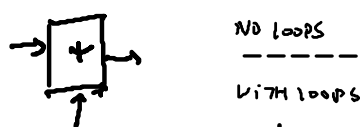
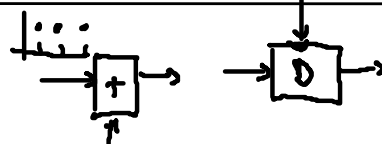
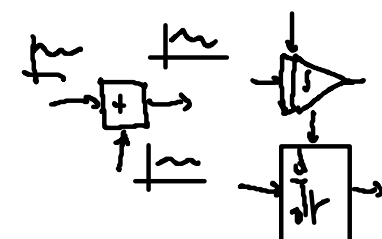
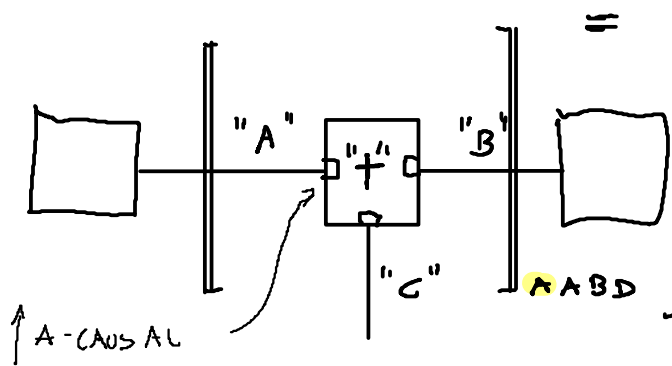


TIME ↓	HIERARCHY ↗		SEMANTICS ↗	
	FLAT	CBD	SYNTAX	DENOTATIONAL "WHAT" / OPERATIONAL "HOW"
{NOW}	ALGEBRAIC (ALG-CBD)			
DN	DISCRETE-TIME (DT-CBD)			
TR	CONTINUOUS-TIME (CT-CBD)			

CBD CAUSAL BLOCK DIAGRAM
 ABD A-CAUSAL BLOCK DIAGRAM

"COMPUTATIONAL CAUSALITY"
 CAUSE → CONSEQUENCE



$$m \nu A + n \nu B + p \nu C = \phi$$

$$(m \nu A, n \nu B, p \nu C) \in \mathbb{R}^3$$

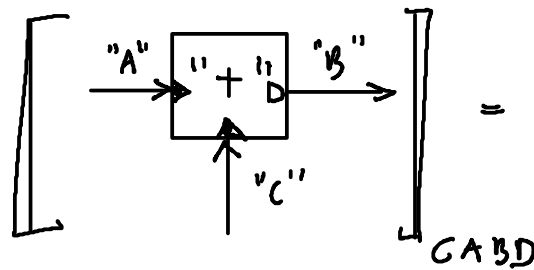
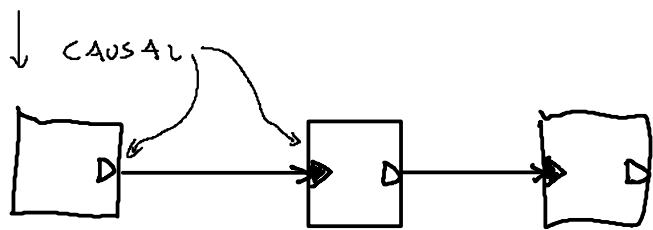
A-CAUSAL

$$+: \mathbb{R} \times \mathbb{R} \rightarrow \mathbb{R}$$

MATH

"WHAT"

CAUSALITY ASSIGNMENT

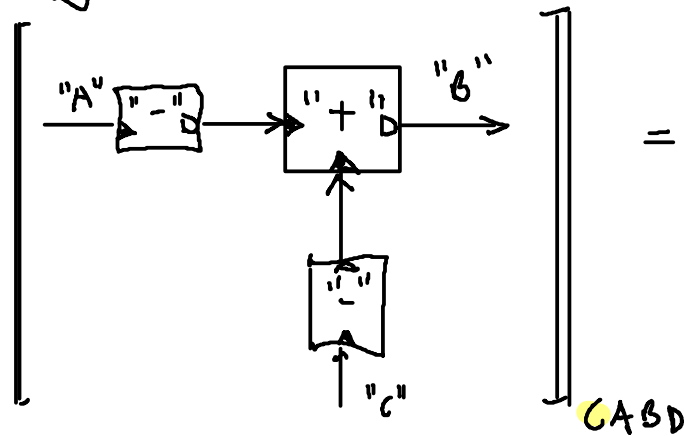
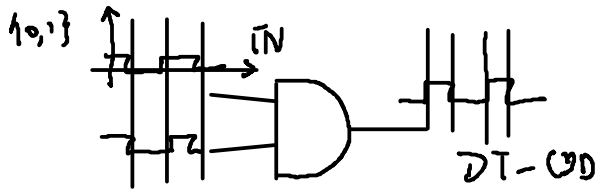


$\nu A, \nu B, \nu C ; \text{float}$

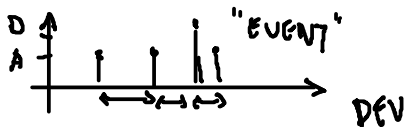
$$\nu B := \nu A + \nu C$$

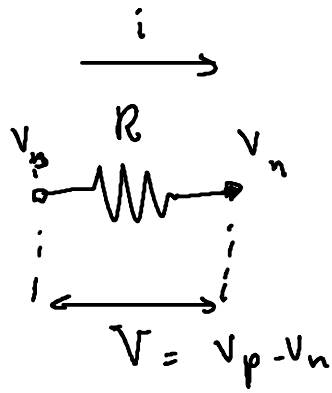
CODE

"How"



$$\nu B := - \nu A - \nu C$$





$$V := R \times i$$

$$R := V/i$$

$$i := V/R$$

$$V - Ri = \phi$$

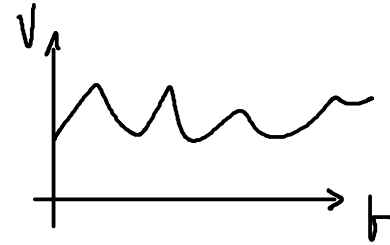


MODÉLICA



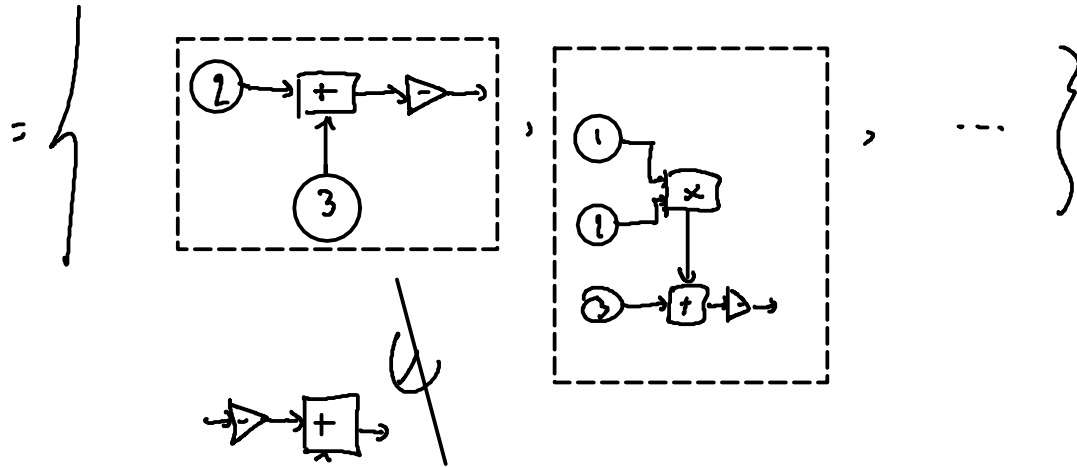
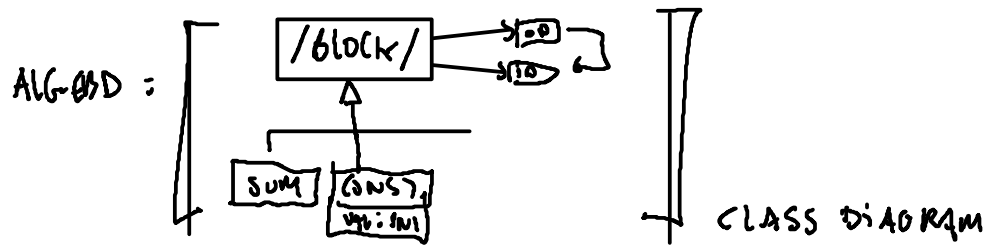
SIMULINK

CAUSALITY
ASGN.



LANGUAGE

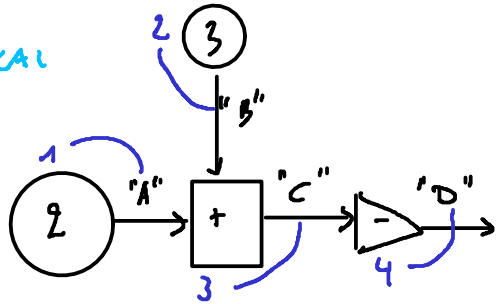
$$L = \left["A+B" \right]_{n \in \mathbb{N}} = \{ "AB", "AAB", \dots \}$$



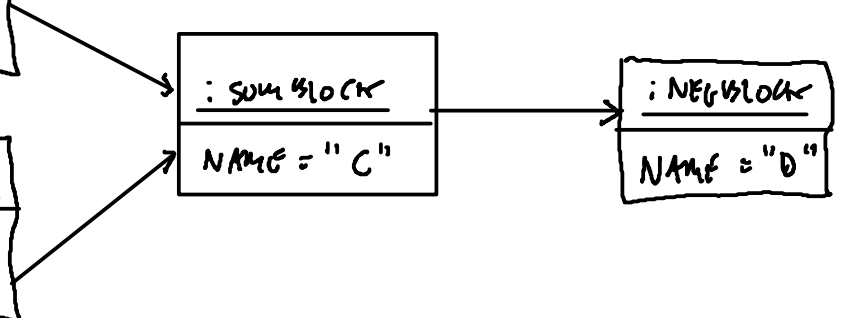
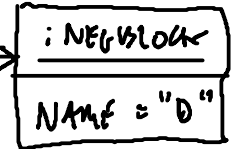
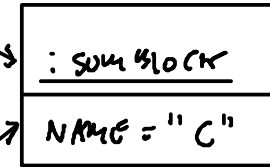
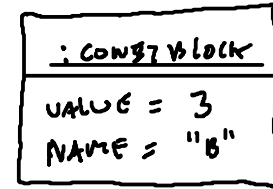
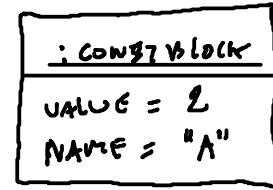
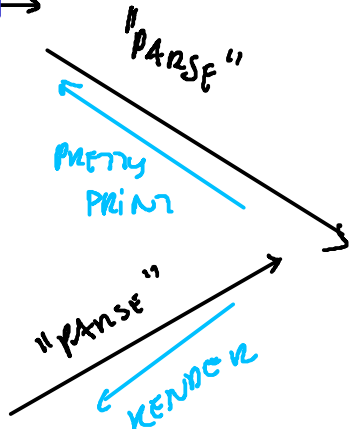
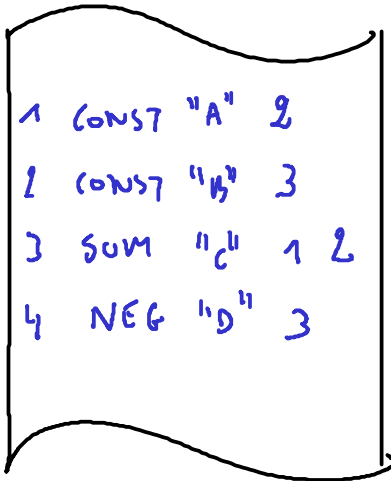
CONCRETE SYNTAX

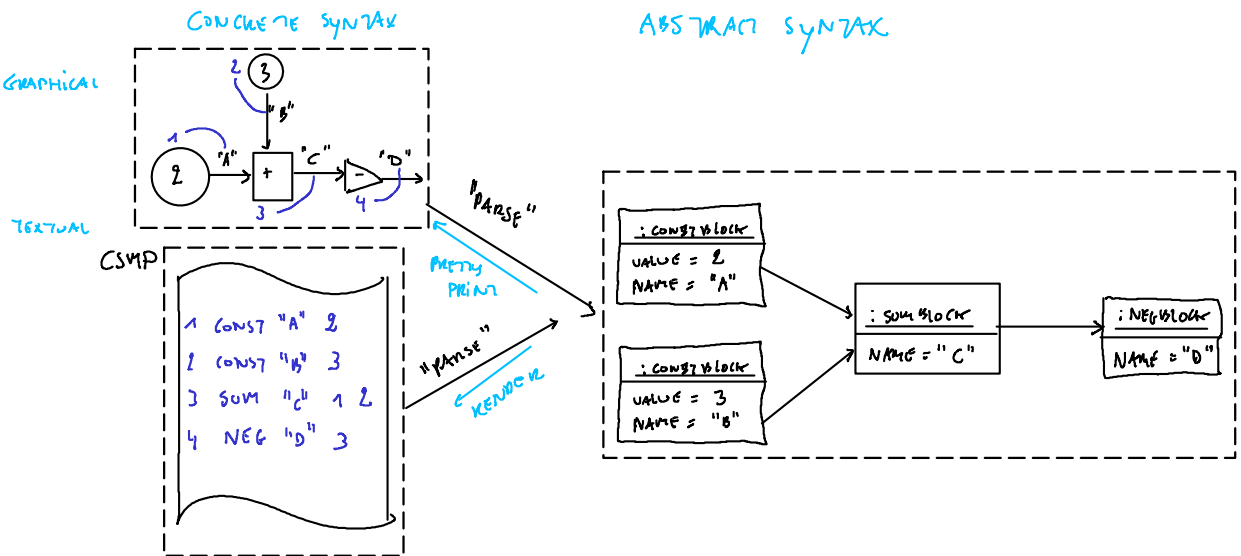
ABSTRACT SYNTAX

GRAPHICAL



TEXTUAL
CSMP





SEMANTICS

DENOTATIONAL "WHAT?"

$(m_A, m_B, m_C, m_D) \in \mathbb{R}^4$ SUCH THAT

$\llbracket \cdot \rrbracket_{\text{ALG-COD}} \left\{ \begin{array}{l} m_A = 2 \\ m_B = 3 \\ m_C = m_A + m_B \\ m_D = -m_C \end{array} \right. \xrightarrow{\text{SET UP EQNS}} (2, 3, 5, -5)$

$$\begin{cases} 1 \cdot m_A + 0 \cdot m_B + 0 \cdot m_C + 0 \cdot m_D = 2 \\ 0 \cdot m_A + 1 \cdot m_B + 0 \cdot m_C + 0 \cdot m_D = 3 \\ -1 \cdot m_A + (-1) \cdot m_B + 1 \cdot m_C + 0 \cdot m_D = 0 \\ 0 \cdot m_A + 0 \cdot m_B + 1 \cdot m_C + 1 \cdot m_D = 0 \end{cases}$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ -1 & -1 & 1 & 0 \\ 0 & 0 & 1 & 1 \end{bmatrix} \begin{bmatrix} m_A \\ m_B \\ m_C \\ m_D \end{bmatrix} = \begin{bmatrix} 2 \\ 3 \\ 0 \\ 0 \end{bmatrix}$$

$\det(M) \neq 0 \Rightarrow$ UNIQUE SOLUTION

||| D
0

OPERATIONAL SEMANTICS "How"

```

float vA := 0;
float vB := 0;
float vC := 0;
float vD := 0;
vA := 2;
vB := 3;
vC := vA + vB;
vD := -vC;

```

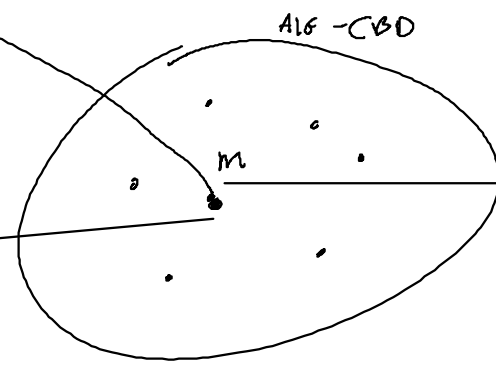
```

vD := -vC;
vA := 2;
vB := 3;
vC := vA + vB;

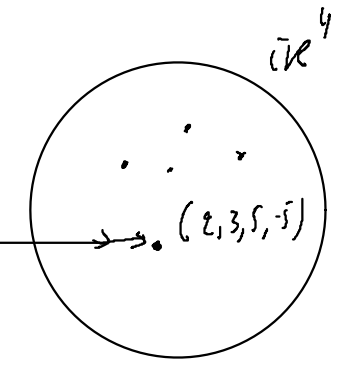
```



ABSTRACT SYNTAX



SEMANTIC DOMAIN

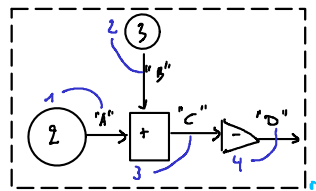


SEMANTIC MAPPING

$\llbracket \cdot \rrbracket$

- DENOTATIONAL
- OPERATIONAL

CONCRETE SYNTAX

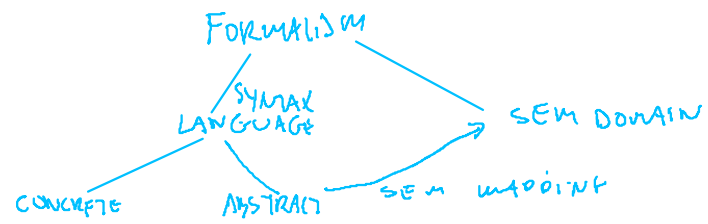


SMP

```

1 CONST "A" 2
2 CONST "B" 3
3 SUM "c" 1 2
4 NEG "D" 3

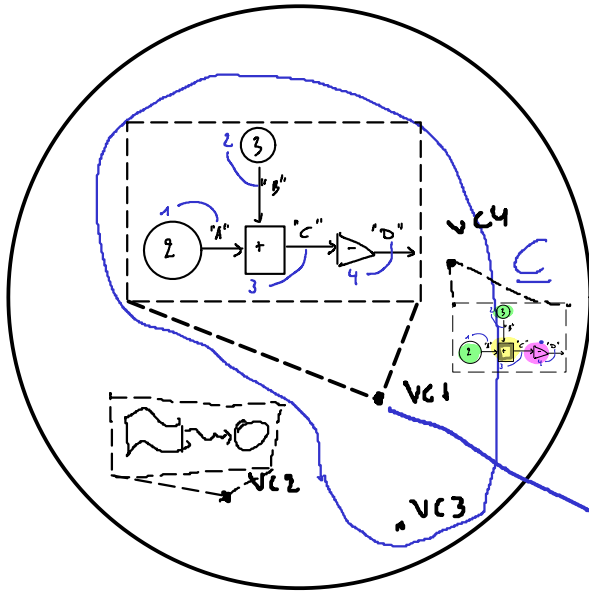
```



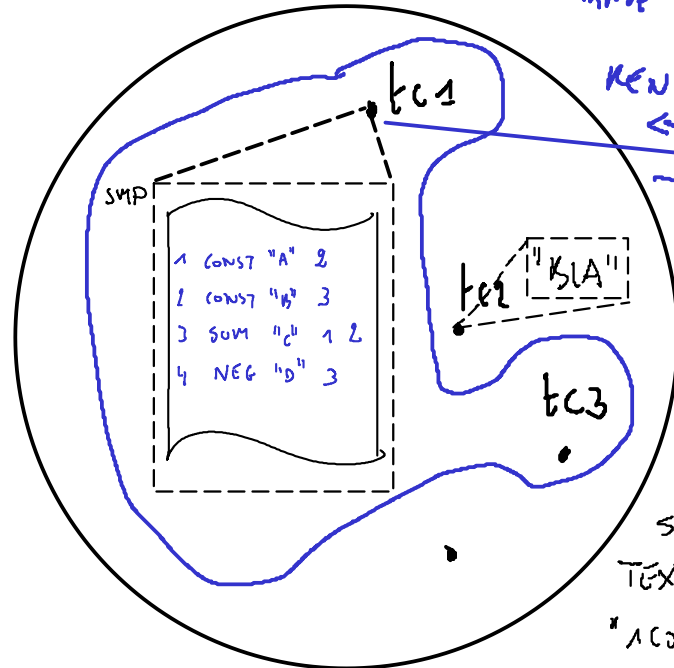
concrete syntax

abstract syntax

semantics



2D DRAWINGS



STRINGS
TEXT FILES
"1 CONST 'A' 2"

RENDER V

PARSE

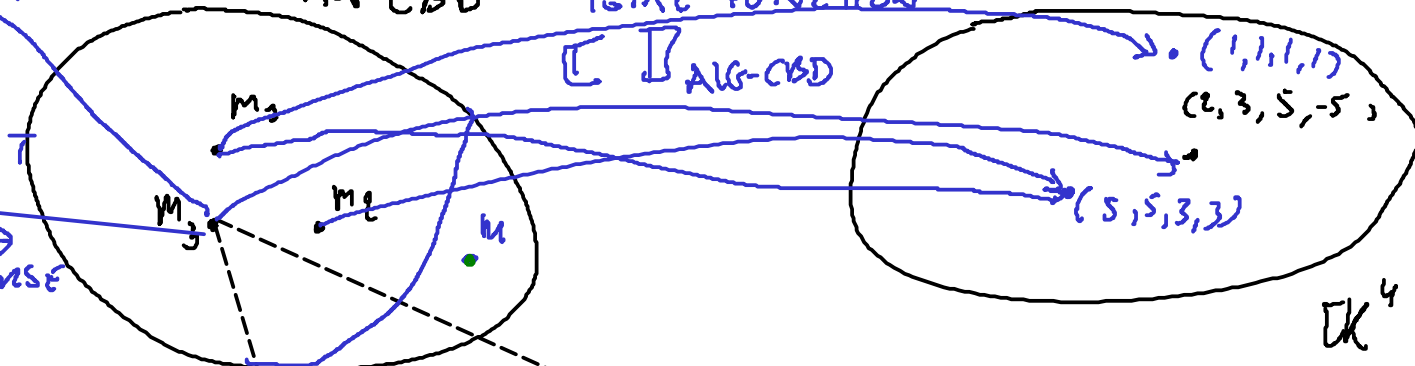
RENDER T

PARSE

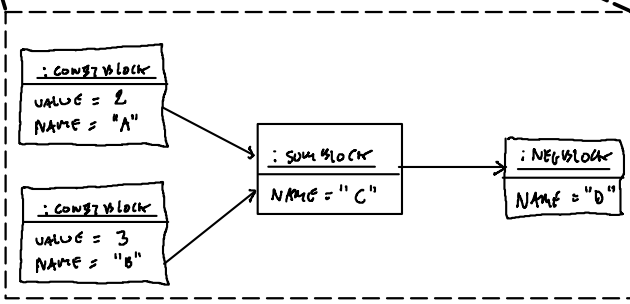
ALG-CBD

SEM MAPPING
TOTAL FUNCTION

SEMANTIC DOMAIN



OK⁴



SEMANTIC DOMAIN

UNIQUE L

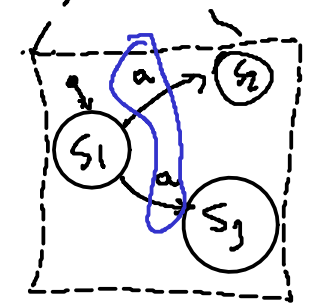
$$\{ S_1 \xrightarrow{a} \{ S_2, S_3 \} \}$$

[IP]

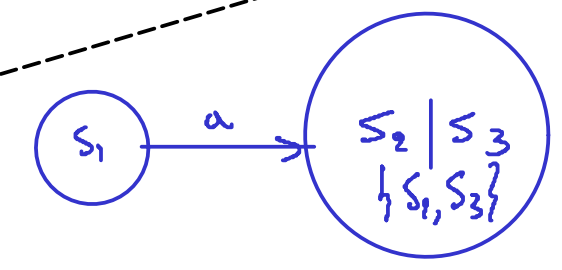
~~$$\{ S_2 \xrightarrow{a} S_2 \}$$~~

~~$$\{ S_1 \xrightarrow{a} S_3 \}$$~~

$$\{ S_2 \xrightarrow{a} S_2, S_1 \xrightarrow{b} S_3 \}$$

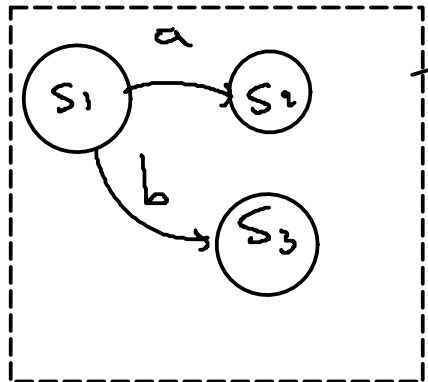


NFA ≡



NON-DENUMERATION

DFA

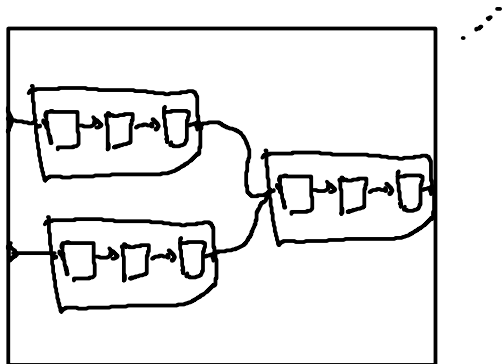
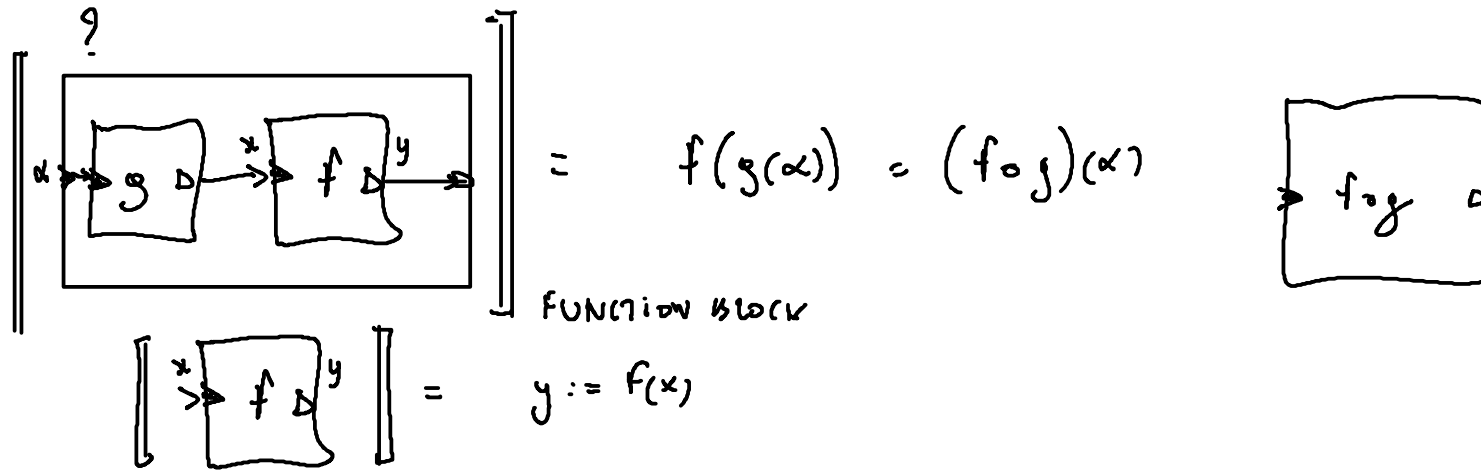


$$L = \{ "a" \}$$

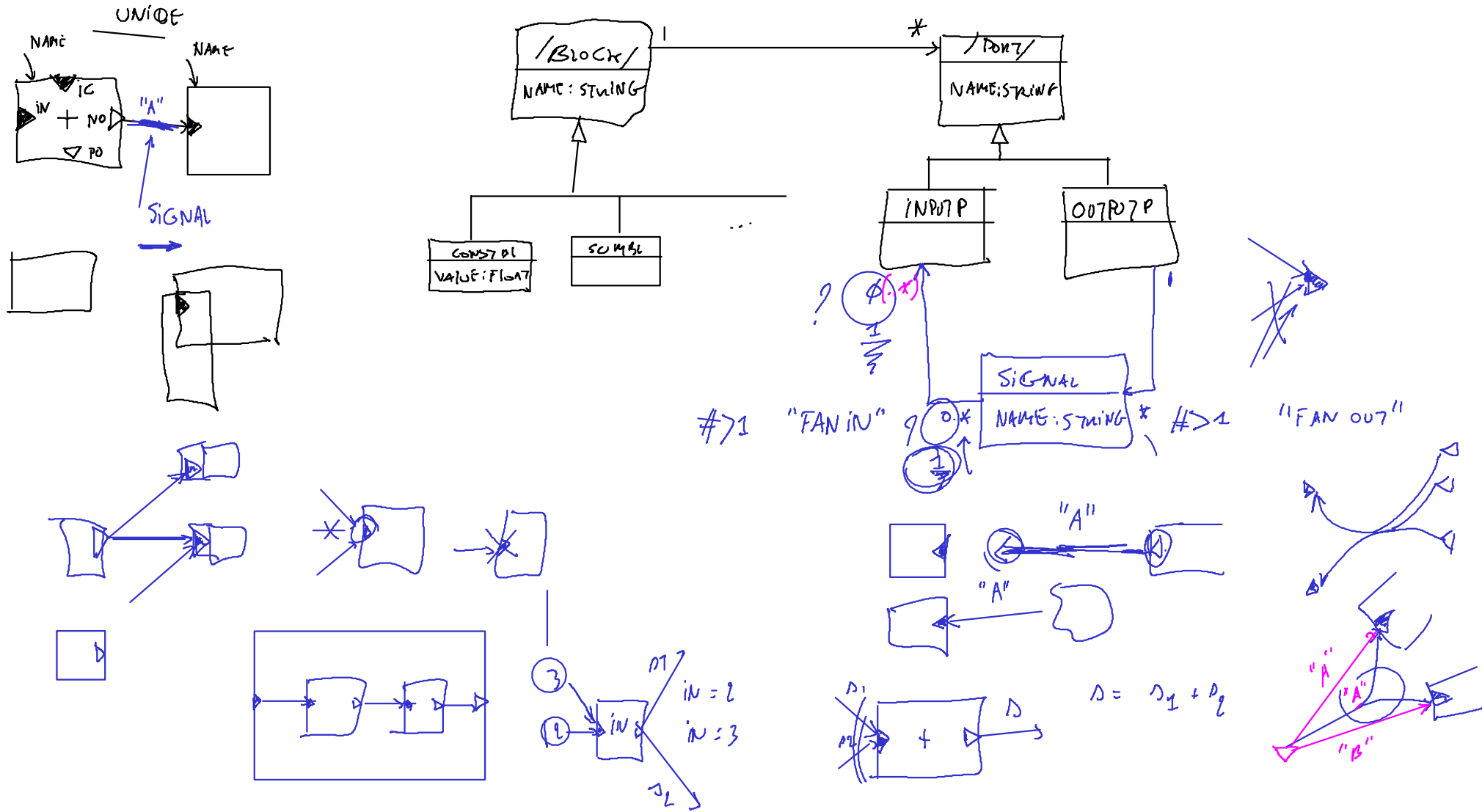
$$S_1 \xrightarrow{a} S_2$$

$$S_1 \xrightarrow{b} S_3$$

HIERARCHY



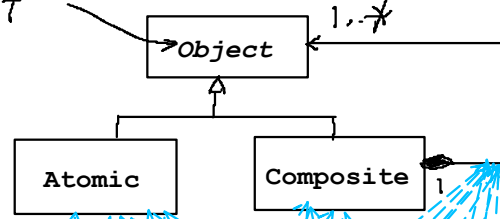
the Class Diagram describing the CBD language (including adding hierachy) will be re-visited later



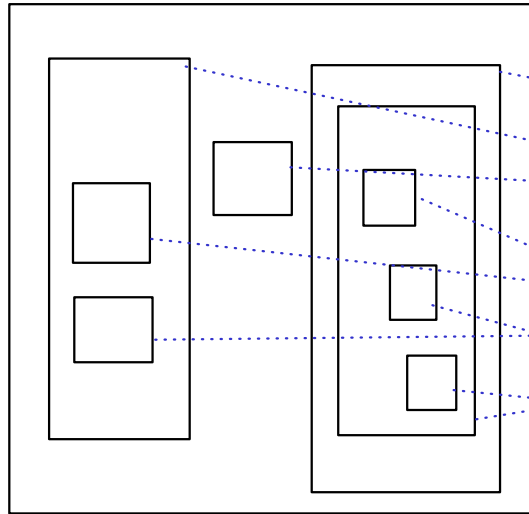
hierarchy

composite pattern

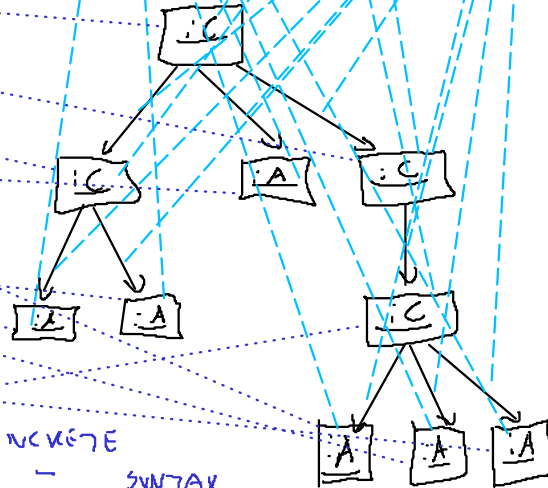
SLANTED MEANS
ABSTRACT



CLASS DIAGRAM



CONCRETE
SYNTAX



CONFORMS TO

OBJECT DIAGRAM

CONCRETE
-
ABSTRACT
SYNTAX
MAPPING

ABSTRACT
SYNTAX