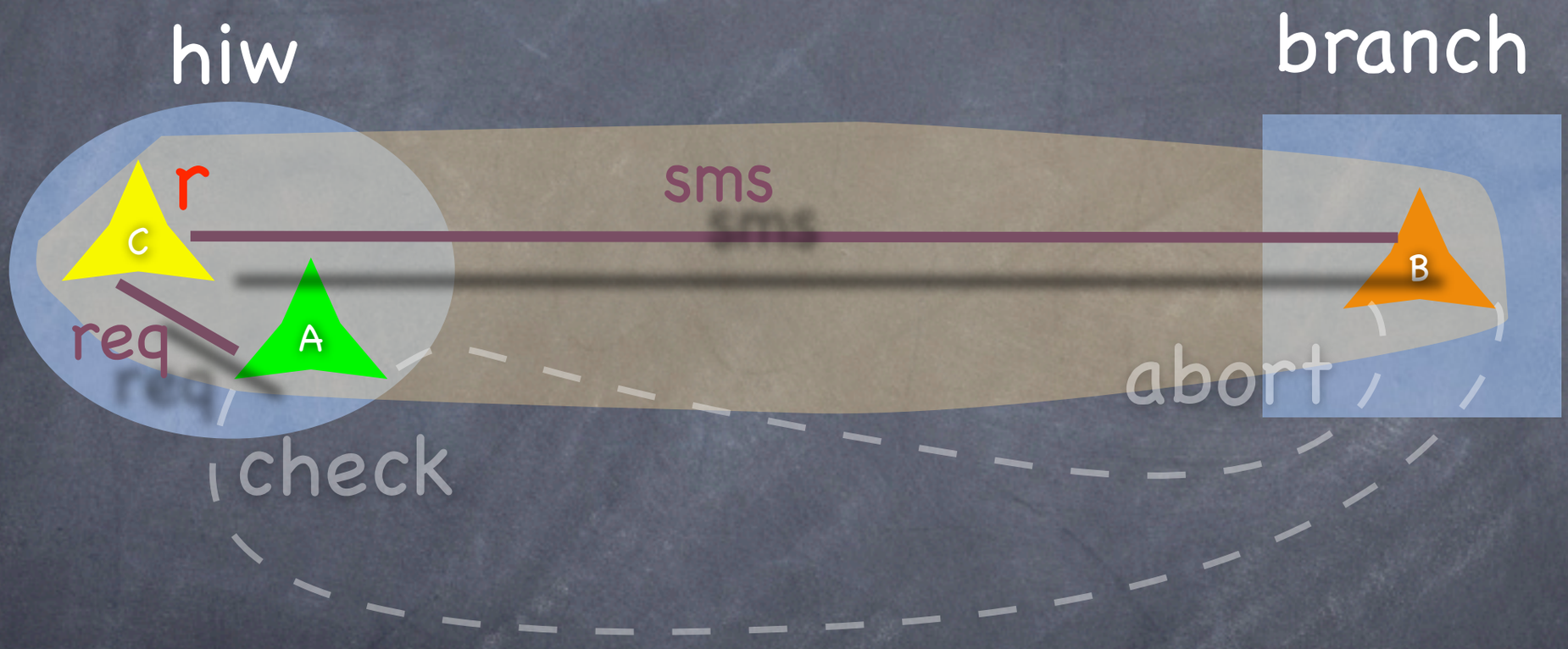

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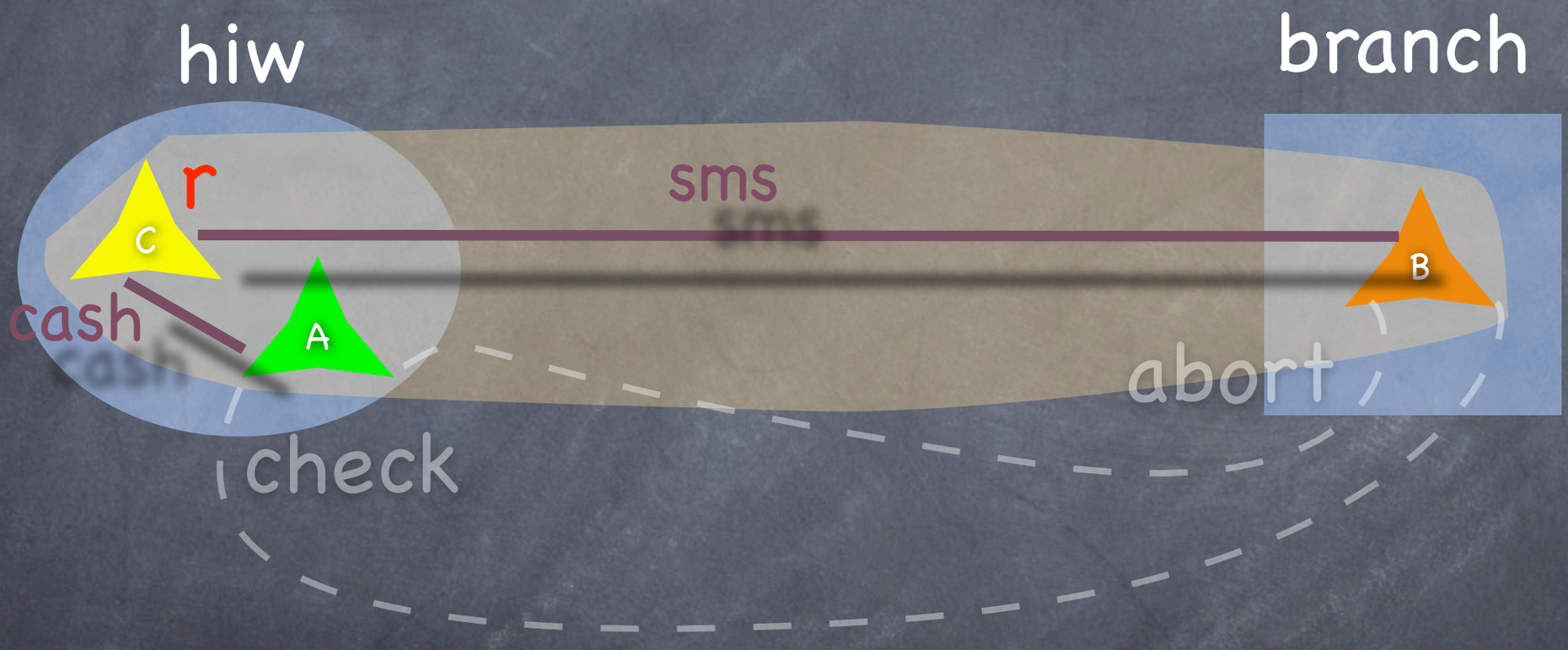

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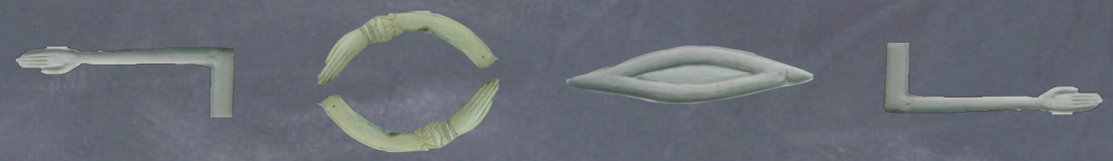
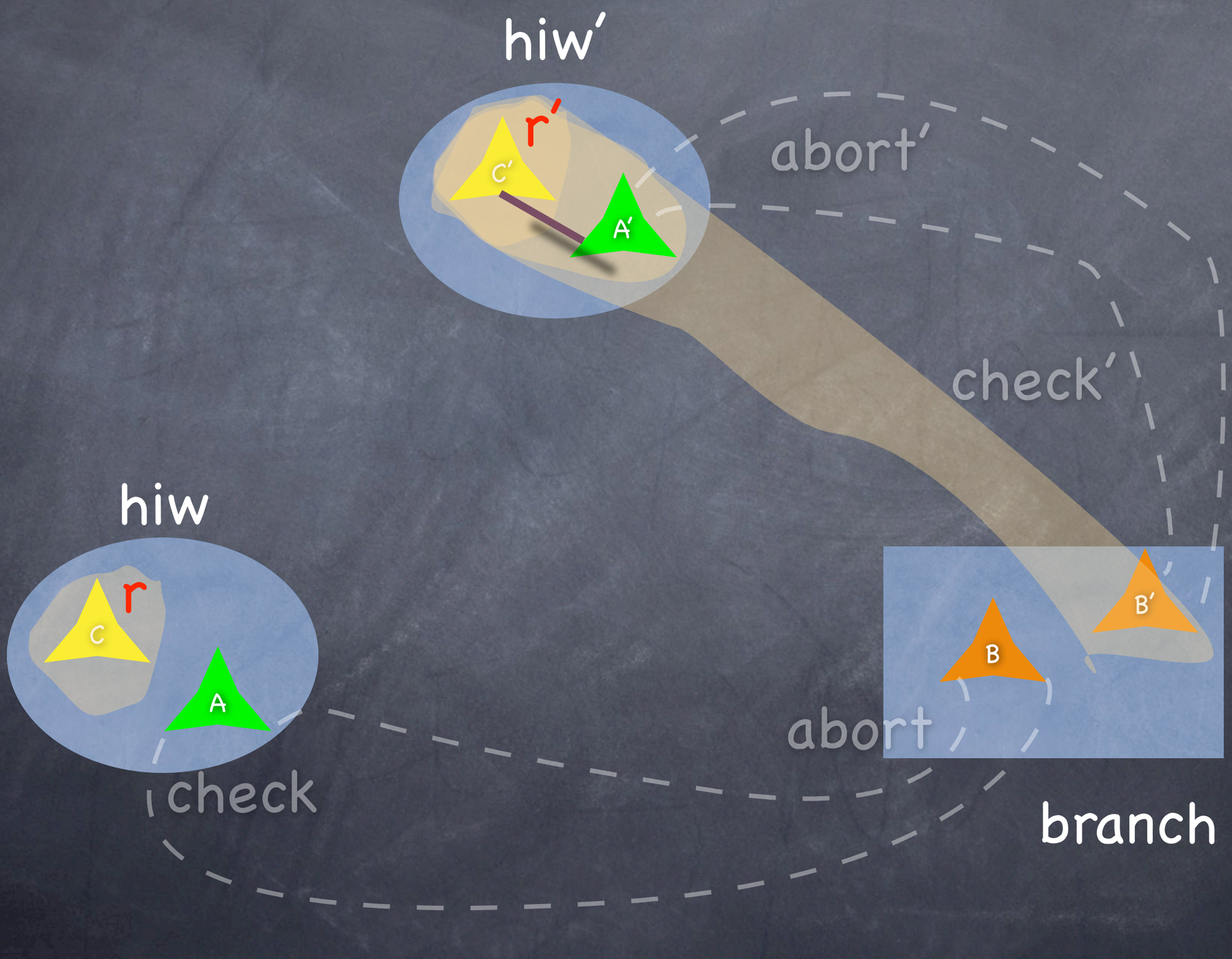
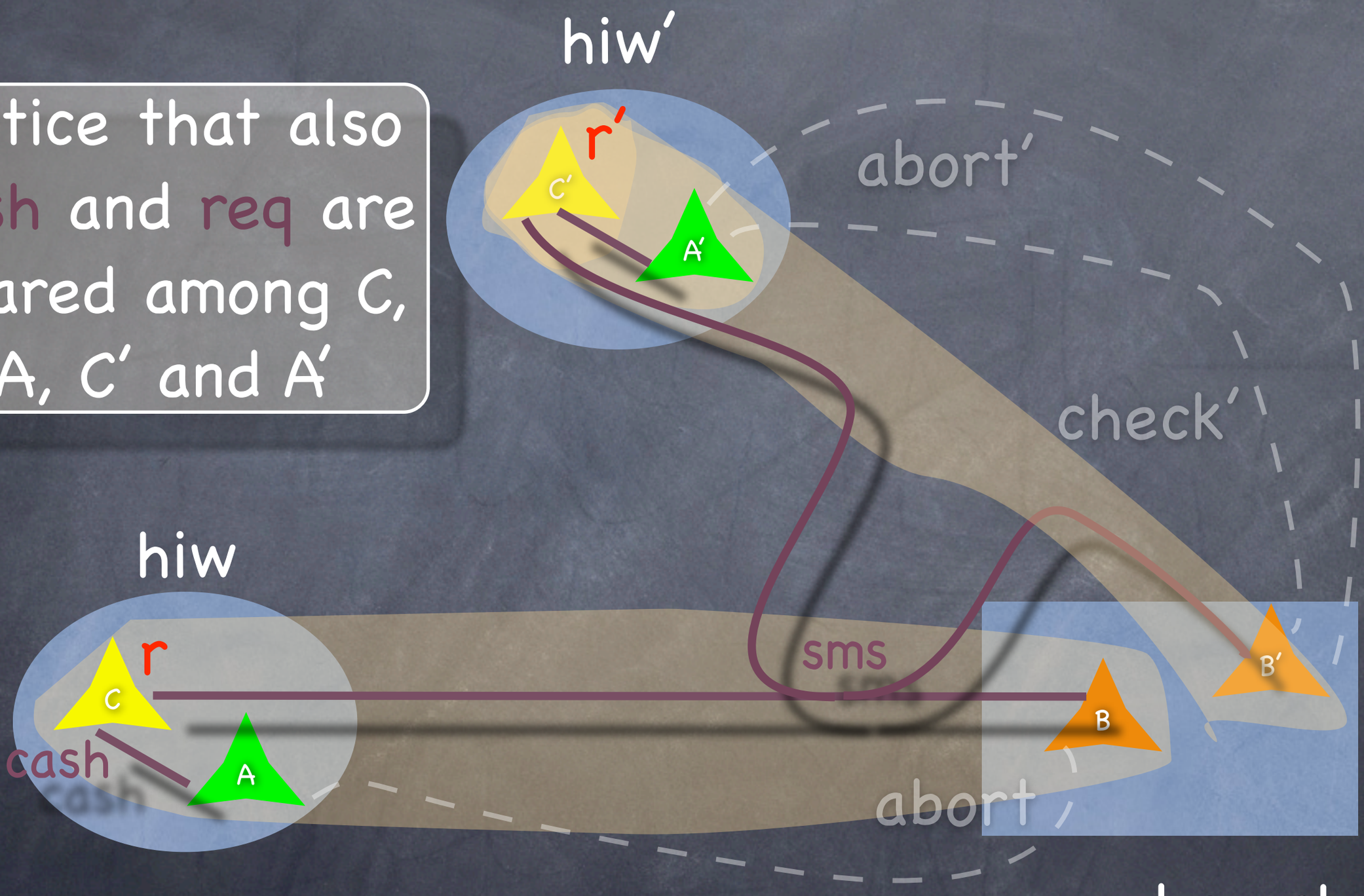
Real life is harder



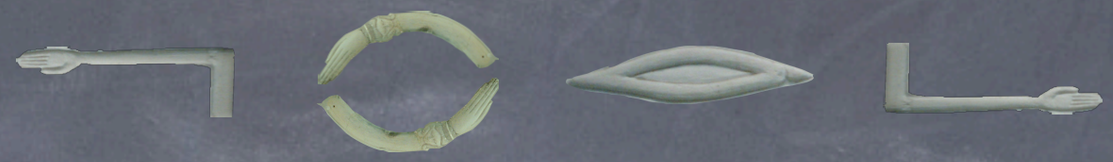


Real life is harder

Notice that also cash and req are shared among C, A, C′ and A′



Play time



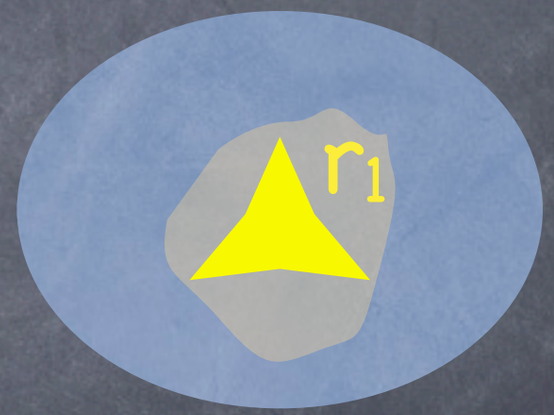
$l :: s \Rightarrow \mathsf{merge}\ e.\ \overline{start}.\ \mathsf{rec}\ X.(\mathsf{merge}\ e.X)$

|

$\mathsf{install}[*s \Rightarrow \mathsf{merge}\ e.\overline{start}]$

$l_0 :: \quad r_0 \triangleright \mathsf{invoke}\ s.\ start().\ P$

$l_1 :: \quad r_1 \triangleright \mathsf{invoke}\ s.\ start().\ P$



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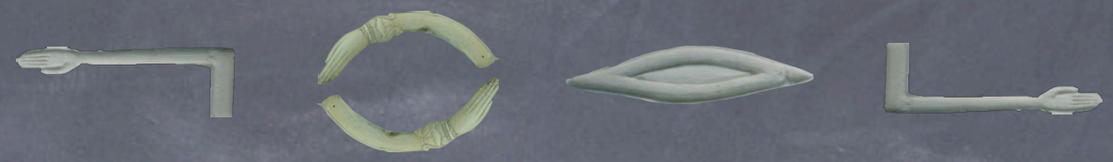


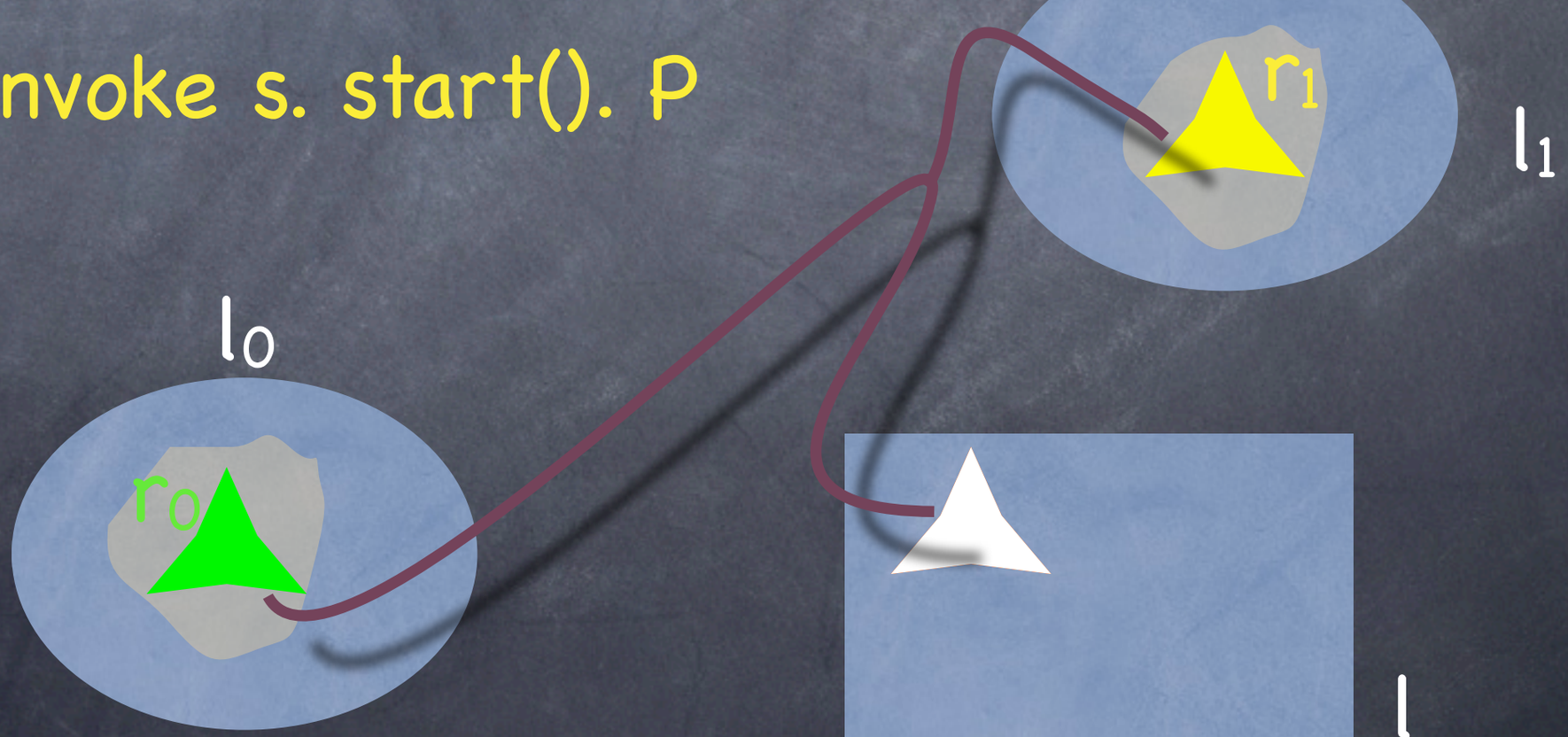
$l :: s \Rightarrow \text{merge } e.\ \overline{start}.\ \text{rec } X.(\text{merge } e.X)$

|

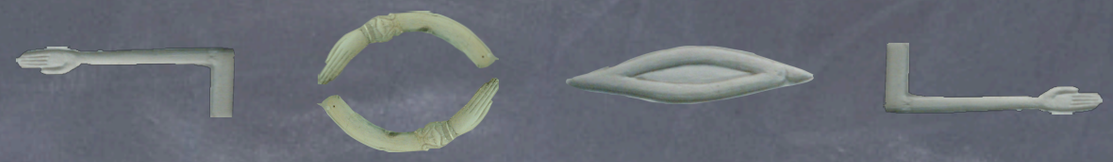
$\text{install}[*s \Rightarrow \text{merge } e.\overline{start}]$

$l_0 :: \quad r_0 \triangleright \text{invoke } s.\ start().\ P$

$l_1 :: \quad r_1 \triangleright \text{invoke } s.\ start().\ P$



Play time



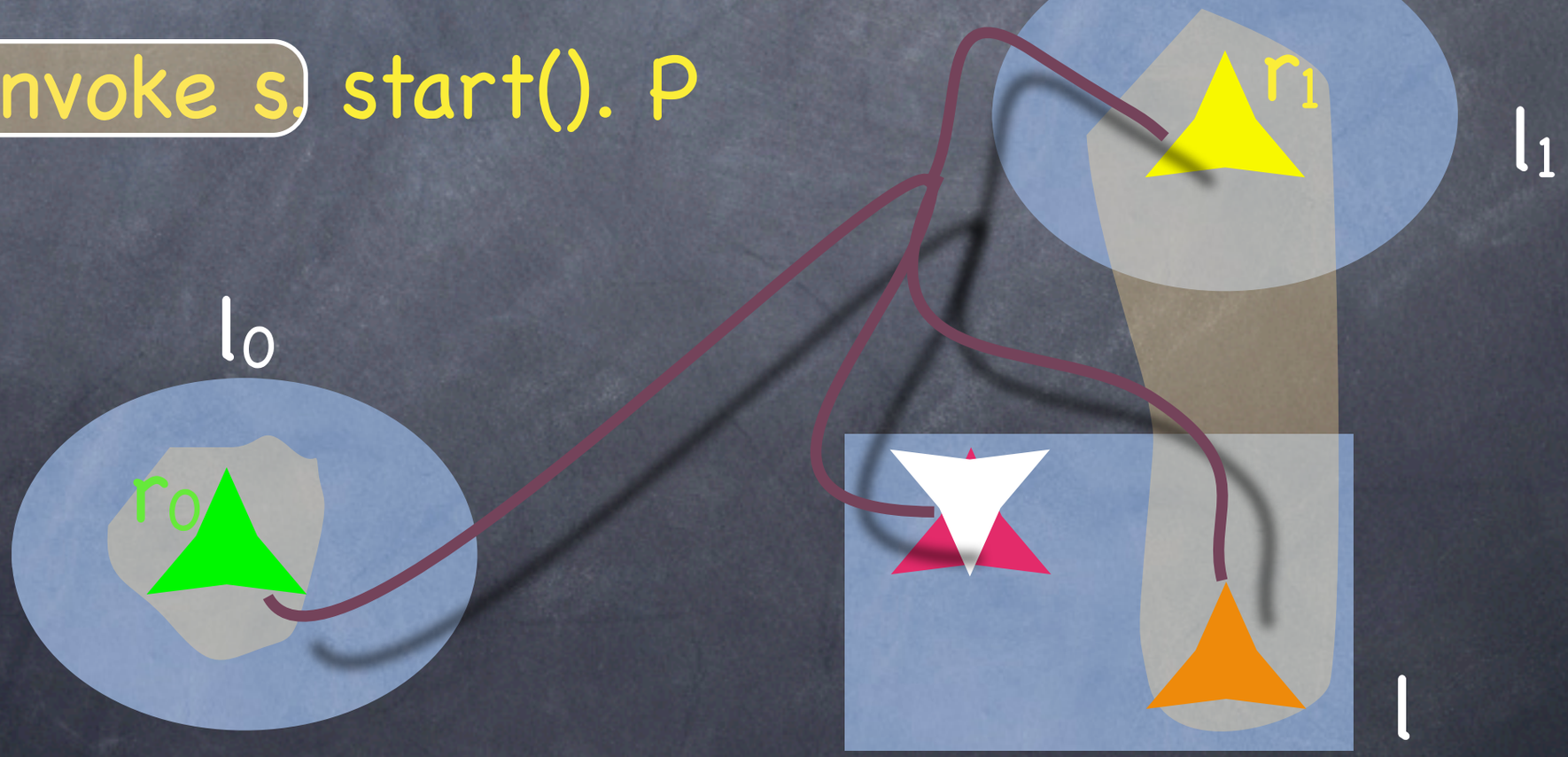
l :: s => merge e. $\overline{\text{start}}$. rec X.(merge e.X)

|

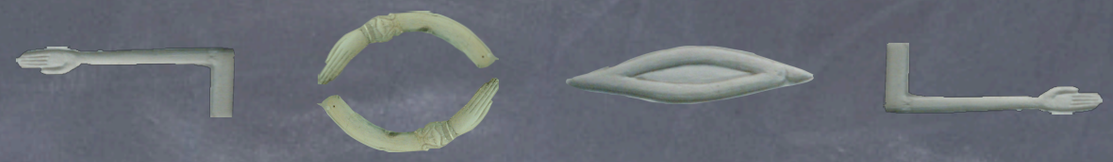
install [*s => merge e.$\overline{\text{start}}$]

l_0 :: r_0 ▷ invoke s. start(). P

l_1 :: r_1 ▷ invoke s. start(). P



Play time



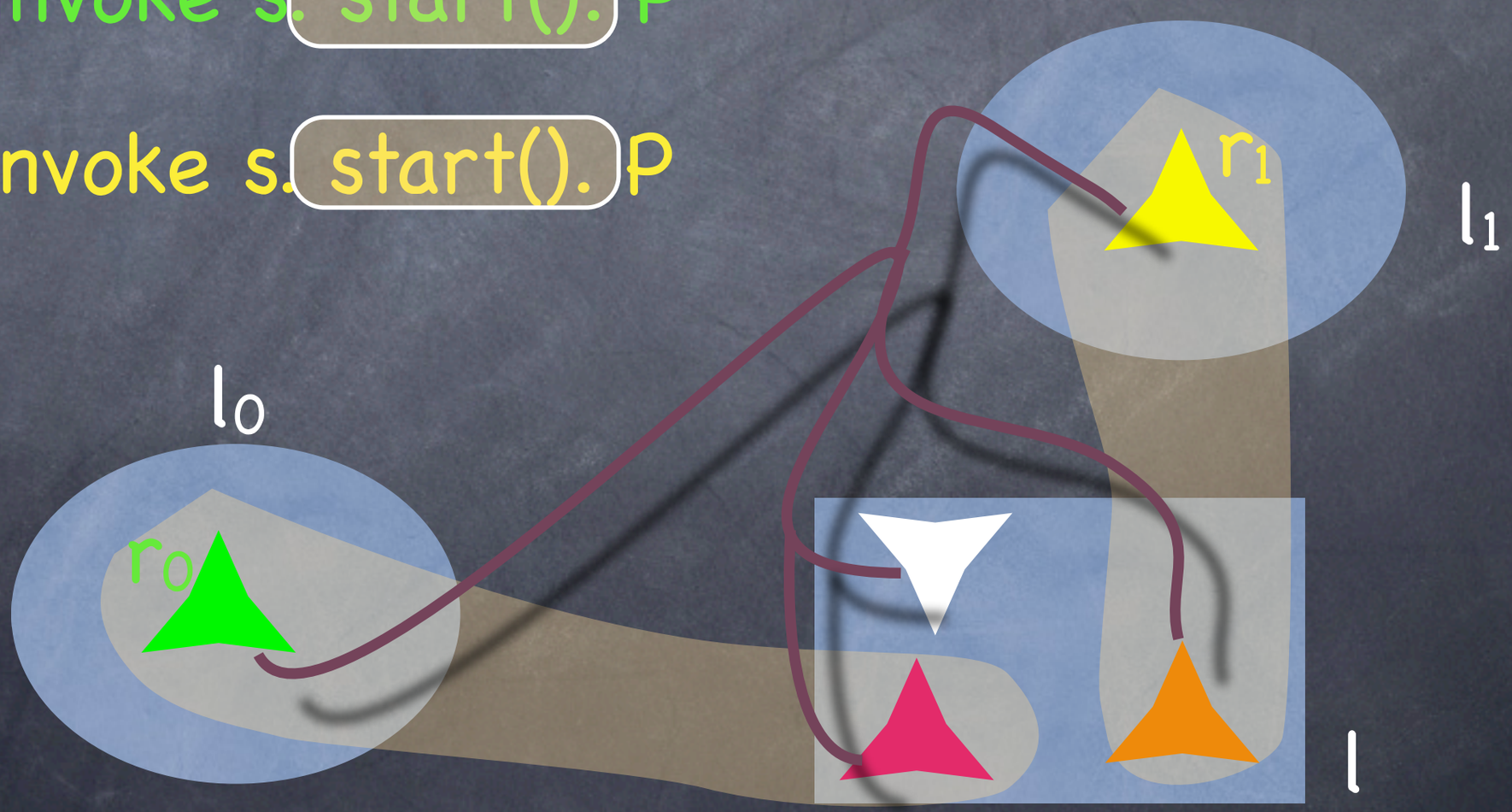
$l :: s \Rightarrow \mathsf{merge}\ e.\ \overline{start}.\ \mathsf{rec}\ X.(\mathsf{merge}\ e.X)$

|

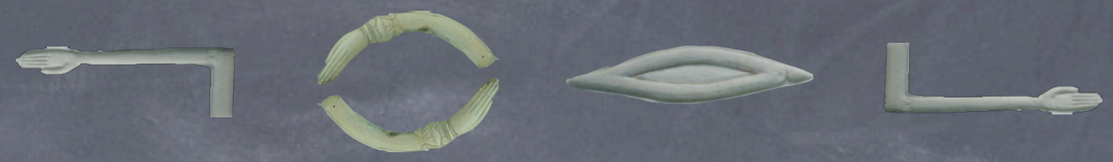
$\mathsf{install}\ [{}^{*}s \Rightarrow \mathsf{merge}\ e.start]$

$l_0 :: \quad r_0 \triangleright \mathsf{invoke}\ s.\ start().\ P$

$l_1 :: \quad r_1 \triangleright \mathsf{invoke}\ s.\ start().\ P$



Play time



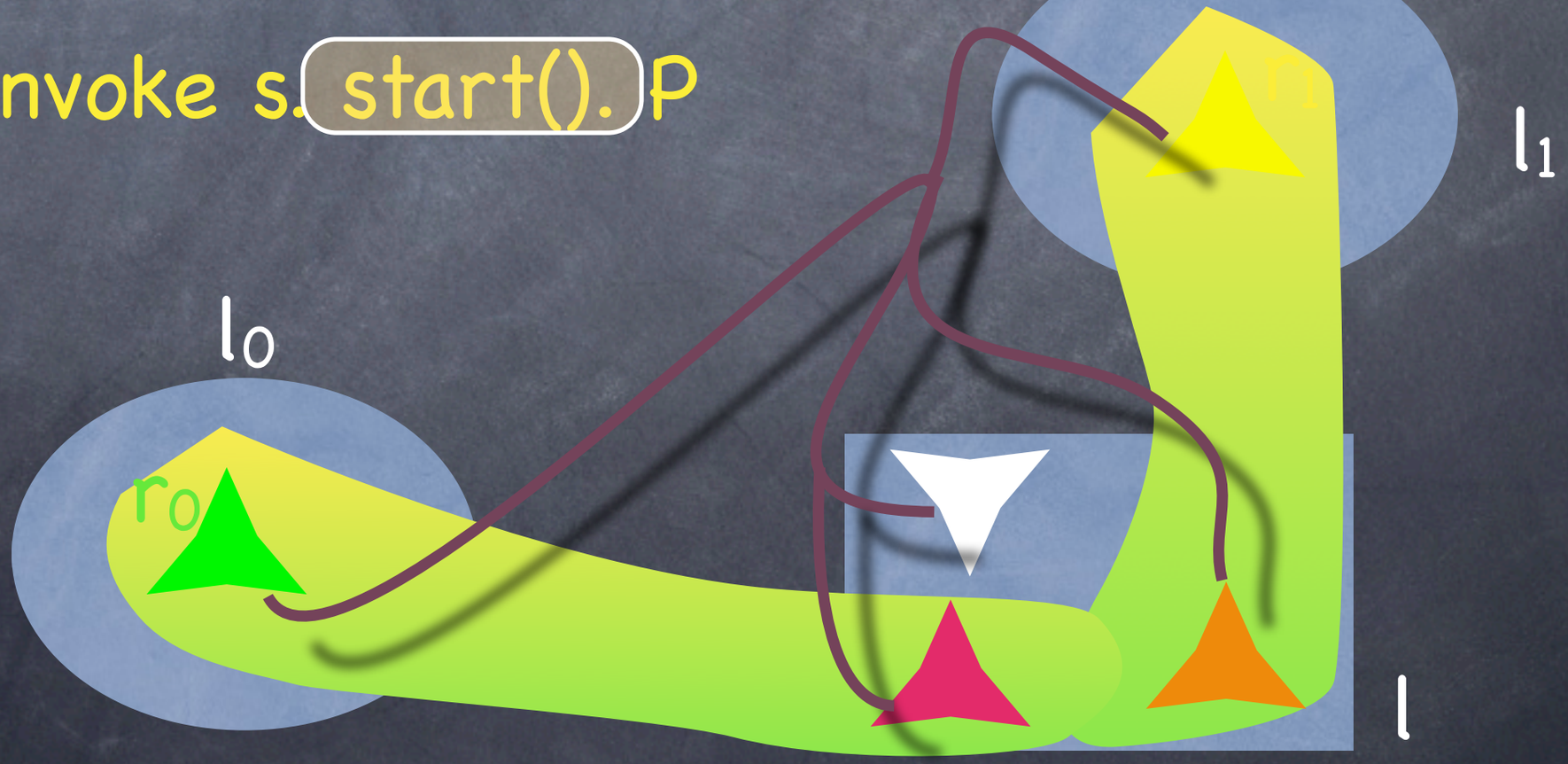
$l :: s \Rightarrow$ merge $e.\ \overline{start}.$ rec $X.$(merge $e.X$)

|

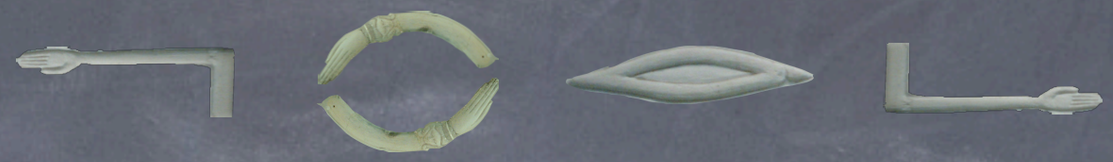
install [*$s \Rightarrow$ merge $e.\overline{start}$]

$l_0 ::$ $r_0 \triangleright$ invoke $s.$ start(). P

$l_1 ::$ $r_1 \triangleright$ invoke $s.$ start(). P



Play time

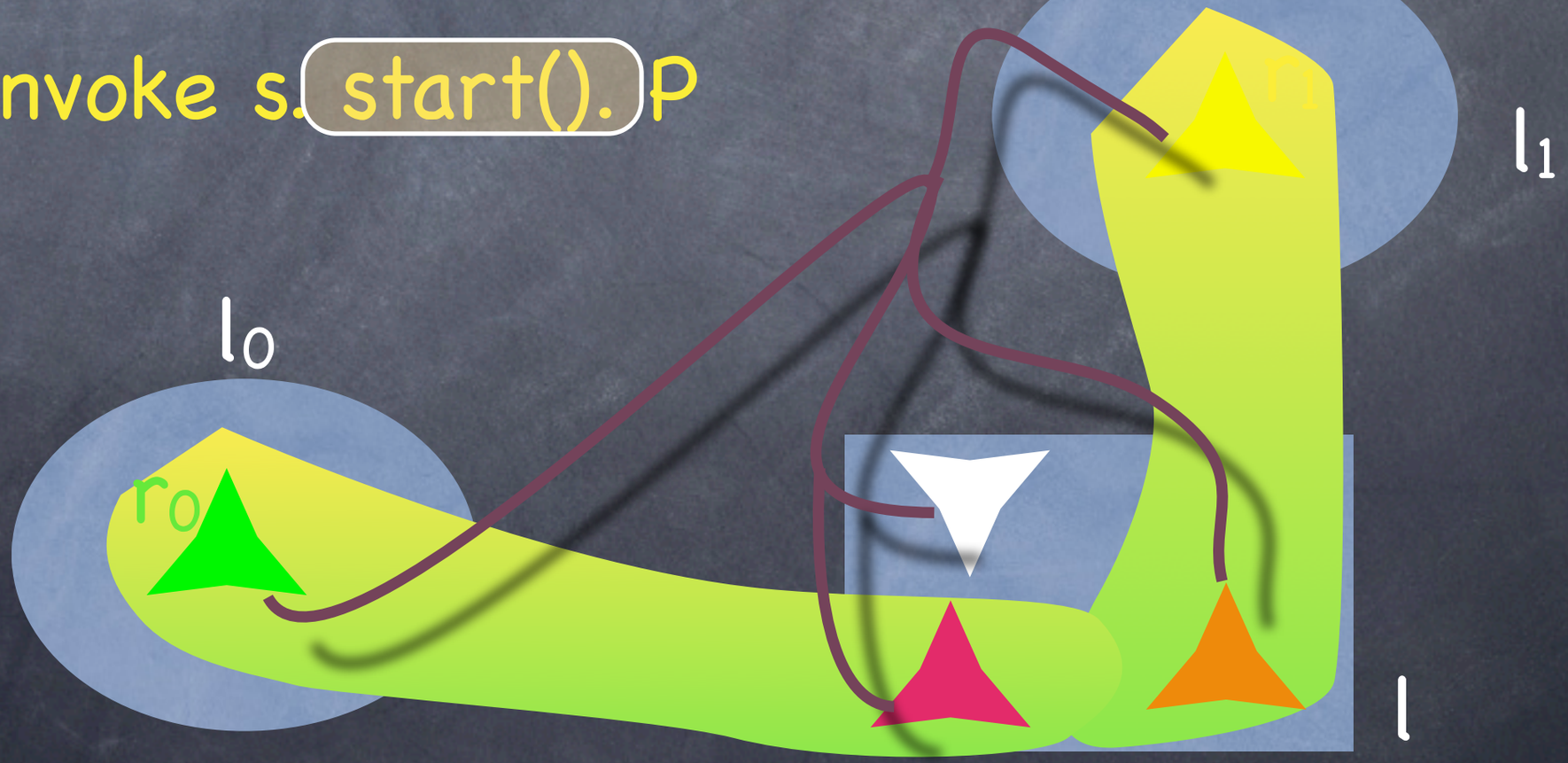


l :: s => merge e. start. rec X.(merge e.X)

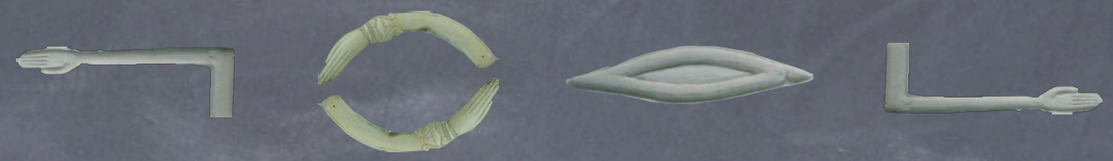
install [*s => merge e.start]

l_0 :: r_0 ▷ invoke s. start(). P

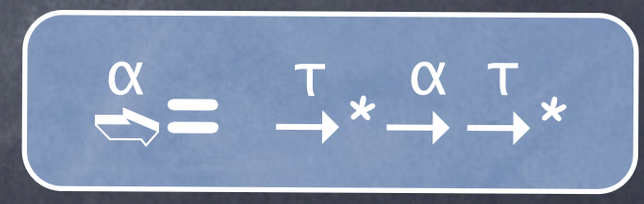
l_1 :: r_1 ▷ invoke s. start(). P



μse bisimulation

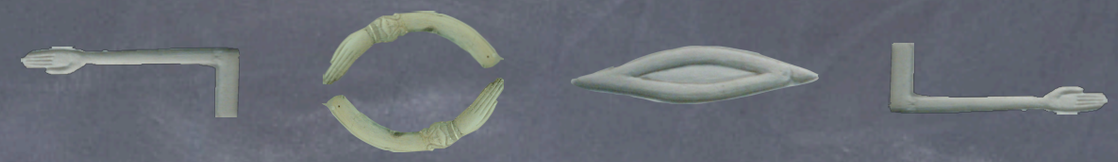


- A binary relation B on μse systems is a weak bisimulation if
  - B is symmetric
  - whenever $(S, T) \in B$, for each transition $S \xrightarrow{\alpha} S'$ such that $bn(\alpha) \cap fn(T) = \varnothing$, there is a transition $T \stackrel{\alpha}{\Rightarrow} T'$ and $(S', T') \in B$



- Bisimilarity is the largest bisimulation

Bisimulation at work



Specification

$$l :: *a \Rightarrow data(\mathtt{x}).\overline{ret}\ \mathtt{fun}(\mathtt{x})$$

Implementation 1

$$l :: (\nu a_1, a_2)\big((\nu av)(*a \Rightarrow av?(u).\mathsf{invoke}\ u) \mid$$

$$\mathrm{rec}\ X.av!a_1.X \mid \mathrm{rec}\ X.av!a_2.X$$

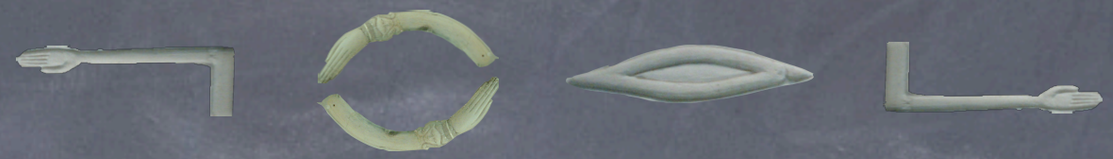
$$*a_1 \Rightarrow data(\mathtt{x}).\overline{ret}\ \mathtt{fun}(\mathtt{x}) \mid *a_2 \Rightarrow data(\mathtt{x}).\overline{ret}\ \mathtt{fun}(\mathtt{x})\big)$$

Implementation 2

$$(\nu e)l :: a \Rightarrow \mathrm{rec}\ Y.(\mathsf{merge}\ e.\mathsf{install}[a \Rightarrow Y]) \mid$$

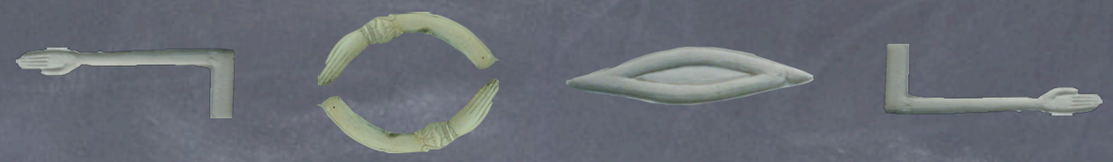
$$\mathrm{rec}\ X.(\nu r)r \rhd \mathsf{merge}\ e.(data(\mathtt{x}).\overline{ret}\ \mathtt{fun}(\mathtt{x}) \mid X)$$

Conclusions



- Bonelli, Compagnoni (TGC07)
  - correspondence assertions to relate many 2-party sessions
- Carbone, Honda, Yoshida (POPL08)
  - statically fixed number of participants
  - delegation
  - (distributed) randez-vous
- Caires, Viera, Seco (TR-07) conversation calculus
  - exception handling
  - nesting of sessions
- Sensoria's SCC
  - similar primitive for service invocation
  - only 2-party sessions
  - on service invocation, both client and service instance are in a freshly generated session

Future directions



- Session types for controlling progress properties of multiparty sessions (conditional liveness)
- "Sophisticated" communication primitives (e.g., multi/broad-cast)
- Implementation
  - Clustering P2P networks with *μse*'s primitives
- Closing session
  - session nesting used only for controlling intra-session communication: $s\triangleright(P|Q)\ e\ s\triangleright(P \mid s\triangleright Q)$
  - exception hangling (?)