NFMW 1996, Ilkley

A Formally Based Framework for Supporting Design and Analysis of Asynchronous Hardware Systems

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Background

Hardware design:

- enhanced performance, functionality
- speed-to-market

Need:

- fast prototyping
- simulation
- early design analysis

Asynchronous design:

- increased speed
- reduced power
- easier design (compositional)

AMULET microprocessor (Steve Furber, Manchester)

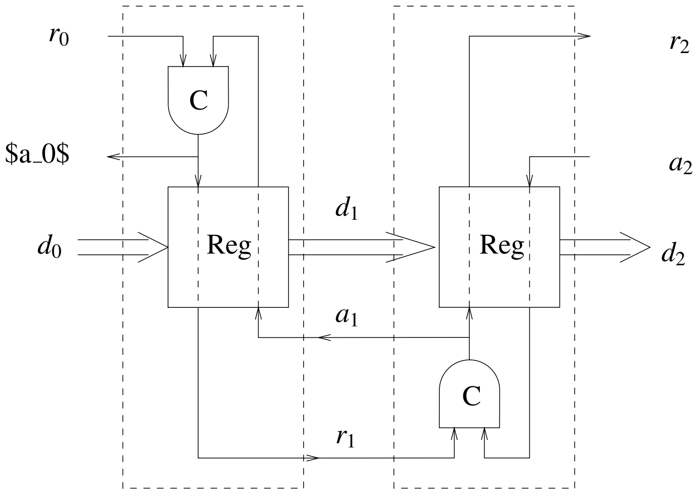
Problems facing asynchronous design:

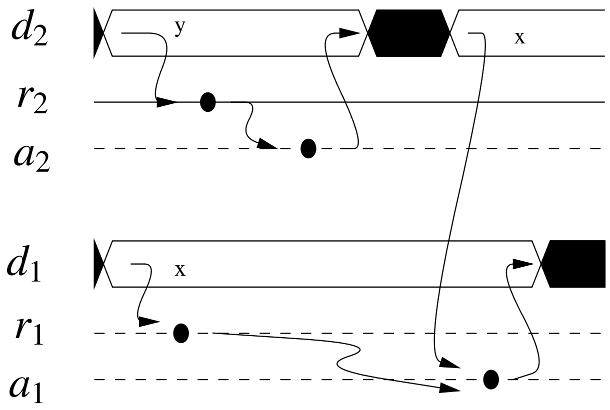
- lack of specialised design tools
- design analysis

Require:

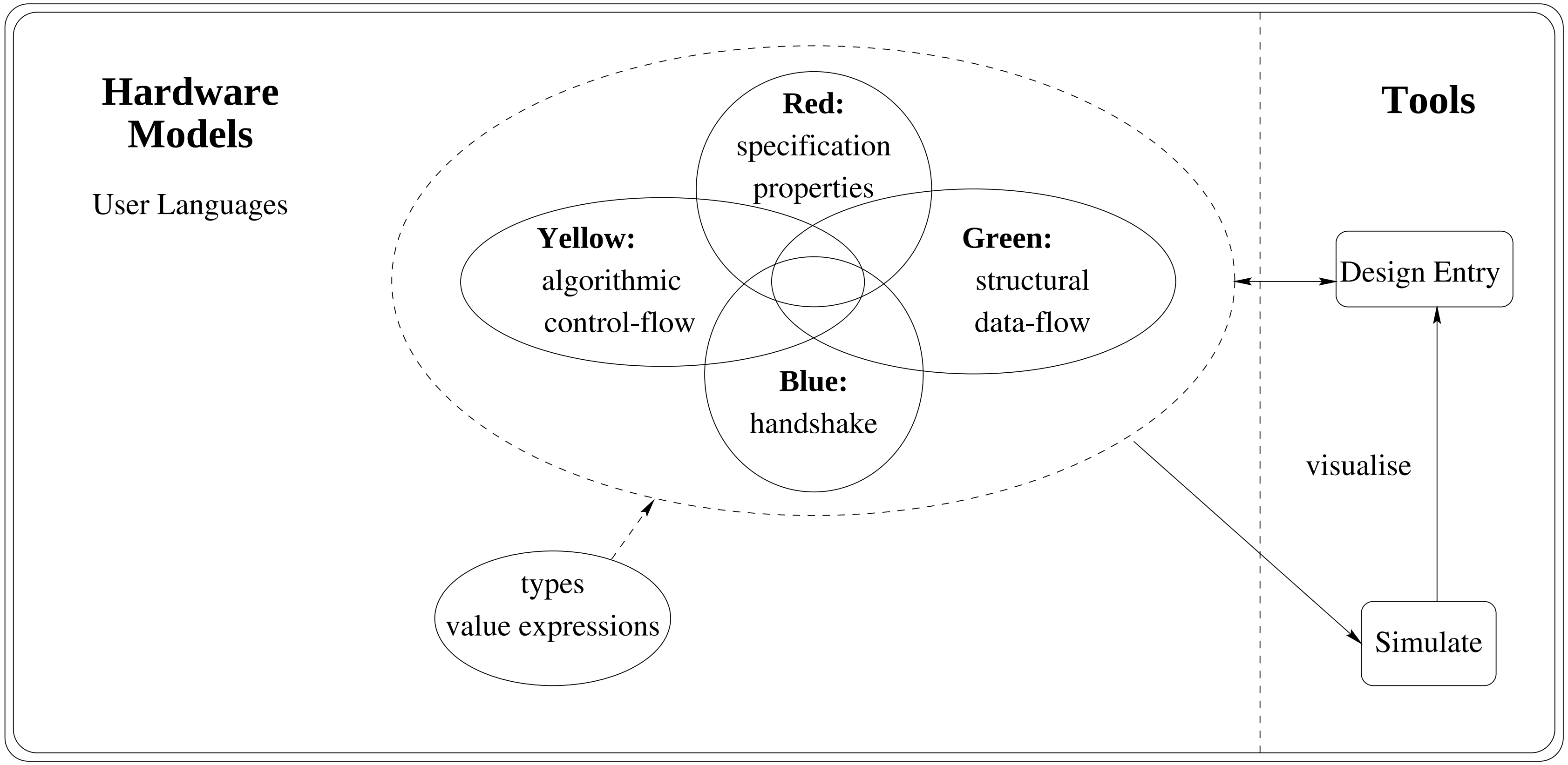
- design methodology
- suitable design representation
- analysis tools
  - deadlock detection
  - high level power, speed estimation
  - functional verification

Micropipelines

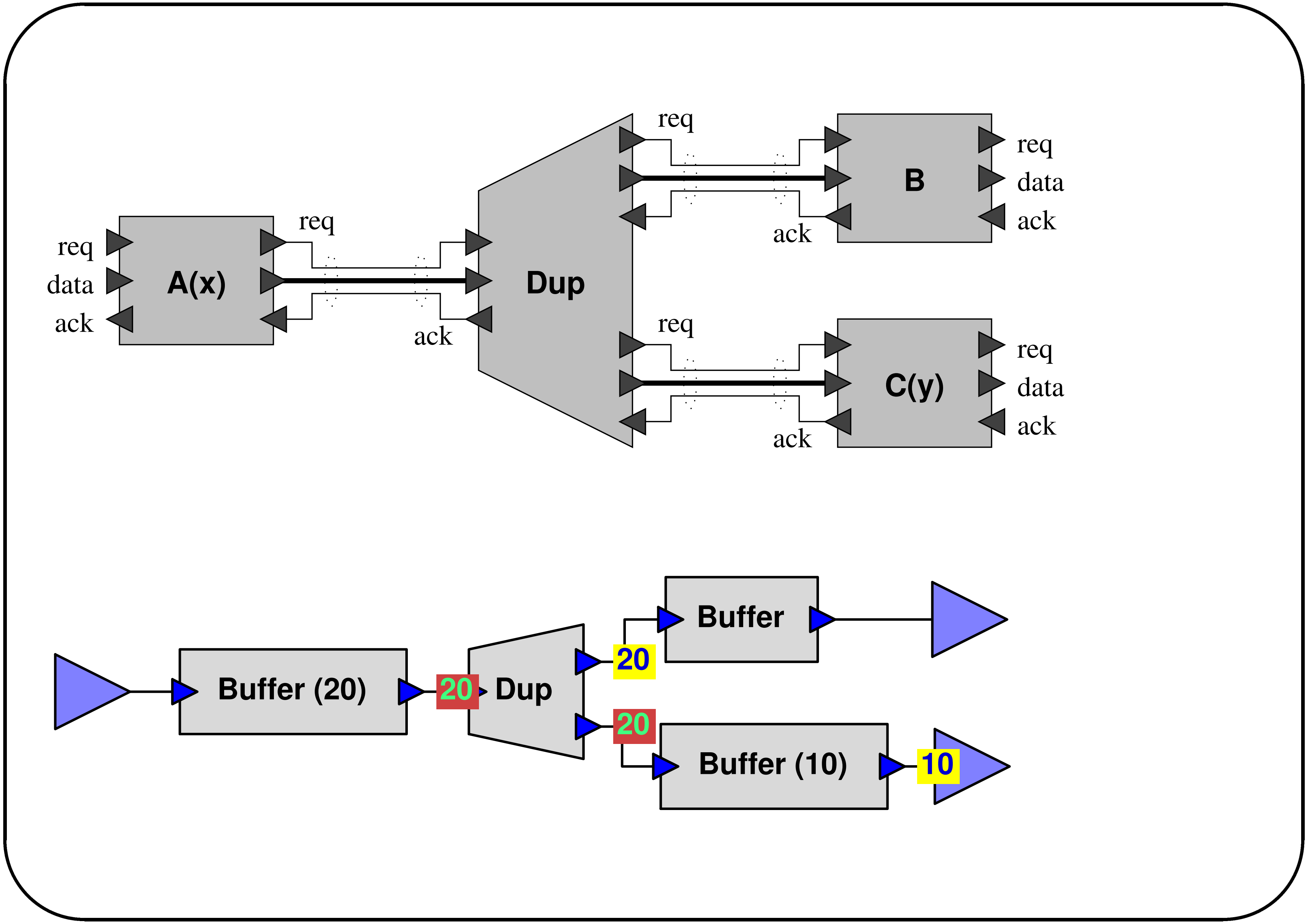




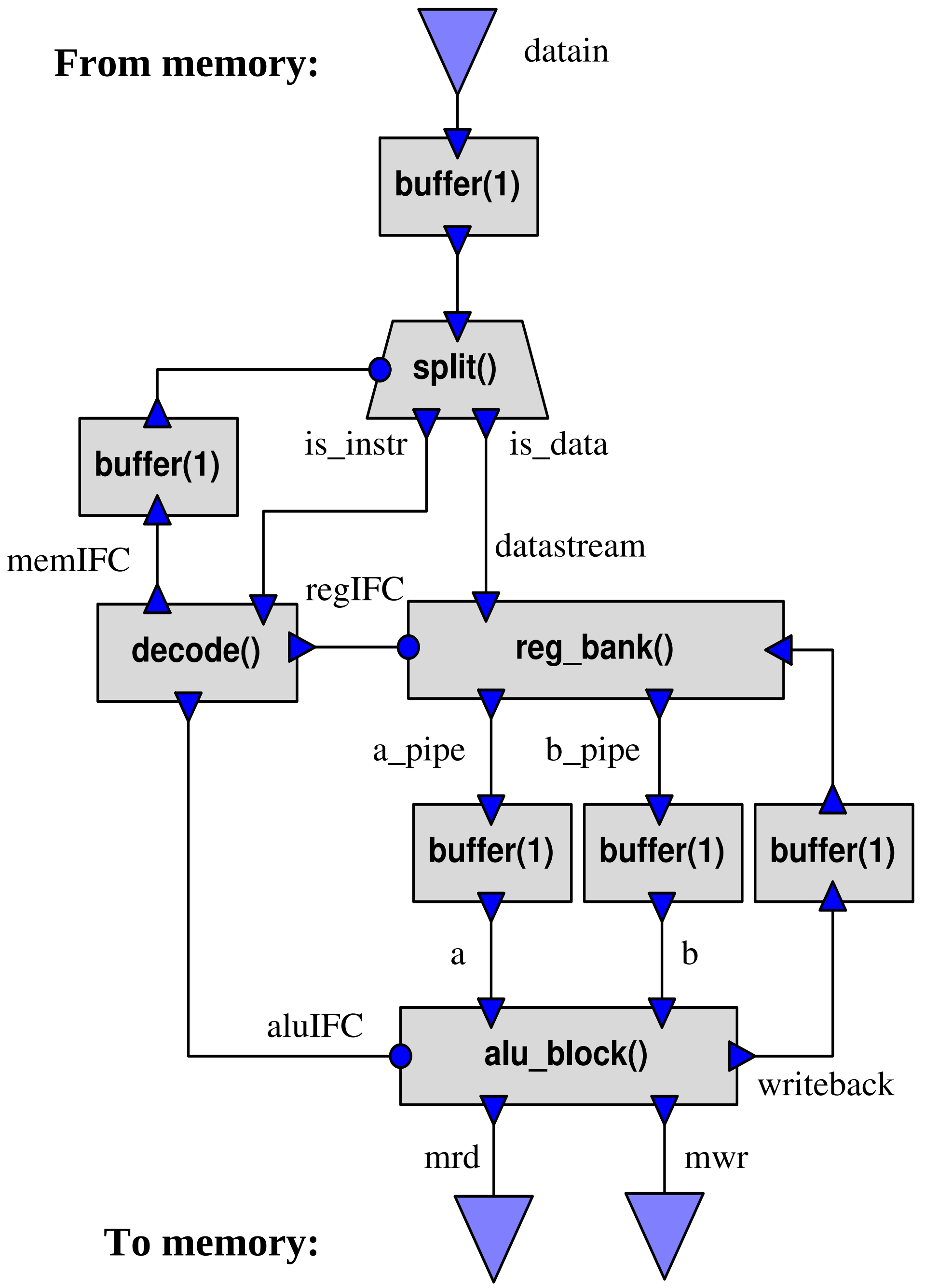
Rainbow Design Framework



- User-oriented language design (AMULET)
- Abstract representation of bundled data
- Mixed-view modelling
- Hierarchical design
- Application-specific


req
data
ack
A(x)
req
ack
Dup
req
ack
B
req
data
ack
req
ack
C(y)
req
data
ack
Buffer (20)
20
Dup
20
Buffer
20
Buffer (10)
10

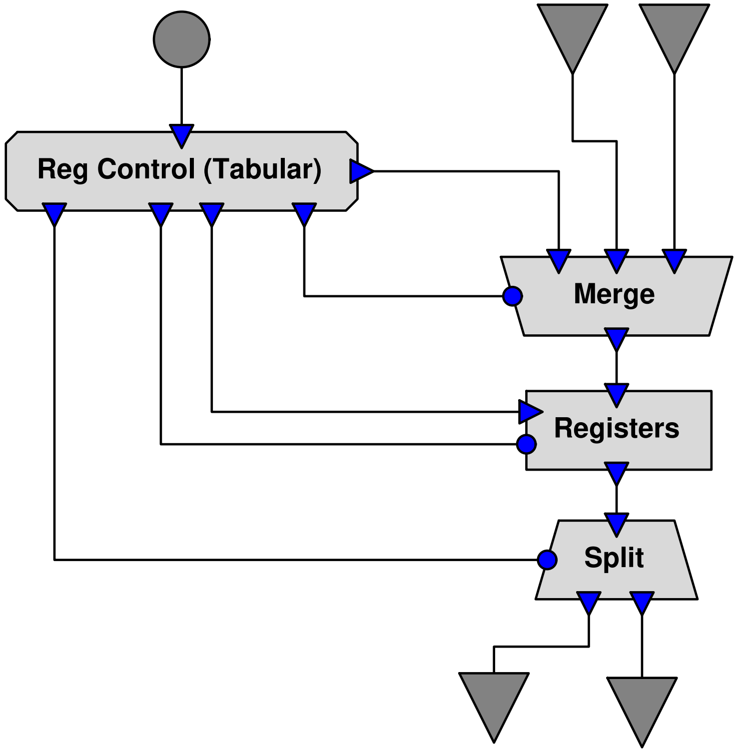
Example: Simple Processor



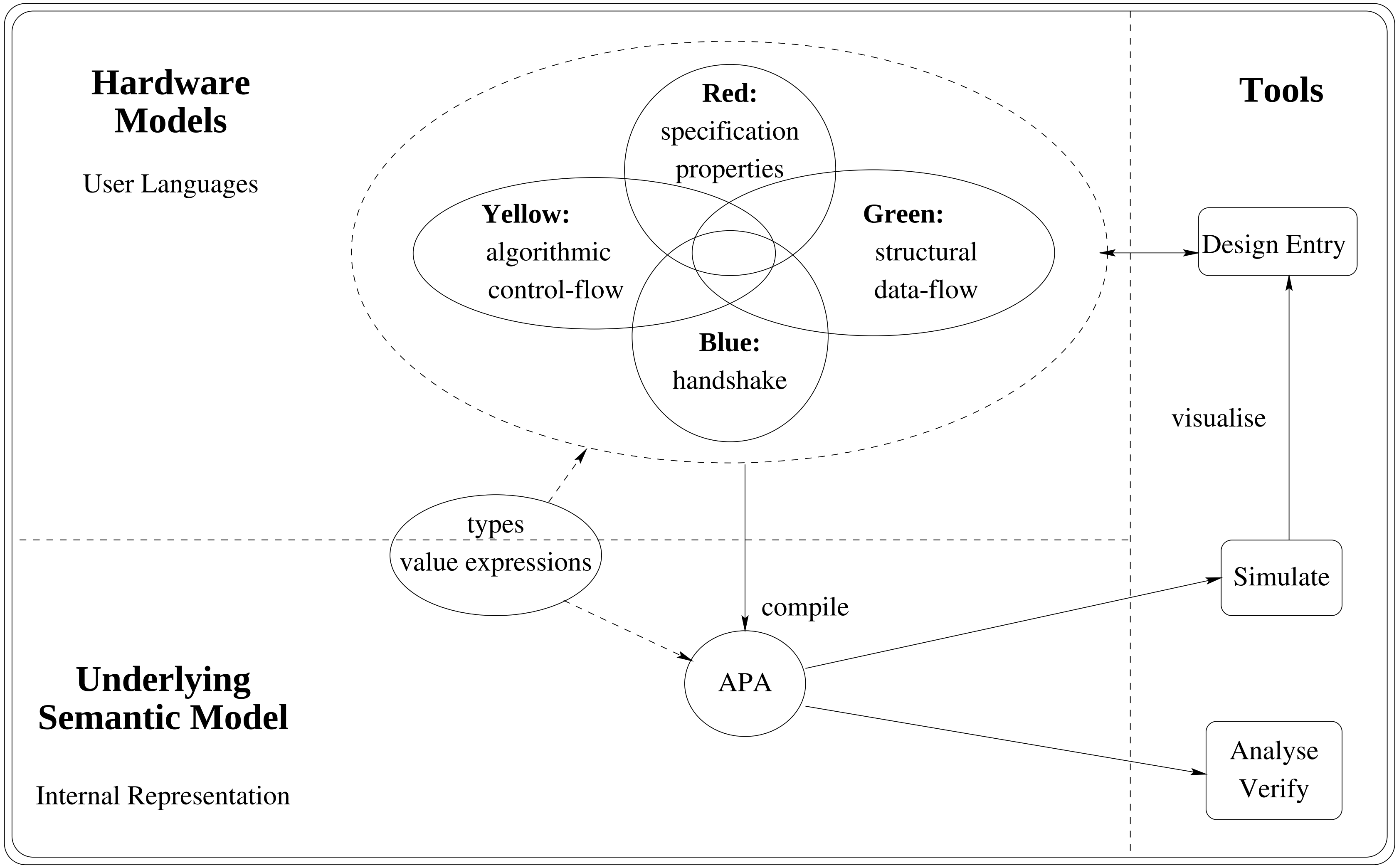
Green Table — ALU:

```
table alu_block (input  aluIFC: aluctrl;
                 input  a,b: val;
                 output mrd: memread;
                 output mwr: memwrite;
                 output writeback: val) = {
    FETCHINC, a,   -  =>  a,    -,      a+1
 or FROMMEM,  a,   b  =>  a+b,  -,      -
 or TOMEM,    a,   b  =>  -,    (a,b),  -

 or ADD,      a,   b  =>  -,    -,      a+b
 or SUB,      a,   b  =>  -,    -,      a-b
 or AND,      a,   b  =>  -,    -,      a/\b
 or CMP,      a,   b  =>  -,    -,      a>b

 or MOV,      a,   -  =>  -,    -,      a
 or NOT,      a,   -  =>  -,    -,      not a
}.
```

- Yellow Decoder: `fetch(); execute(); store()`
- Green sub-network: register bank (textual or schematic)



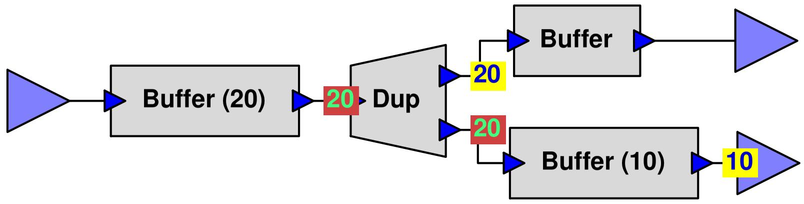
Formal Semantics



APA

- developed from EPA (ELLA Process Algebra)
- complex actions
- bundled dataflow blocks as basic constructs
- Ada-like rendezvous communication primitive
- Rainbow sub-languages map to APA
- transition rule define APA semantics

Example:



$$\dfrac{\mathcal{B}[20] \xrightarrow{[o!20]} \mathcal{B}[20] \qquad \textsf{Dup} \xrightarrow{[i?20]\ /\ o_1!20} \textsf{Dup}_{o_2!20}}{\mathcal{B}[20]\ >>\ \textsf{Dup} \xrightarrow{o_1!20} \mathcal{B}[20]\ >>\ \textsf{Dup}_{o_2!20}}\ \boxed{\textsf{Pipe}}$$

$$\mathcal{B}[\,]\mid\mathcal{B}[10] \xrightarrow{i_1?20} \mathcal{B}[20]\mid\mathcal{B}[10]$$

$$\mathcal{B}[20]\ >>\ \textsf{Dup}\ >>\ \mathcal{B}[\,]\mid\mathcal{B}[10]$$
$$\xrightarrow{\varepsilon} \mathcal{B}[20]\ >>\ \textsf{Dup}_{o_2!20}\ >>\ \mathcal{B}[20]\mid\mathcal{B}[10]$$

Summary

- micropipeline design methodology
- rainbow Design framework with interworking
- abstract modelling
- application-specific methods
- prototype tool implementation
  - Visual Green editor/simulator
  - Rainbow expression compiler/evaluator
  - embedded into extensible design environment
- formal semantics
- analysis

URL:

`http://www.cs.man.ac.uk/fmethods/projects/AHV-PROJECT/ahv-project.html`