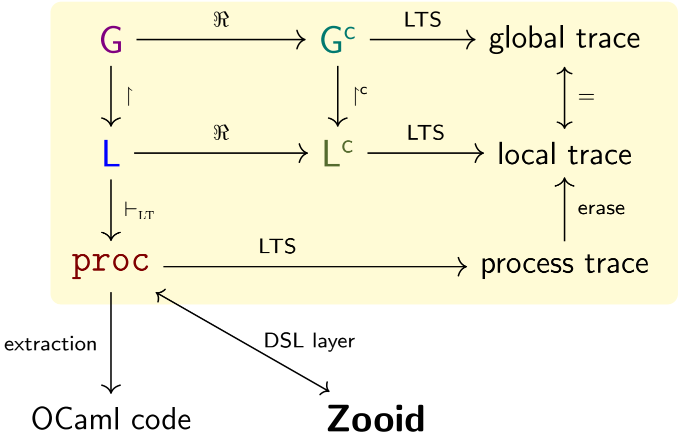
Act II

Smol-Zooid: multiparty with shallower embedding

Goals

1. Certifying **individual** processes of a **distributed system**
2. Extracting runnable code
3. Avoiding complex formalisations of binders, whenever possible

Overview



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erase
proc
LTS
process trace
extraction
DSL layer
OCaml code
Zooid

Smol Zooid

- We combine **shallow/deep embeddings** of binders
  - We use DeBruijn indices for the deeply embedded binders
- SZooid constructs are **well-typed by construction**
- We leverage **Coq code extraction** mechanism
- For simplicity, SZooid does not cover choices

Core Processes

In: http://github.com/emtst/gentleAdventure

```
Inductive proc :=
| Inact | Rec (e : proc) | Jump (X : nat)
| Send (p : participant) {T : type}
    (x : interp_type T) (k : proc)
| Recv (p : participant) {T : type}
   (k : interp_type T -> proc)

| ReadIO {T : type} (k : interp_type T -> proc)
| WriteIO {T : type} (x : interp_type T) (k : proc).
```

Payload Types

We need to define a type for payload types:

- We need a decidable equality on payload types
- We need a decidable equality on payload values

```
Inductive type := Nat | Bool | ...
Definition interp_type : type -> Type := ...
```

Semantics: events

The semantics is an LTS:

- the labels are the **communication events**
- it is parameterised by a **payload interpretation function**
- traces are obtained as the greatest fixpoint of the LTS step

```
Inductive action := a_send | a_recv.
Record event interp_payload :=
  { action_type  : action;
    subj         : participant;
    party        : participant;
    payload_type : type;
    payload      : interp_payload payload_type
  }
```

Semantics: Recursion Variables and I/O

```
p_unroll : proc -> proc
```

`p_unroll` exposes the first communication action in a process:

- "runs" any I/O action
- unfolds recursion

```
Definition p_unroll : proc -> proc := ...
```

Semantics: step

The step of the LTS is defined as a **function**:

```
Definition step' e E :=
  match e with
  | Send p T x k =>
    if (action_type E == a_send) && (party E == p) &&
       (eq_payload (payload E) x)
    then Some k else None
  | Recv p T k => ...  | _ => None
  end.
Definition step e := step' (p_unroll e).
```

Local Types

We introduce a typing discipline that associates processes with **local types**, that characterise their communication behaviour:

```
Inductive lty :=
  | l_end
  | l_jump (X : nat)
  | l_rec (k : lty)
  | l_send (p : participant) (T : type) (l : lty)
  | l_recv (p : participant) (T : type) (l : lty).
```

Type System

```
Inductive of_lty : proc -> lty -> Prop :=
| lt_Send    p T k L x :
    of_lty k L -> of_lty (@Send p T x k) (l_send p T L)
| lt_ReadIO  T k L :
    (forall x, of_lty (k x) L) -> of_lty (@ReadIO T k) L
| ...
.
```

Smol Zooid: Smart Constructors (I)

- It would be tedious to type up both a local type and a process
- Users would need to provide a proof that processes are well-typed

We define **SZooid** (Smol Zooid), to write well-typed processes by construction, avoiding repetition.

Smol Zooid: Smart Constructors (and II)

```
Definition SZooid L := { p | of_lty p L}.

Definition z_Send  p T x L (k : SZooid L)
   : SZooid (l_send p T L)
   := exist _ _ (lt_Send p x (proj2_sig k)).
...
```

Inferring Local Types

SZooid constructs fully determine their types from their inputs, so we can ask Coq to infer local types associated with SZooid terms:

```
Definition AZooid := { L & SZooid L }.
```

Subject Reduction

```
Theorem preservation (e : proc) (L : lty)
    (H : of_lty e L) (E : rt_event) :
  forall e',
    step e E = Some e' ->
      exists L', lstep L (ev_erase E) = Some L' /\
                 of_lty e' L'.
```

Extraction

- We convert `proc` to function calls in an **ambient monad**
- We extract the monadic code to OCaml
- The ambient monad needs to be implemented in OCaml
- Processes are extracted using Higher-Order modules, so it is straightforward to change the underlying transport
- **Remark:** SZooid does not provide an implementation of the ambient monad, but Zooid does, using TCP/IP sockets: `https://github.com/emtst/zooid-cmpst`

Extraction Module

```
Module ProcExtraction (MP : ProcessMonad).
  Fixpoint extract_proc (d : nat) (p : proc) : MP.t unit
    := match p with
       | Send p T x k
         => MP.bind (MP.send T p x)
                    (fun=> extract_proc d k)
       ...
End ProcExtraction.
```

Example Extraction

```
Module  ALICE (MP : ProcessMonad) : PROCESS(MP).
  Module PE := ProcExtraction(MP).
  Definition proc :=
    Eval compute in PE.extract_proc 0 alice.
End ALICE.

Extraction ALICE.
```

Summary

- We have seen how to encode a small calculus of Multiparty Processes, with a basic type system
- **Next: how do we relate traces of individual processes to a larger system?**