Foundations of Computing: case of Oware/Awale

Ghana Dot Com
@GAF
17, June 2020

Outline

- The theory and types of Boards
- Representing positive and negative numbers
- Model of Oware and architecture
- Primitives and functions ADD, NEG, SUB,MUL, DIV
- Oware programming

Theoretical computer science

Computational complexity

Information theory

Compression

Cryptography

Algorithms

Coding theory

Computability theory

Hardware

Turing machine

Logic

Formal methods

Computational geometry

Parallel processing

Automata theory

Graph theory

Quantum computing

OWARE

Africa's Forgotten Mechanical Computer

Prof. Nii Narku Quaynor

Universities using Oware book

- UDELAS, Panama
- Universidad Santo Tomas, Columbia
- Univates, Brasil; Instituto Federal, Brasil
- Universidad Nacional de Education, Ecuador
- Universidad Autonoma de San Luis Potosi, Mexico
- University of Cape Coast, Ghana

Demonstration on an Oware Board

Number representation (1 bit)

Binary	Number
0	**0**
1	**-1**

Number representation (3 bits)

Binary	Number	
011	**3**	
010	**2**	
001	**1**	2s complement ie
000	**0**	complement number
111	**-1**	add 1
110	**-2**	to get negative
101	**-3**	
100	**-4**	

2s complement
(3 bits)

(-3):

```
  111
~-011
-----
  100
   +1
-----
  101
=====
```

-(-3):

```
  111
~-101
-----
  010
   +1
-----
  011
=====
```

Oware number representation

Oware	Number	
4	**4**	
3	**3**	
2	**2**	
1	**1**	
0	**0**	10s complement
9	**-1**	
8	**-2**	
7	**-3**	
6	**-4**	
5	**-5**	

10s complement

(-1957):	**-(-1957):**
999999	**999999**
~-1957	**~-998043**
———	**———**
998042	**1956**
+1	**+1**
———	**———**
998043	**1957**
=====	**=====**

Description of Oware board

Source

d(6,s)	d(5,s)				d(1,s)
d(6,r)	d(5,r)				d(1,r)

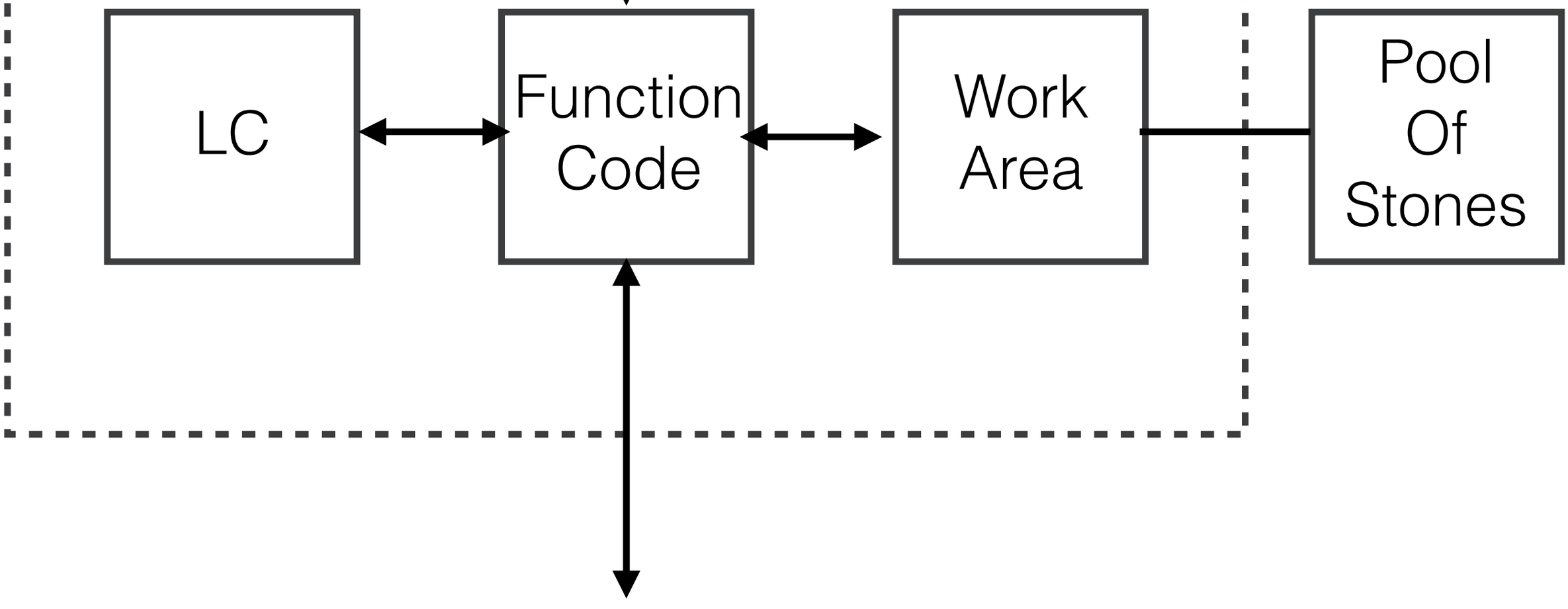
Results

W is work area, the left hole and **P**, is pool of stones on right

Oware Architecture

Source

Read only input
<S6,S5,S4,S3,S2,S1>



Results

Read/Write input/output
<R6,R5,R4,R3,R2,R1>

Conventions

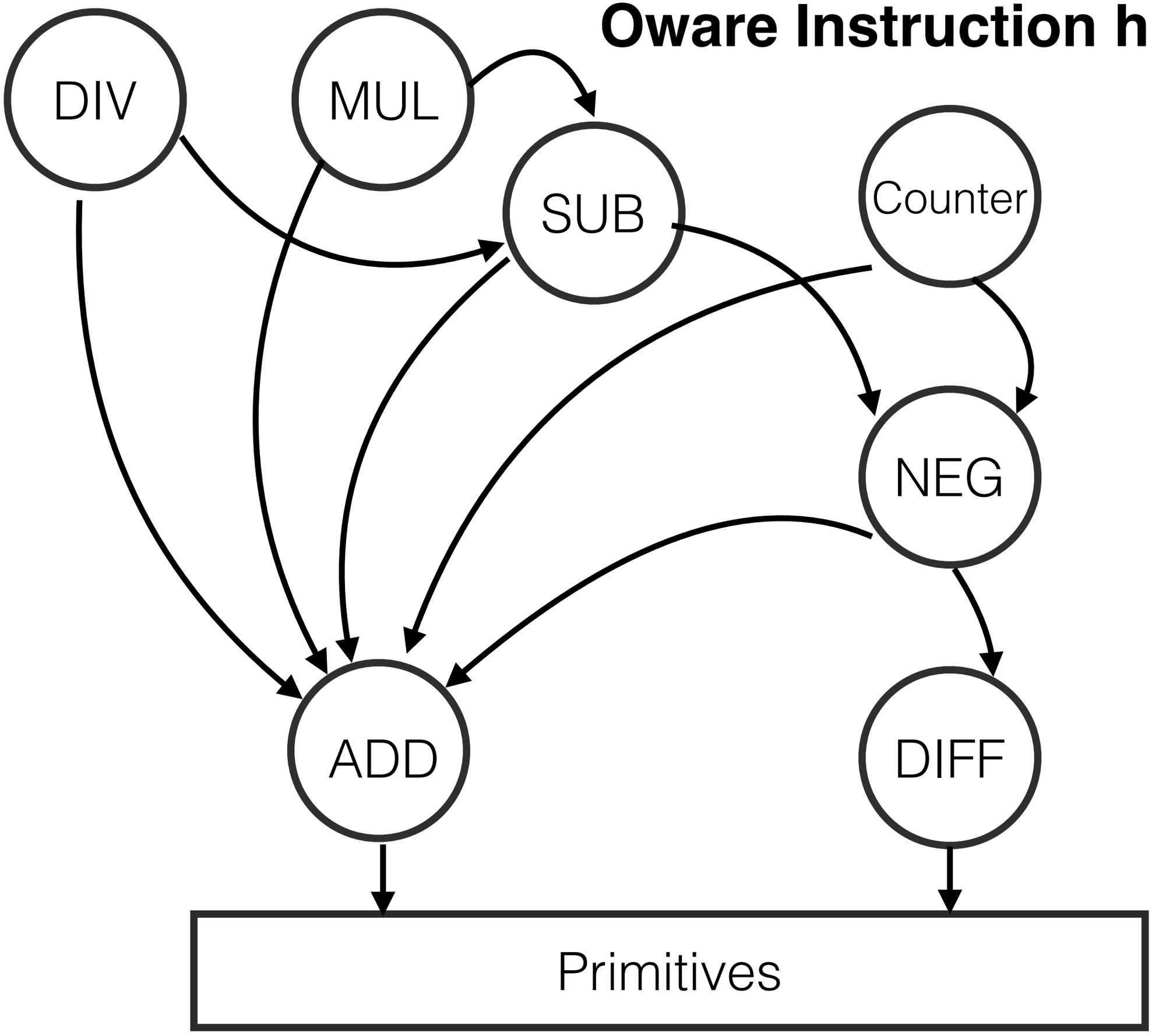
- Results are by convention in second row

- Can cascade operations, follow one operation with another

OWARE PRIMITIVES

d(6,*),..,d(1,*)<-n	Constant
W</- d(i,s)	Copy
W<-d(i,r)	Move
d(i,r)<- excess_10(W)	If W>=10
W<-1	
P<-9	
d(i,r)<-W	Else

Oware Instruction hierarchy



ADD (S,R)

```
W=0
P=large
For i= 1 to 6 {
  W</- d(i,s)
  W<-d(i,r)
  If |W|>=10 {
    d(i,r)<- excess_10(W)
    W<-1
    P<-9}
  else {
    d(i,r)<-W}
}
```

DIFF (n6,n5,..,n1) ~ complement

W=0
P=large

d(6,s),..,d(1,s)= 999 999

d(6,r),..,d(1,r)= n6,n5,..,n2,n1

for i=1 to 6 {
  d(i,r)= (d(i,s)-d(i,r))
  }

NEGATE (n6,n5,..,n1) ~ negative

W=0
P=large

DIFF(n6,n5,..,n2,n1)

d(6,s),..,d(1,s)<-1

ADD (S,R)

SUBTRACT (A,B) ~ A-B

W=0
P=large

NEGATE(B)

d(6,s),..,d(1,s)<-A

ADD (S,R)

Sign (R) ie when negative

```
If d(6,r) in {5,6,7,8,9} then {
  sign=1
}
Else {
  sign=0
}
```

MULTIPLY (A,B)

Down counter

Board1

S=999 999

R=B

Summation

Board2

S=A

R=0

```
Do forever {
  With Board1 {
    If r==0 then terminate
    Else ADD (S,R)
  }
  With Board2 {
    ADD (S,R)
  }
}
```

DIVIDE (A,B) ie A/B

Up counter

Board1

S=1

R=0

Summation

Board2

S=-B

R=A

```
Do forever {
  With Board2 {
    ADD(S,R)
    If sign (R) then terminate
  }
  With Board1 {
    ADD (S,R)
  }
}
```

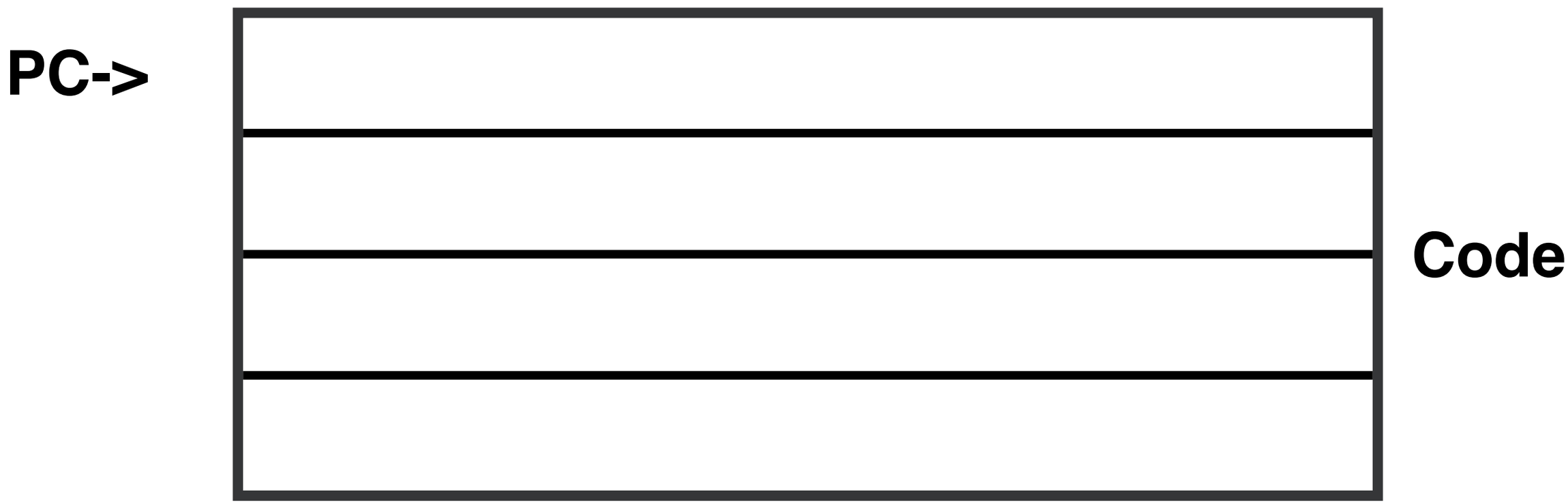
Conditionals

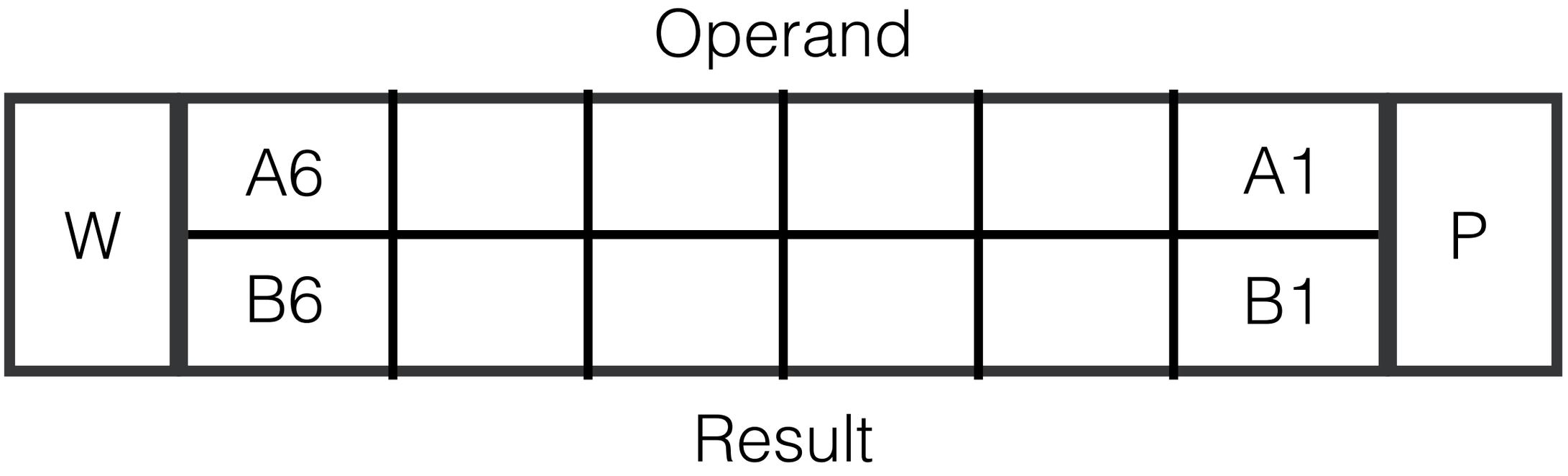
A>B	(A-B) => +ve
A>=B	(A-B) => 0, +ve
A<B	(A-B) => -ve
A<=B	(A-B) => -ve,0
A=B	A-B) => 0

Demonstration from iPhone App (Oware Calculus)

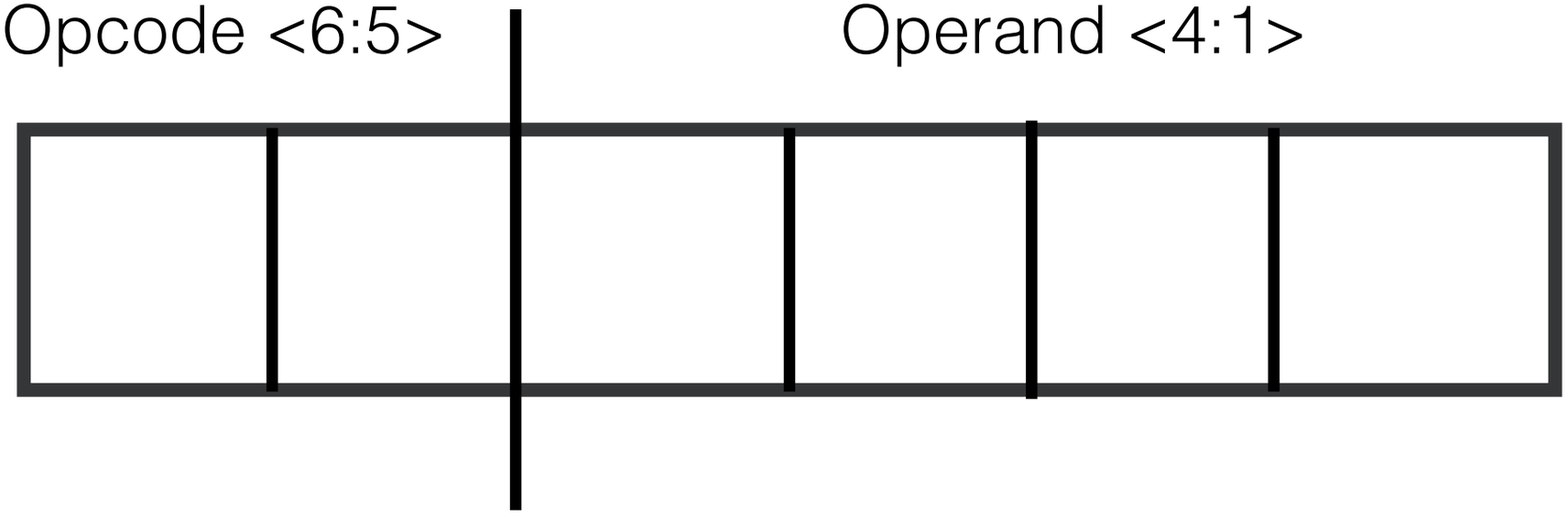
Advanced topics

Stored Program model





Oware instruction format



Opcode	Operation	Result
00	NOP	Nothing
01	LOADR n	r<-n, pc<-pc+1
02	LOADS n	s<-n, pc<-pc+1
03	STORER n	(n)<-r, pc<-pc+1
04	STORES n	(n)<-s, pc<-pc+1
05	ADD	r<-s+r, pc<-pc+1
06	NEG	r<- -s, pc<-pc+1
07	SUB	r<- r-s, pc<-pc+1
08	MUL	r<- r*s, pc<-pc+1
09	DIV	r<- s/r, pc<-pc+1
10	BR n	pc<-pc+n
11	BP n	If r +ve then pc<-pc+n
12	BN n	If r -ve then pc<-pc+n
13	BZ n	If r ==0 then pc<-pc+n
XX	Reserved	
99	HALT	

Example program (a+b*c)

```
LOADS  b
LOADR. c
MUL
LOADS a
ADD
```

Conclusion

- Why don’t Africans use Oware as a calculator
- Why excitement about Abacus instead?
- Is this another colonization of Africa.
- Let us work together to liberate Africa from techno-domination or colonization

Thank you