Compilation of LOTOS Abstract Data Types

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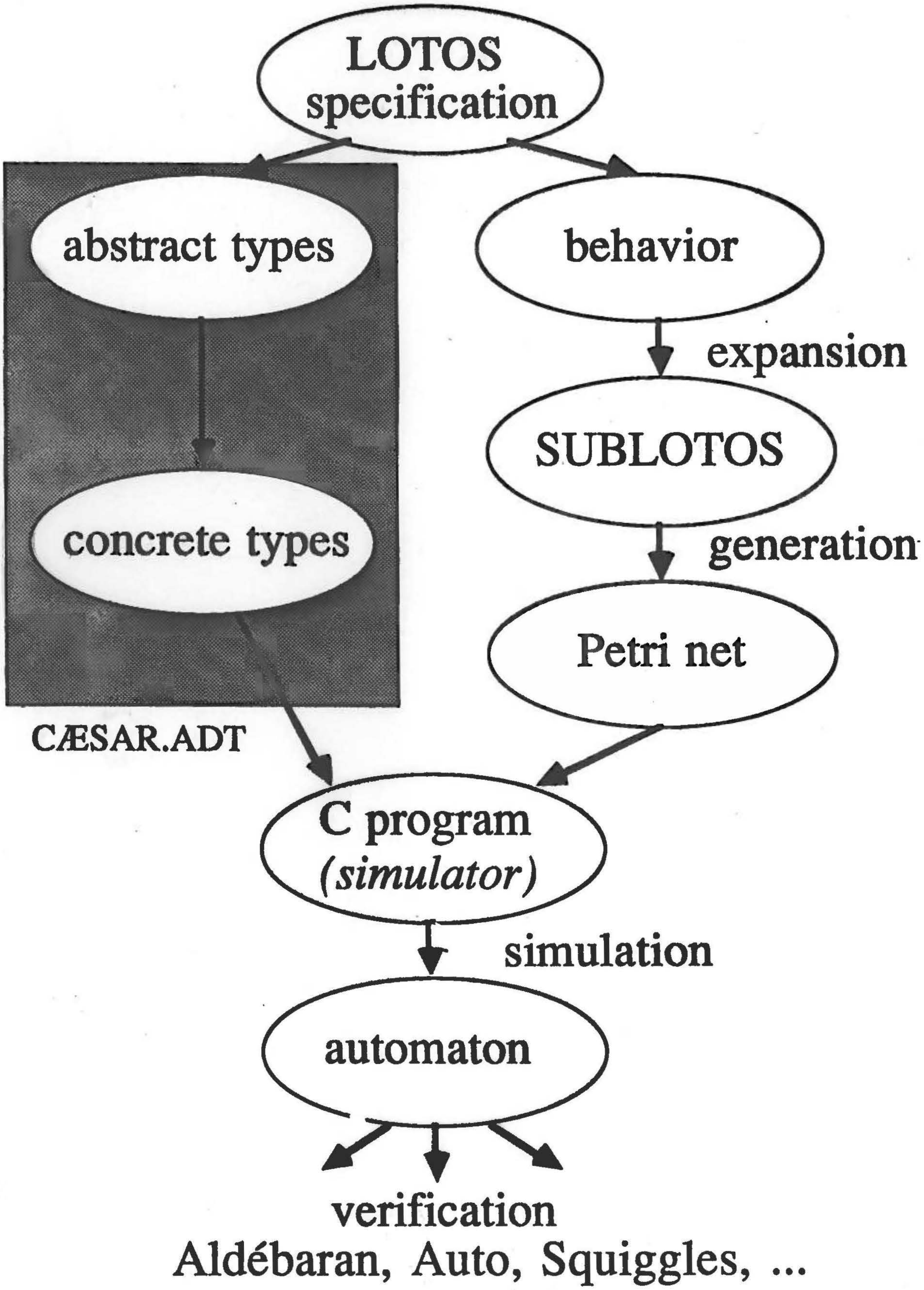
CÆSAR and CÆSAR.ADT



Compiling ADTs

Problem

Executing LOTOS abstract data type specifications

Existing solutions

1. dynamic term rewriting
2. code generation for rewriting machines [Wolz-Boehm]

Our approach

1′. static compilation

- performing computations at compile-time
- no pattern-matching, unification, backtracking, ... at run-time

2′. target language: C

Issues

- **data representation**
  LOTOS sorts → C týpes
- **translation of equations into deterministic code**
  LOTOS operations → C functions

[Schnoebelen, "Refined Compilation of Pattern-Matching for Functional Languages", SCP, 1988]

Example

- taken from the transport service [ISO-8072]
- history of requests
- transformations:
  - some operations removed: **NonEmpty**, eq, ne
  - one operation introduced: App

```
type TransportServiceBasicTSPRequestHistory is ...
sorts
  History
opns
  NoTReqs :   -> History
  App     :   TSP, History -> History
  Append  :   TSP, History -> History
  Empty   :   History -> Bool
eqns
  forall t, t1, t2 :  TSP,
        h, h1, h2 :  History
  ofsort History
    not (IsTReq (t)) => Append (t, h)  = h;
    IsTReq (t)       => Append (t, h)  = App (t, h);
  ofsort Bool
    Empty (NoTReqs)    = true;
    Empty (App (t, h)) = Empty (h) and not (IsTReq (t));
endtype
```

Implementing data

1. **apply flattening to the specification**

2. **treat each sort S in turn**

Here: $S =$ `History`

3. **consider the set of operations with result of sort S**

Here:

```
NoTReqs  :  -> History
App      :  TSP, History -> History
Append   :  TSP, History -> History
```

4. **divide this set in two parts**

- **constructors**: not completely defined by the equations

- **non-constructors** completely defined by the equations
  non-constructor operations can always be rewritten

Here:
⋆ constructors: `NoTReqs` and `App`
⋆ non-constructors. `Append`

```
not (IsTReq (t)) => Append (t, h) = h;
IsTReq(t)        => Append (t, h) = App (t, h);
```

Constructor identification can be done:

- by hand (as in CÆSAR.ADT)
- automatically [Comon]

5. choose an implementation for values

{ values of sort S } $\subseteq$ { terms made only of constructors }

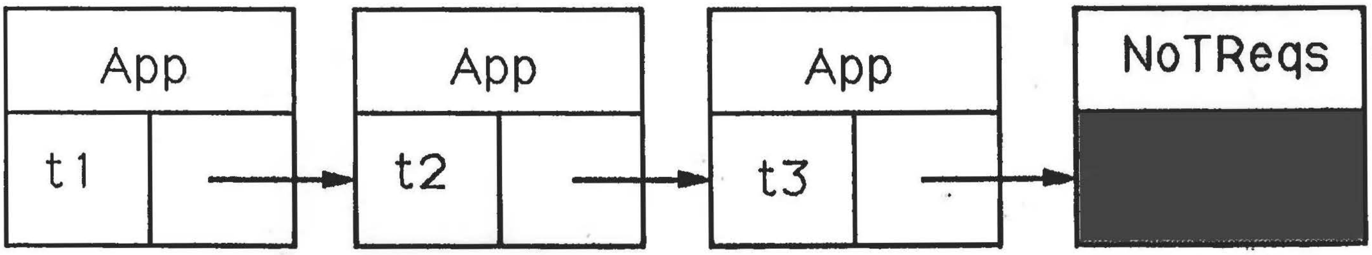
Here:

```
NoTReqs  :  -> History
App      :  TSP, History -> History
```

Syntactical definition:

```
<History> ::= NoTReqs | App (<TSP>, <History>)
```

Example: `App (t1, App (t2, App (t3, NoTReqs)))`



Representation with C data structures:

general: pointers and discriminated unions:

- `<App, t, h>`
- `<NoTReqs>`

optimized: no discriminant

- `<t, h>`
- `NULL`

Compiling operations

Implementation of constructors

- allocation and initialization of a memory cell

```
                ⎧ create a cell <App, t, h>
App (t, h) =    ⎨
                ⎩ return a pointer to it
```

Implementation of non-constructors

- pattern-matching algorithm
- generation by induction on the set of rules

```
Empty (NoTReqs)      = true;
Empty (App (t, h))   = Empty (h) and not (IsTReq (t));
```

⇓

```
                 ⎧ if h0 has the form <NoTReqs> then
                 ⎪   true
Empty (h0)   =   ⎨ else if h0 has the form <App, t, h> then
                 ⎩   Empty (h) and not (IsTReq (t))
```

```
not (IsTReq (t)) => Append (t, h) = h;
IsTReq (t)       => Append (t, h) = App (t, h);
```

⇓

```
                     ⎧ if not (IsTReq (t)) then
                     ⎪   h
Append (t, h)   =    ⎨ else if IsTReq (t) then
                     ⎩   App (t, h)
```

Theoretical issues

Restrictions

- equations are **oriented**
- equations must be **left-linear**

```
              f (t, h, h) = Append (t, h)
                            ⇓
        h = h' => f (t, h, h') = Append (t, h)
```

- **equations between constructors** must be removed

Termination

- What happens if the rewriting system does not terminate?
- The generated code loops (unfinite recursive calls).

```
          f (t, h) = Append (t, f (t, h))
                         ⇓

     f (t, h)  = { Append (t, f (t, h))
```

Confluence

- What happens if the rewriting system is not confluent?
- Call-by-value + decreasing priority is assumed.

```
              g (t, NoTReqs) = false;
              g (t, h) = IsTReq (t);
                        ⇓

                 ⎧ if h has the form <NoTReqs> then
                 ⎪   false
   g (t, h)  =   ⎨ else
                 ⎩   IsTReq (t)
```

Conclusion

- LOTOS ADTs can be translated into C libraries
- a prototype tool exists: CÆSAR.ADT
- translation is general
- translation is fast
- generated code is efficient, even optimal for:
  - integer numbers
  - enumerated types
  - tuples (records)
- other applications:
  - LOTOS → ASN.1
    SDL → C