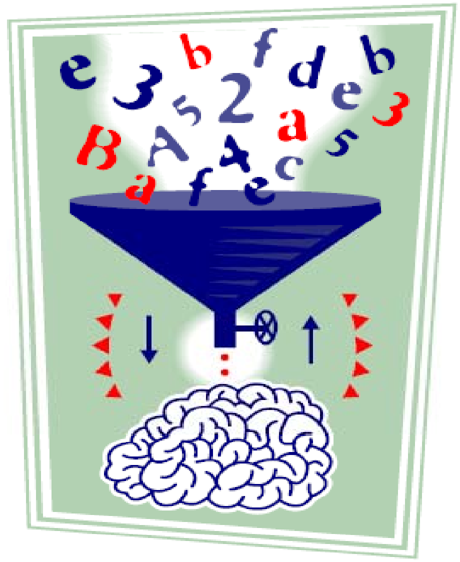
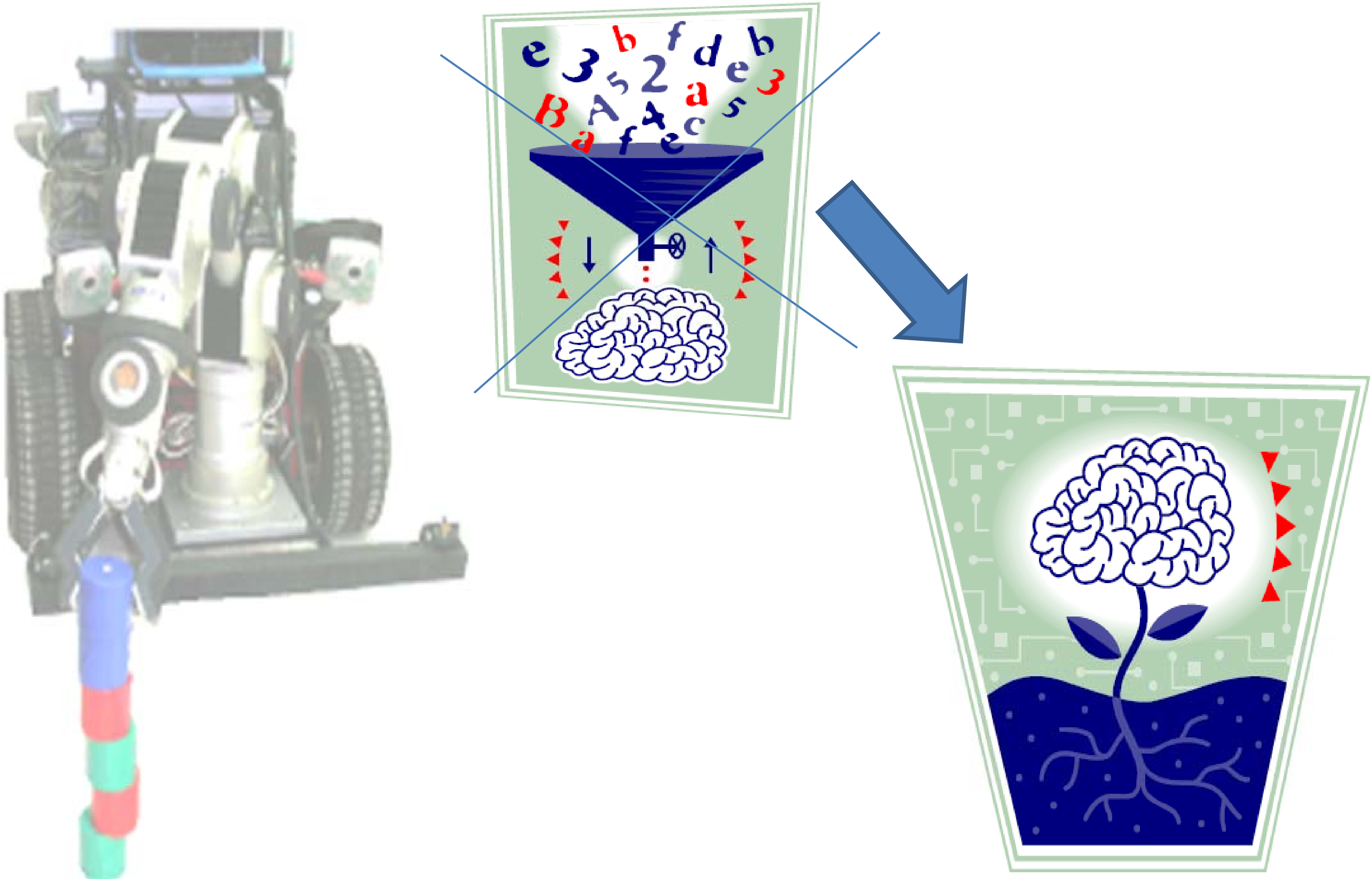
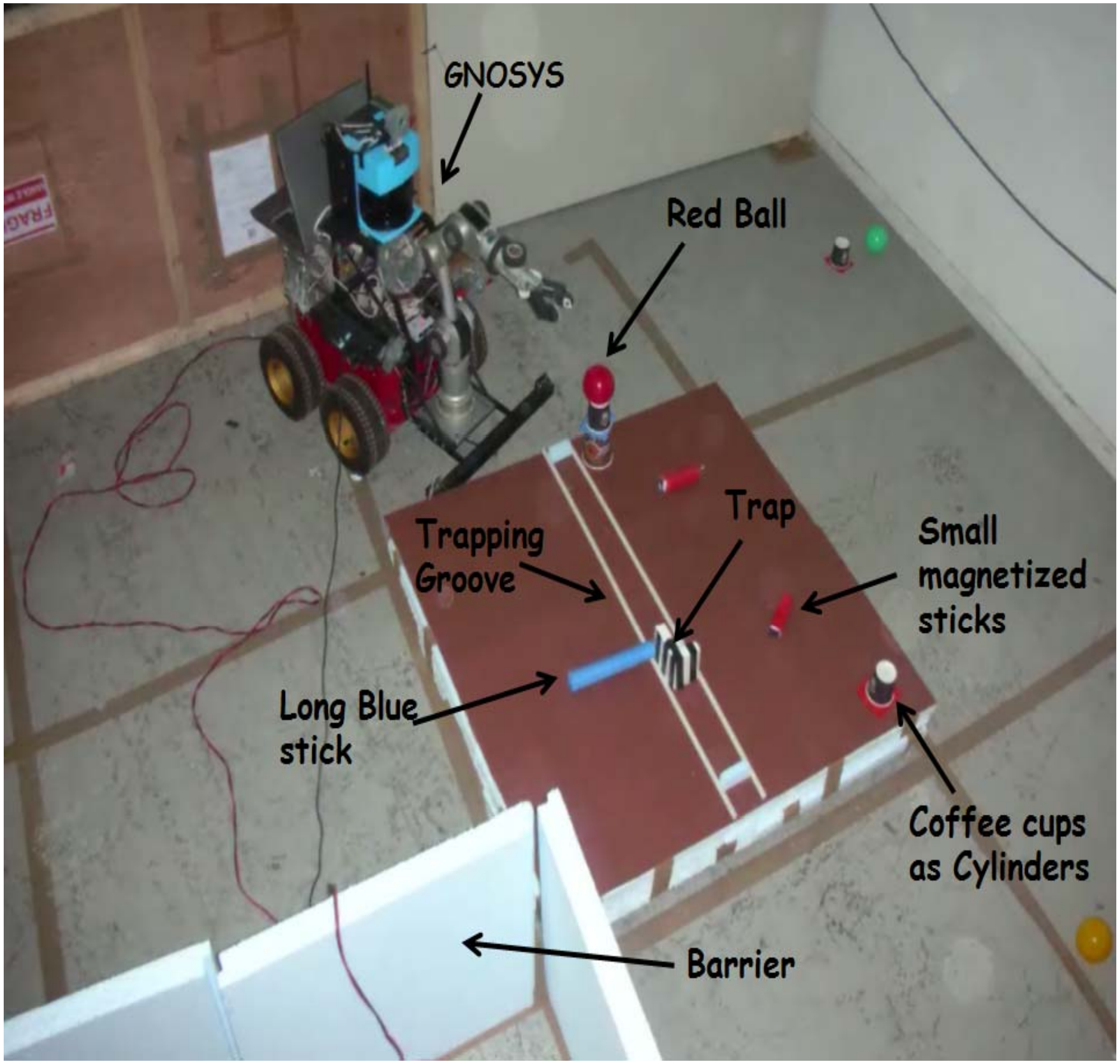
Perception and Synthesis of 'Shape'

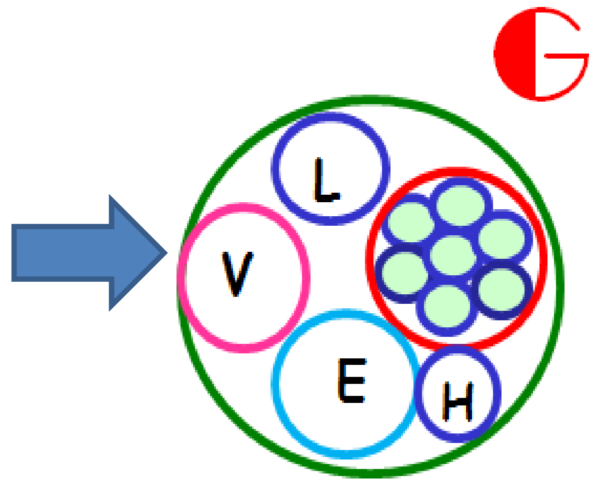
GNOSYS ARCHITECTURE:- FROM AUTOMATION TO AUTONOMOUS



GNOSYS ARCHITECTURE:- FROM AUTOMATION TO AUTONOMOUS

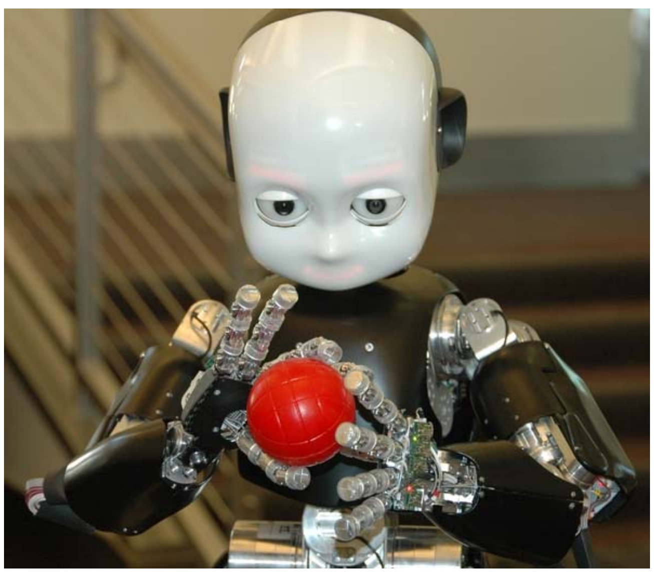


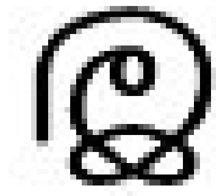

GNOSYS
Red Ball
Trap
Trapping Groove
Small magnetized sticks
Long Blue stick
Coffee cups as Cylinders
Barrier


L
V
E
H

Perception and Synthesis of 'Shape'

‘Shape’ our Bodies to the ‘Shape’ of the World……………



What is 'Shape' ? 

Vauge Concept

It is not easy to give a precise mathematical or quantitative definition of 'shape'

Or even express it in mensurational quantities like length, angles or topology

What is 'Shape' ? 

Vauge Concept

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Shape is the core information in any object/action that survives the effects of

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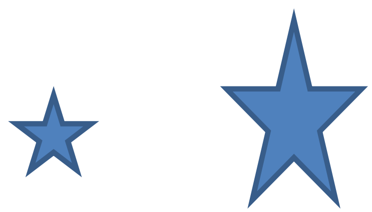

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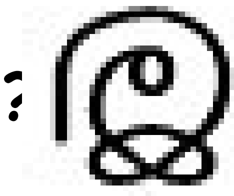

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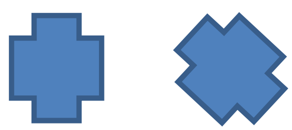
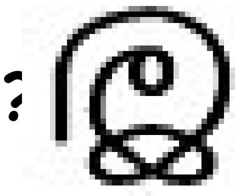


What is ‘Shape’ ? 

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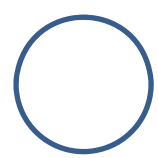
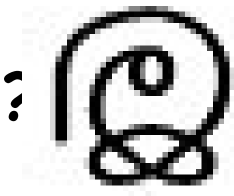
end effectors/bodies used in its creation



Make it on PAPER

Run on a football ground

What is 'Shape' ? 

Vauge Concept

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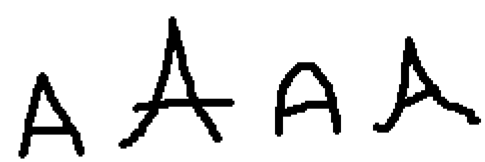
> Shape is the core information in any object/action that survives the effects of
>
> > changes in location
> >
> > scale
> >
> > orientation
> >
> > , end effectors/bodies used in its creation
> >
> > noise, and even minor structural injury



It is this informational invariance that makes 'shape' the seed for any high level sensorimotor interaction.

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Shape is where Seeing and Doing MEET

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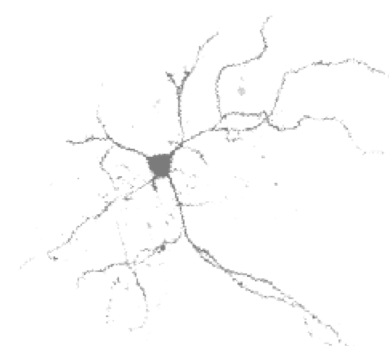
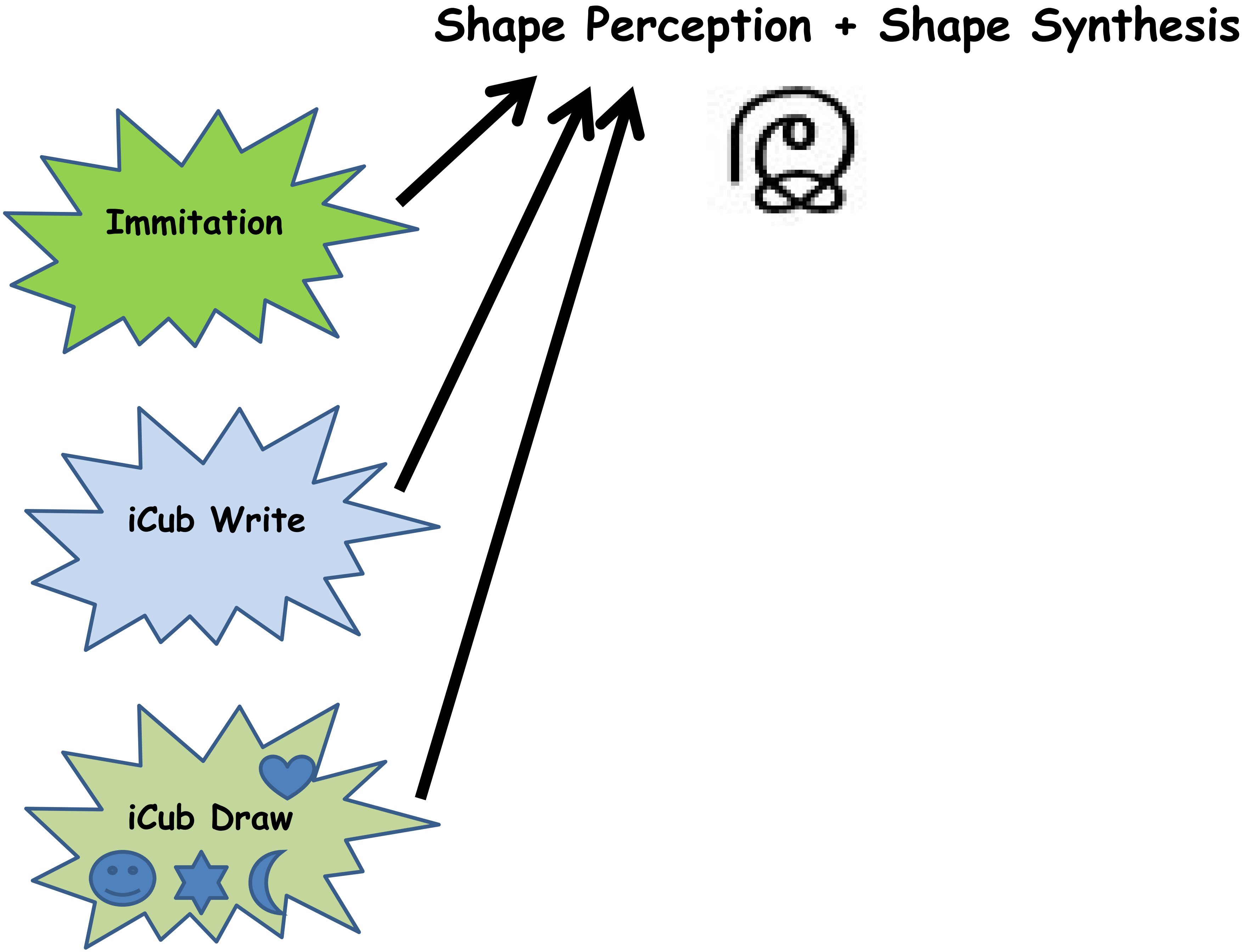
Shape is where Seeing and Doing MEET

Perception and Synthesis of 'Shape'

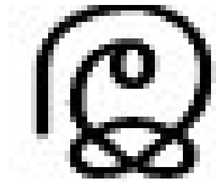
An unified treatment to the dual operations of shape perception and synthesis is critical both from the intrinsic viewpoint of better understanding our own perceptions and actions, to creating autonomous robots that can flexibly aid us in our needs and in the environments we inhabit and create.





Shape Perception + Shape Synthesis
Immitation
iCub Write
iCub Draw

Shape Perception + Shape Synthesis



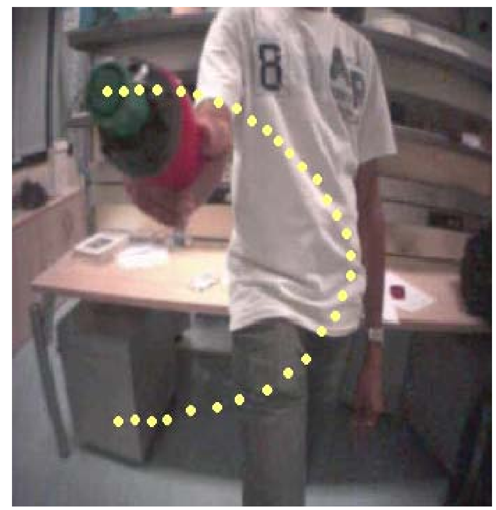
Window to understand
Perception-Reason-Action Loop

Immitation

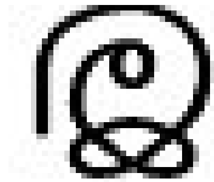
iCub Write

iCub Draw

- Shape Perception + Movement Recognition
  (+ Goal Perception)



Shape Perception + Shape Synthesis



Window to understand
Perception-Reason-Action Loop

Immitation

iCub Write

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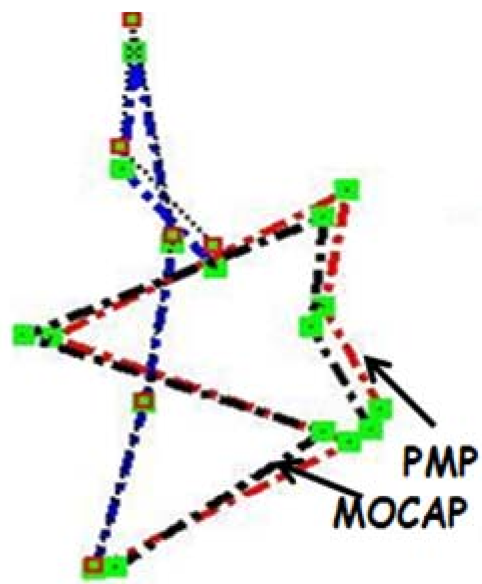
- Shape Perception + Movement Recognition (+ Goal Perception)
- **Pose estimation, Pose tracking**



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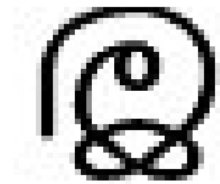


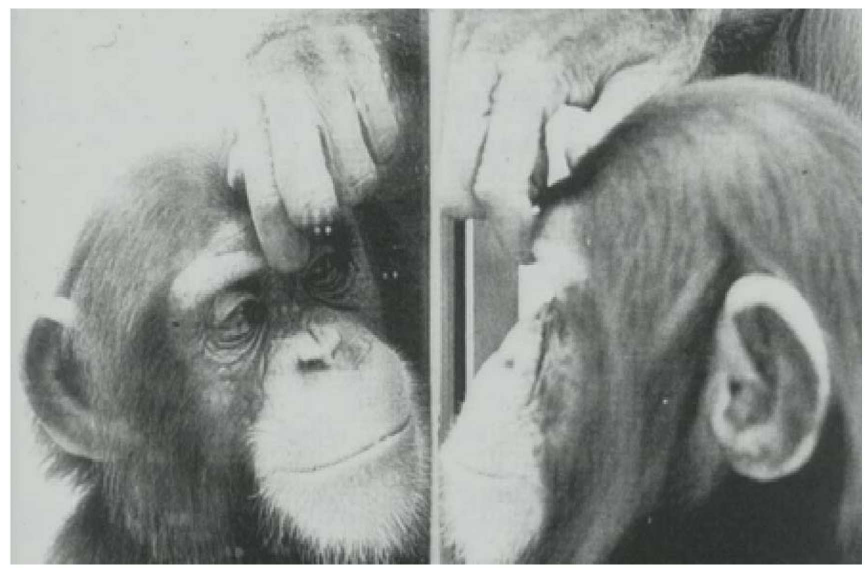
Window to understand
Perception-Reason-Action Loop

Immitation

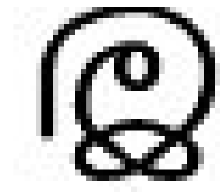
iCub Write

iCub Draw

- Shape Perception + Movement Recognition (+ Goal Perception)
- Pose estimation, Pose tracking
- **Body Correspondance**



Shape Perception + Shape Synthesis



Window to understand
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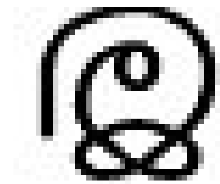
- **Coordinate transformation from from external to egocentric space**

Shape Perception + Shape Synthesis



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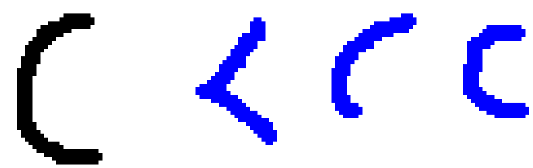
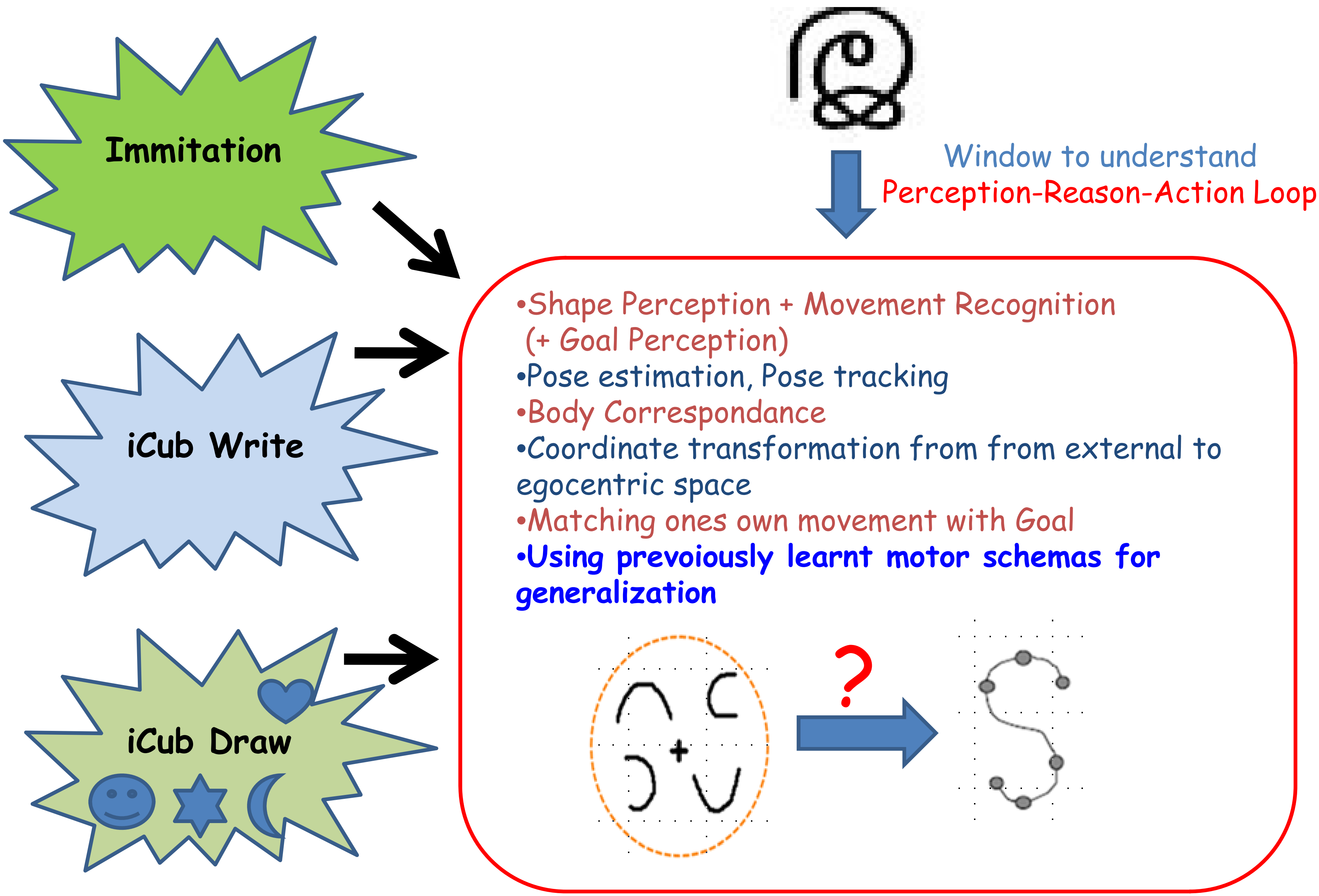
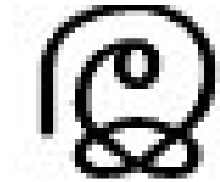


Goal   Solutions

Shape Perception + Shape Synthesis



Shape Perception + Shape Synthesis



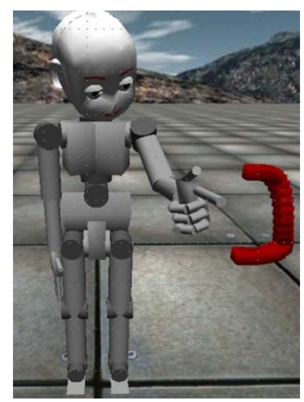
Window to understand
Perception-Reason-Action Loop

Immitation

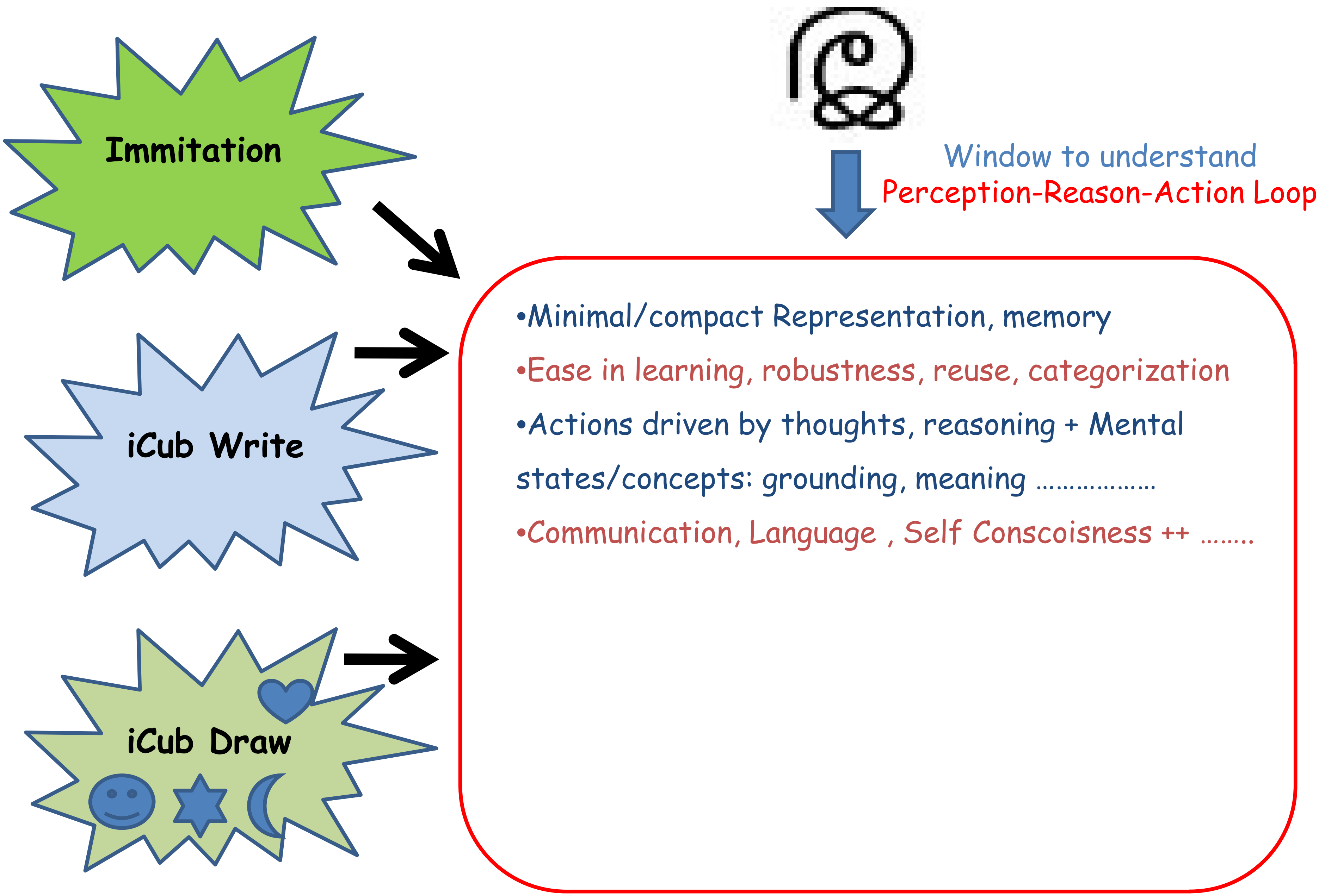
iCub Write

iCub Draw

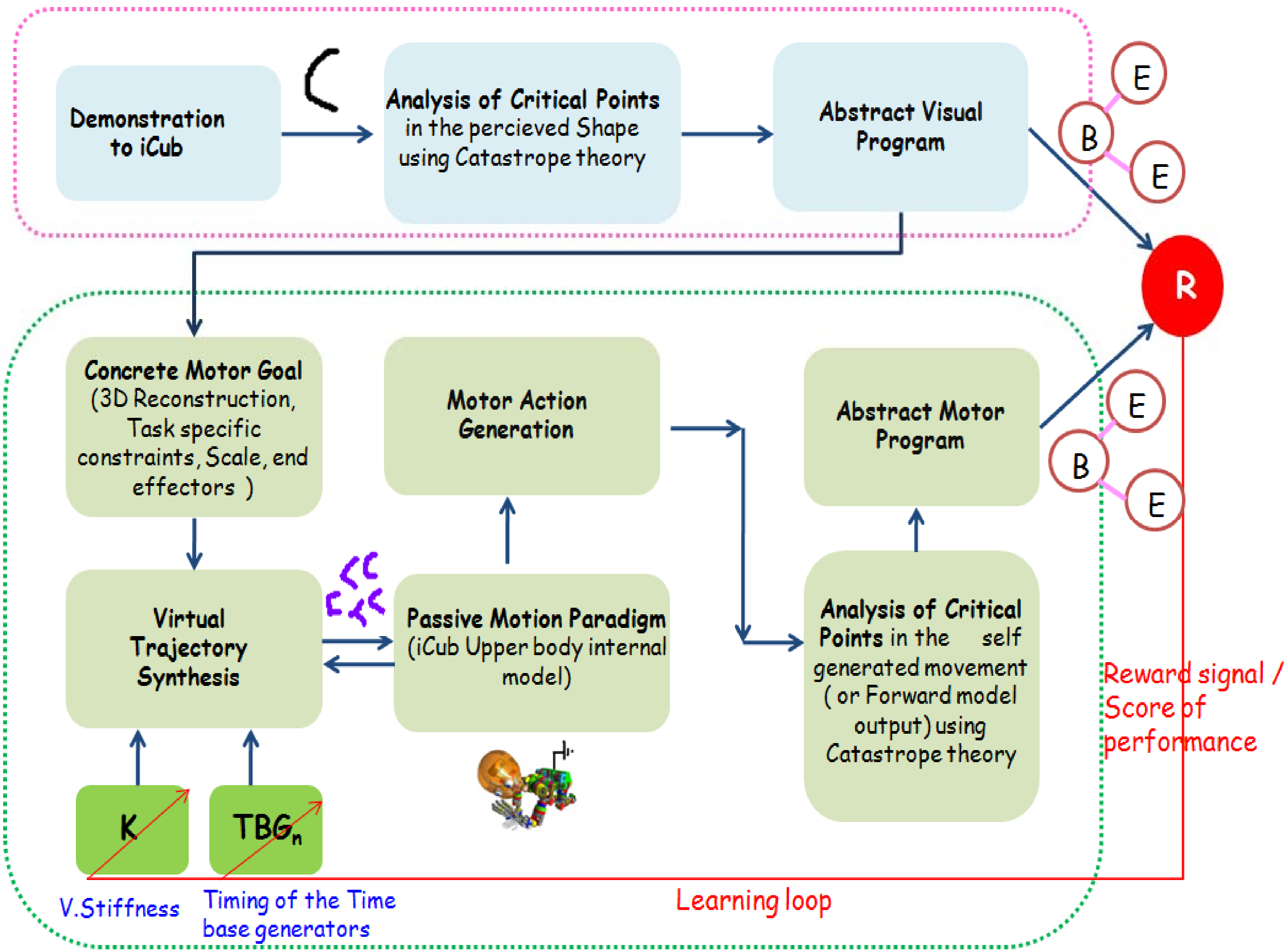
- Shape Perception + Movement Recognition (+ Goal Perception)
- Pose estimation, Pose tracking
- Body Correspondance
- Coordinate transformation from from external to egocentric space
- Matching ones own movement with Goal
- Using prevoiously learnt motor schemas for generalization
- Redundancy resolution



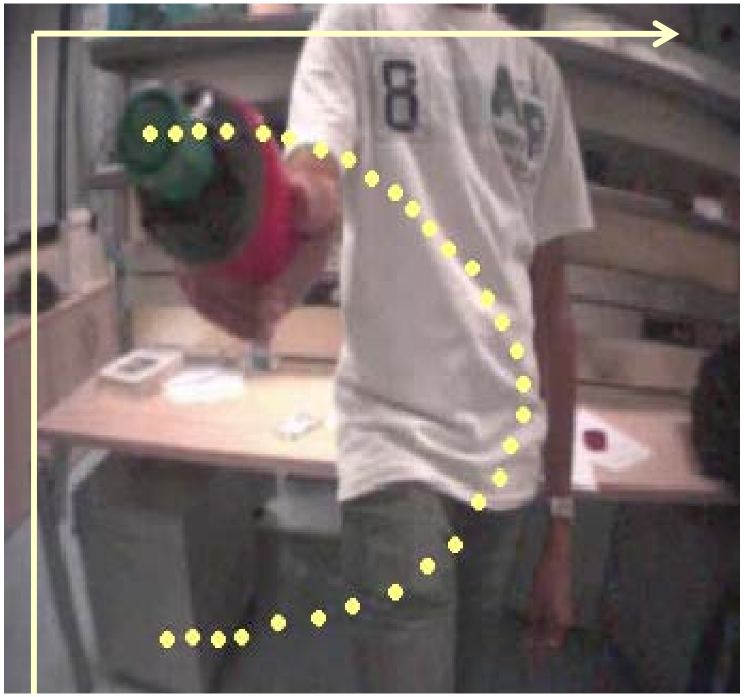
Shape Perception + Shape Synthesis



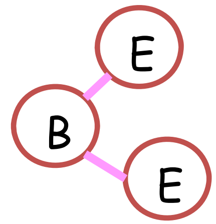
Shapes and Shapeing: Information flows



From Teachers demonstration to Abstract visual program



Catastrophe Theory
+ Morphogenesis



The Chemical Basis of Morphogenesis

A. M. Turing

Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, Vol. 237, No. 641. (Aug. 14, 1952), pp. 37-72.

Atoms of SHAPE - The Catastrophe theory

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- C.T :- Dwells into the **origin of forms** in nature (Morphogenesis)

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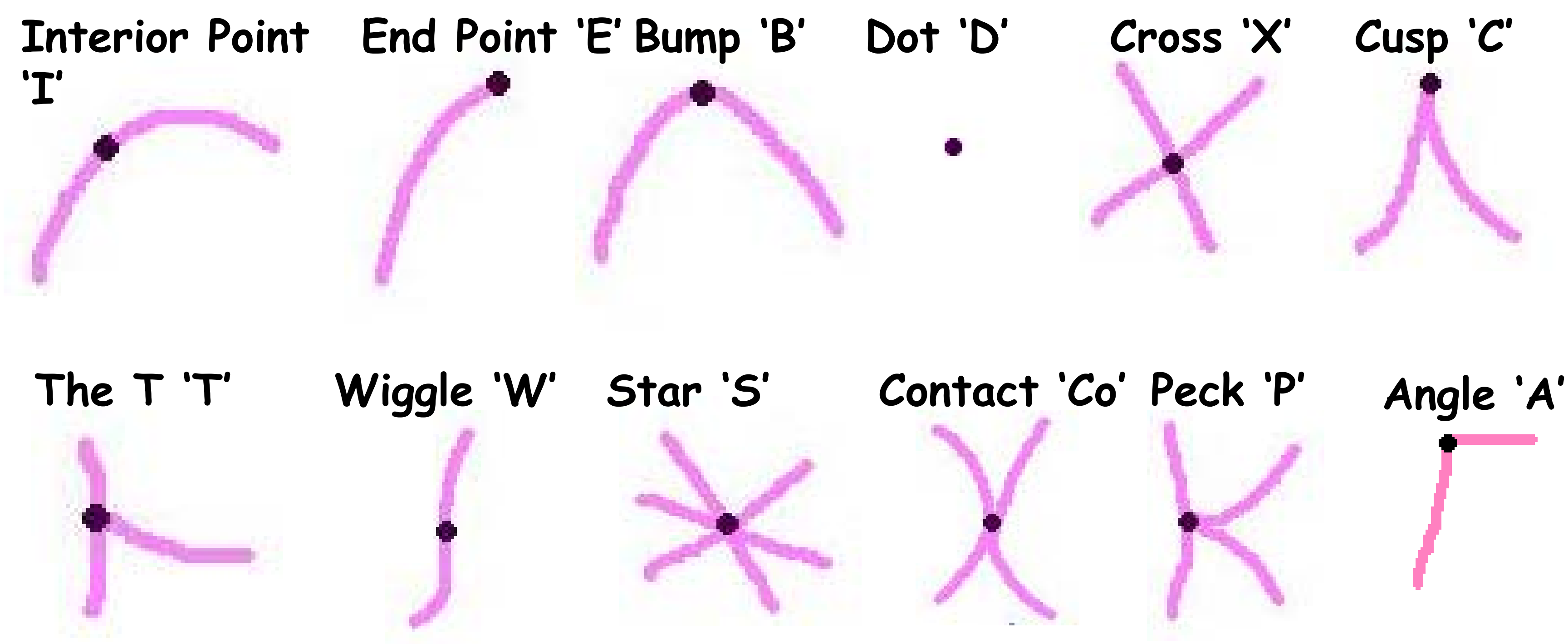
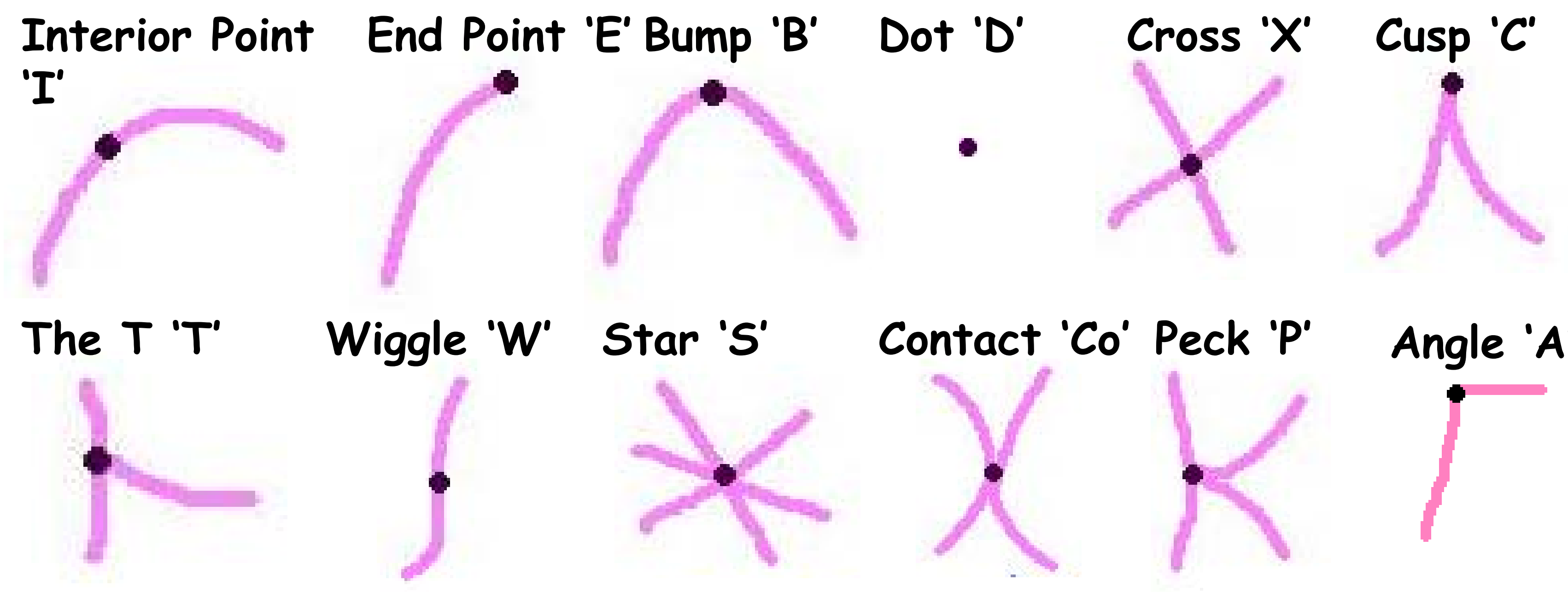
Shape Atoms

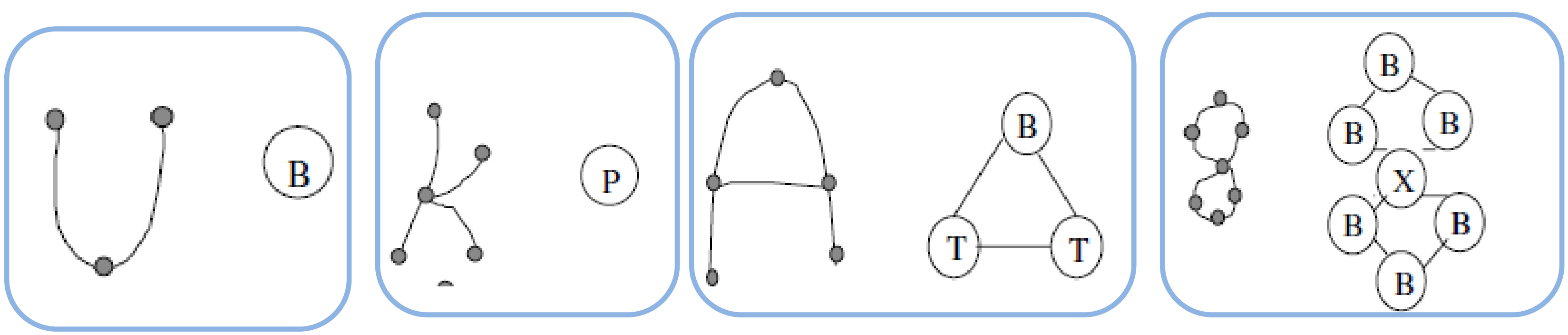


Atoms of SHAPE - The Catastrophe theory

Shape Atoms



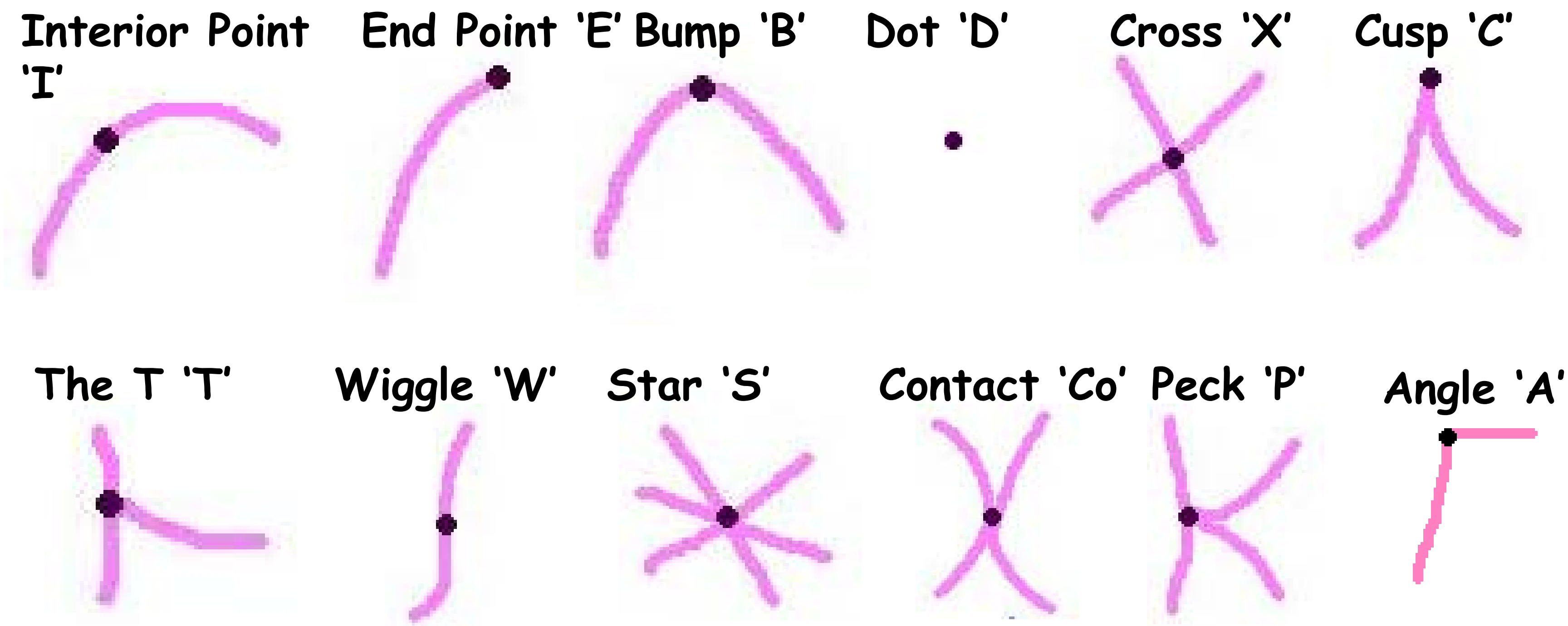
Complex/Global shapes are **'weighted' combinations** of **local shape features**



Shape to Abstact visual programs

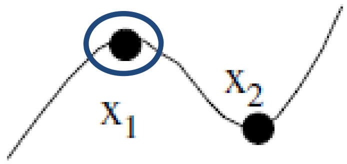
Atoms of SHAPE - The Catastrophe theory

Shape Atoms ????????



- Critical points in a complex shape, are formally charecterized using four measures:

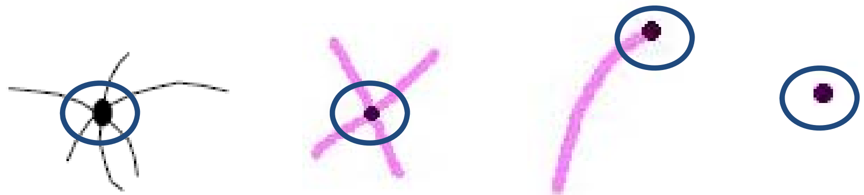
1) Stability
2) Codimension
3) Composition
4) Valency



Simple CP

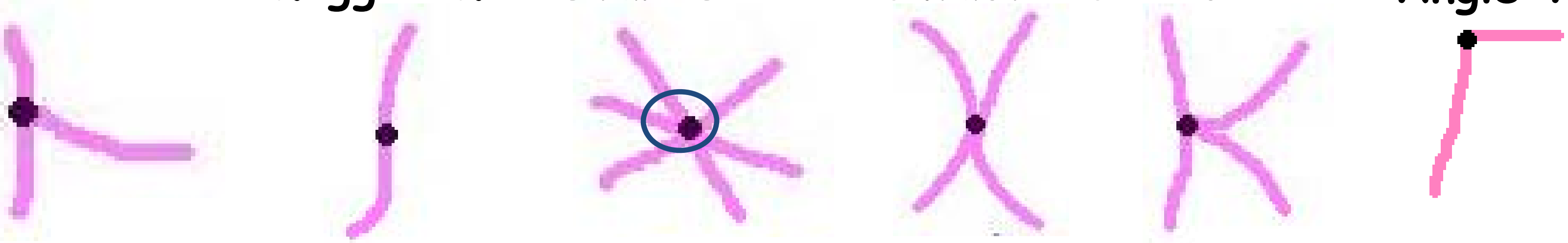
B + B

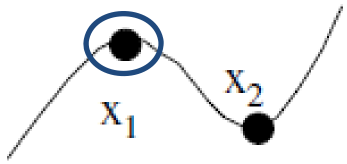
Valency: If enclosed by an infinitely small circle, no of lines that intersect it is the valency



Interior Point 'I' **End Point 'E'** **Bump 'B'** **Dot 'D'** **Cross 'X'** **Cusp 'C'**

The T 'T' **Wiggle 'W'** **Star 'S'** **Contact 'Co'** **Peck 'P'** **Angle 'A'**





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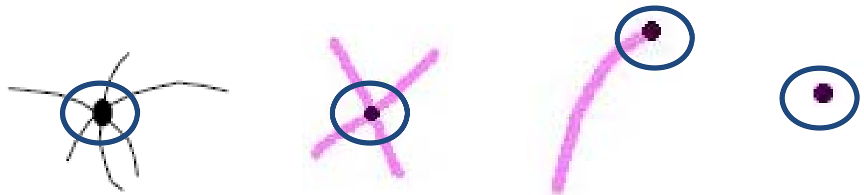
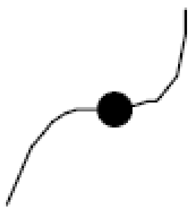
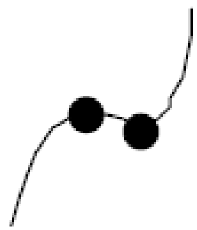


Codimention: Min number of parameters necessary to bring the function back from its perturbed state

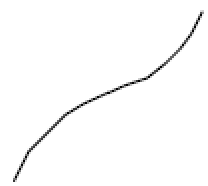


Complex CP

$f(x) = x^3$

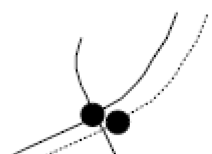


$f_p(x) = x^3 + \varepsilon x, \ (\varepsilon < 0)$



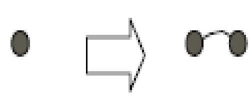
$f_p(x) = x^3 + \varepsilon x, \ (\varepsilon > 0)$

Codim=0



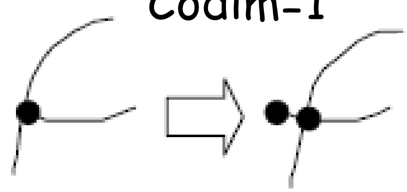
Cross

Codim=1



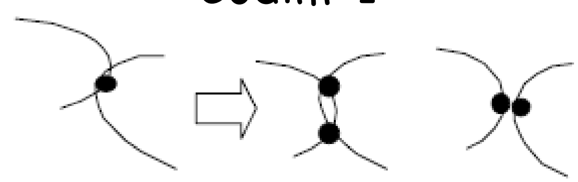
Dot point

Codim=1



T point

Codim=1



Bump (B): A Bump is an interior point where the derivative of either U(t) or V(t) is zero. A bump simply is the minimum or a maximum of a one dimensional smooth function.

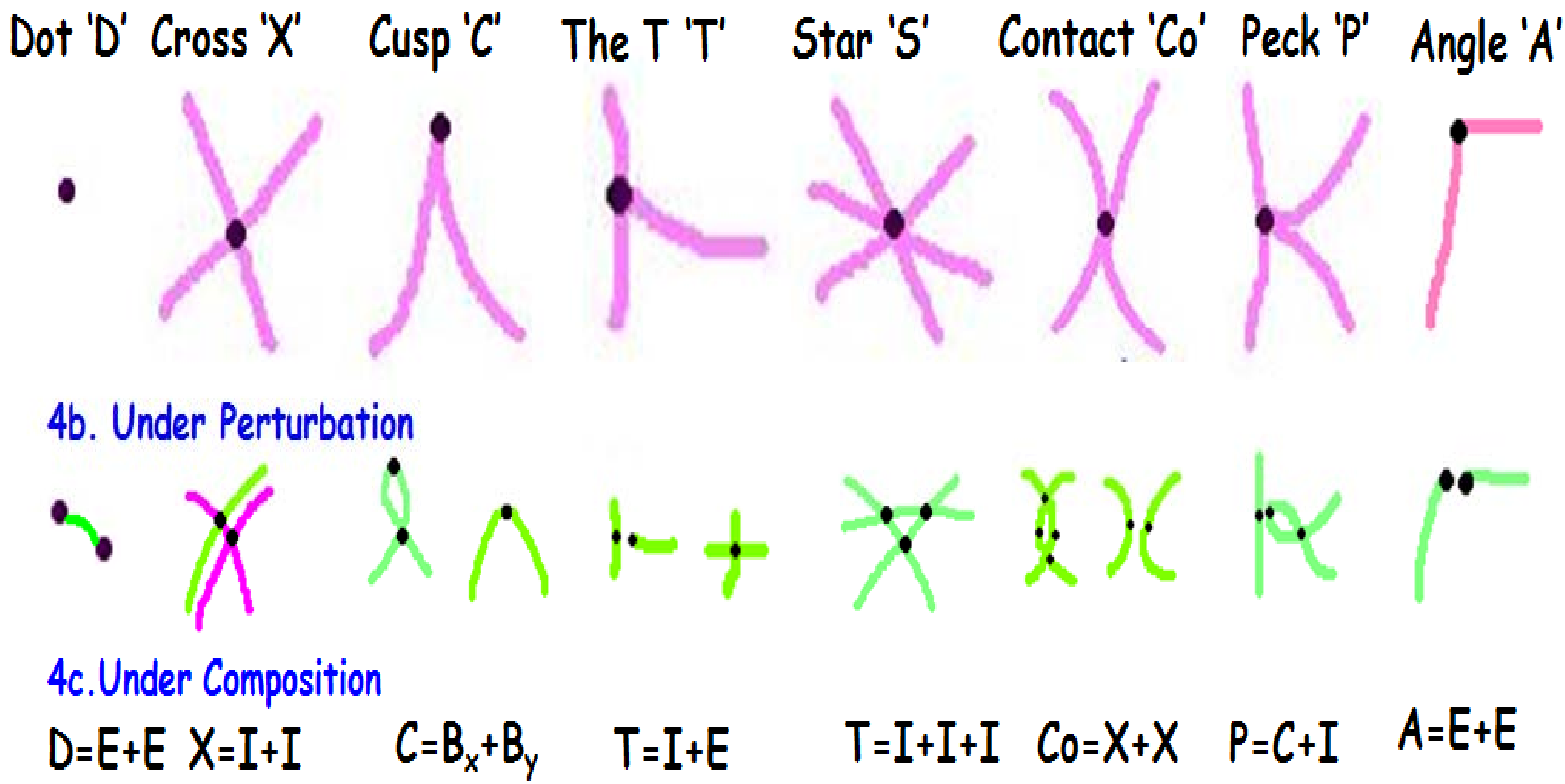
$$U'(t_B) = \left.\frac{dU}{dt}\right|_{t=t_B} = 0; \frac{d^2U}{dt^2} \neq 0; V'(t_B) \neq 0;$$

$$V'(t_B) = \left.\frac{dV}{dt}\right|_{t=t_B} = 0; \frac{d^2V}{dt^2} \neq 0; U'(t_B) \neq 0;$$

Wiggle (W): Wiggle is a complex CP. At a wiggle both the first and second derivative along U or V dimensions vanish .

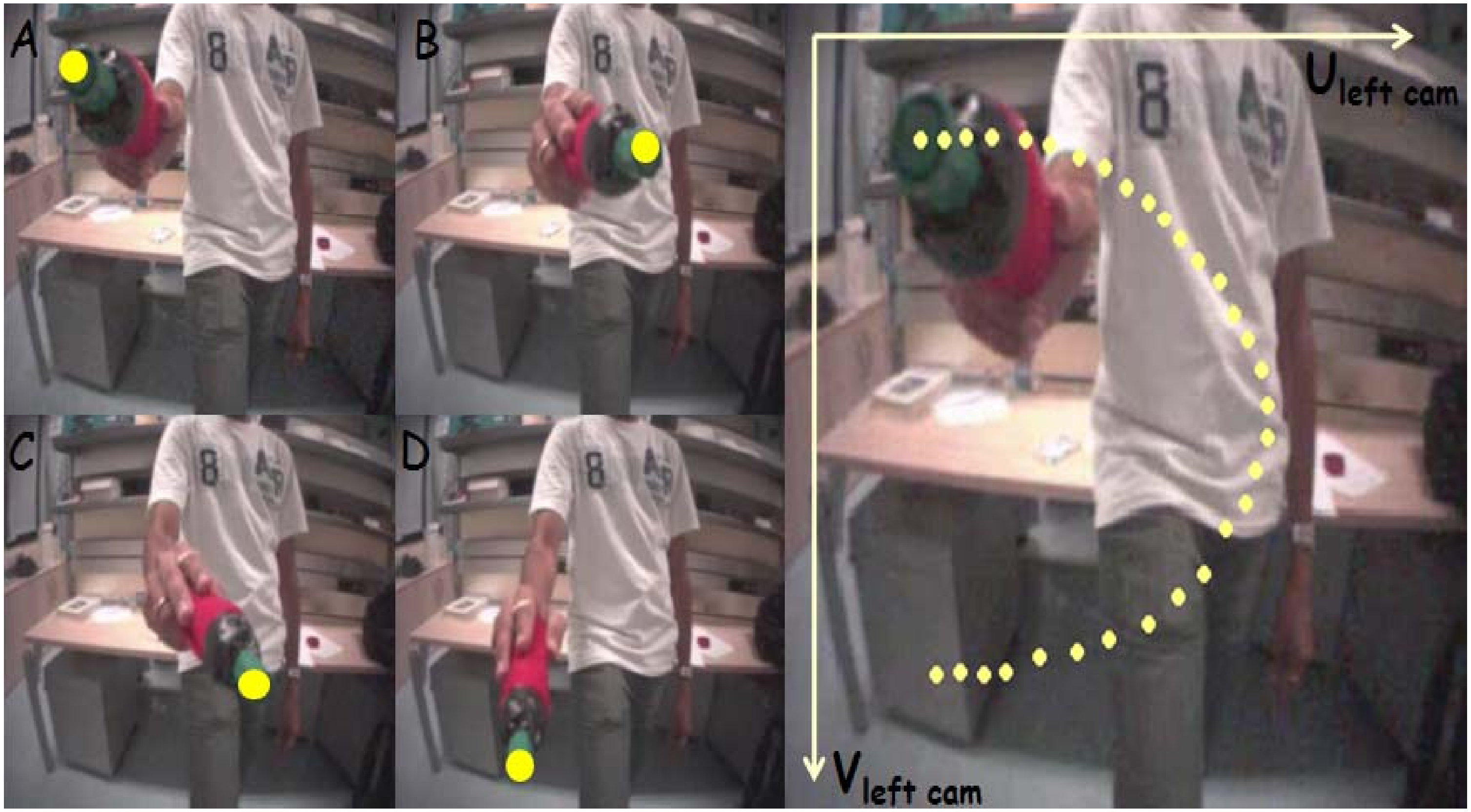
$$\frac{dU}{dt} = \frac{d^2U}{dt^2} = 0; \qquad \frac{dV}{dt} = \frac{d^2V}{dt^2} = 0;$$

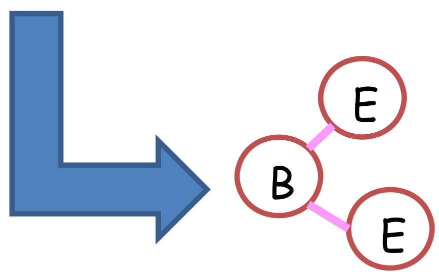
Wiggle is unstable under perturbation and either breaks up into two bumps or vanishes completely.



Dot 'D'
Cross 'X'
Cusp 'C'
The T 'T'
Star 'S'
Contact 'Co'
Peck 'P'
Angle 'A'
4b. Under Perturbation
4c.Under Composition
D=E+E
X=I+I
C=B$_x$+B$_y$
T=I+E
T=I+I+I
Co=X+X
P=C+I
A=E+E

From demonstration to Abstract visual program





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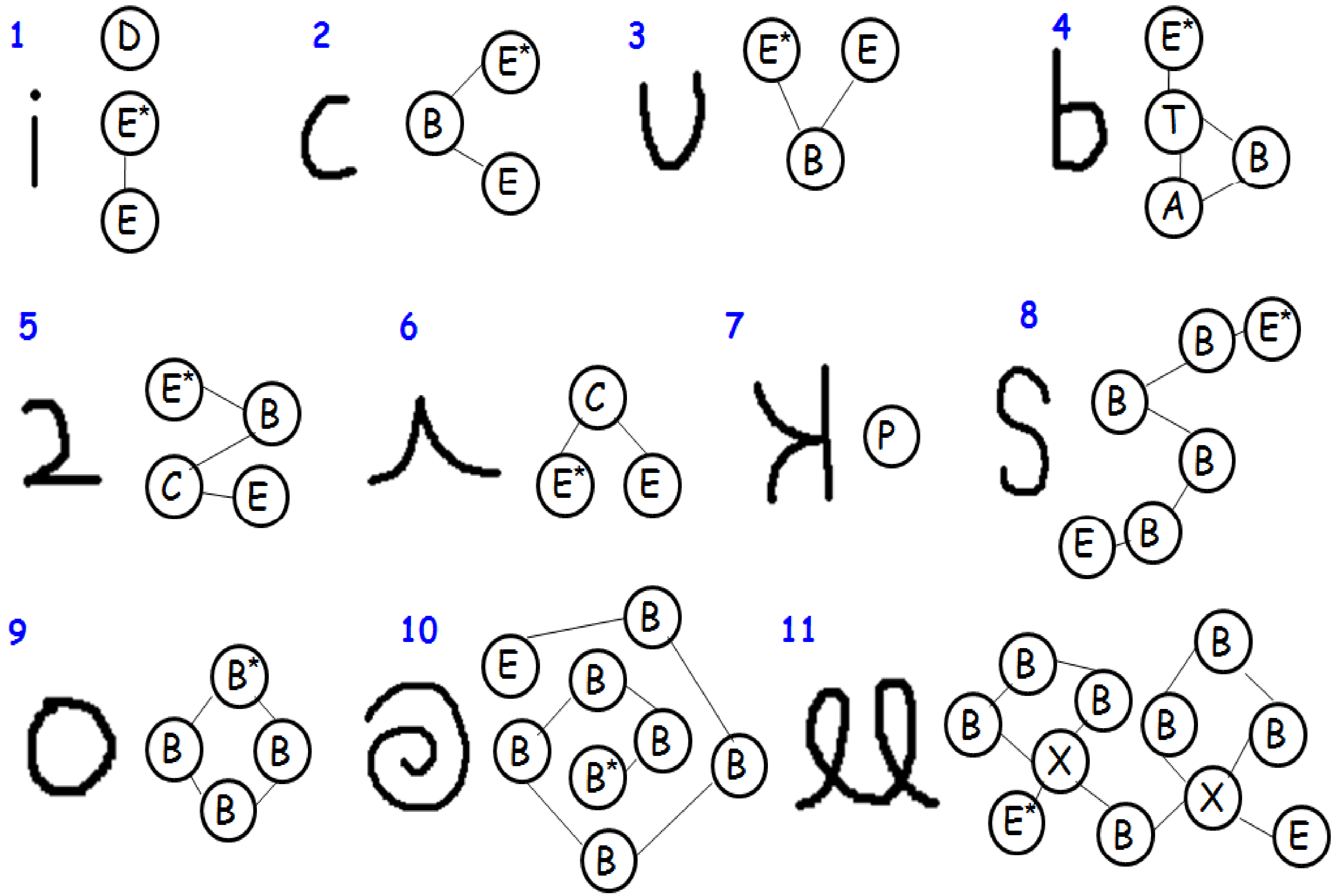
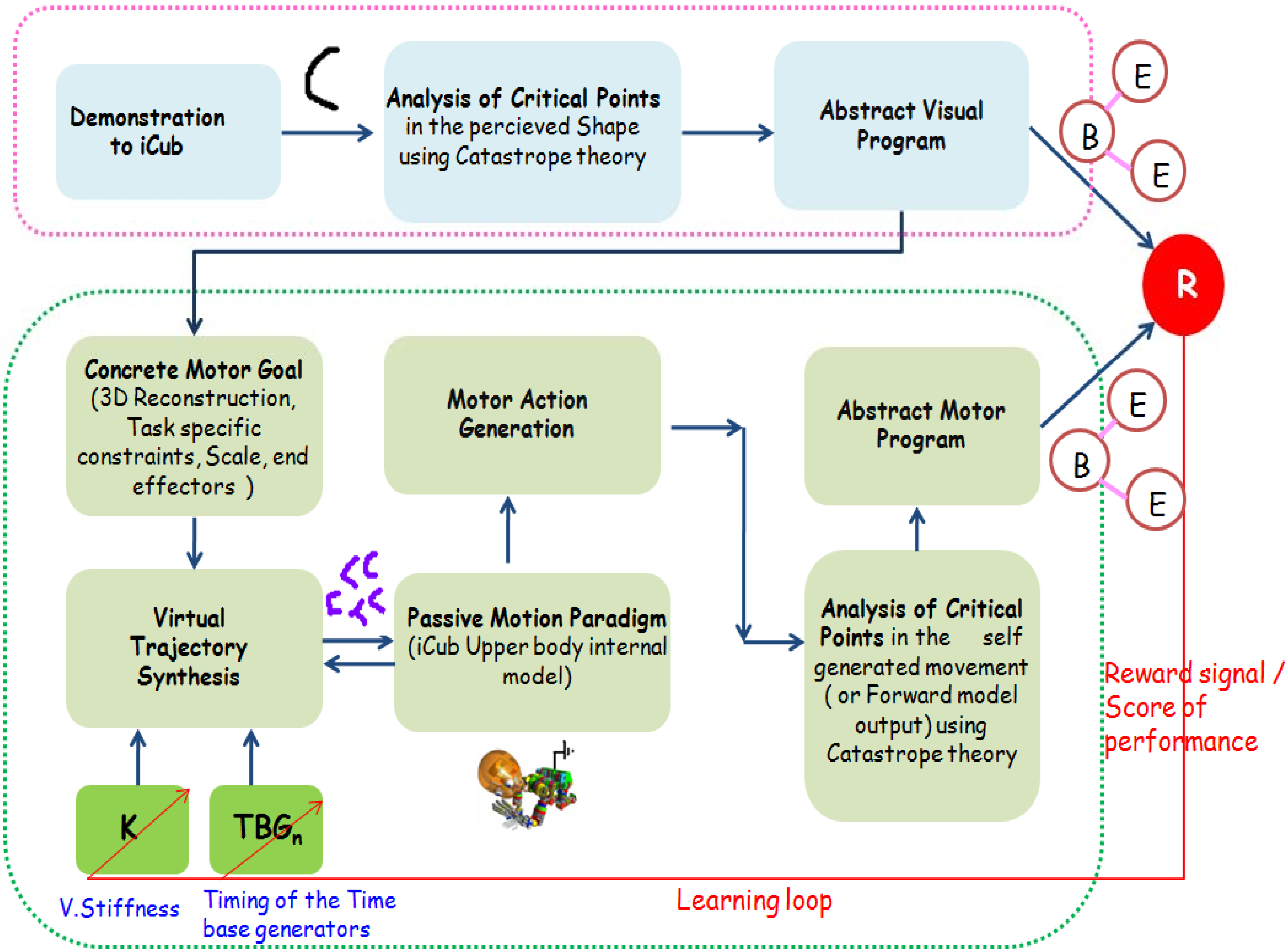
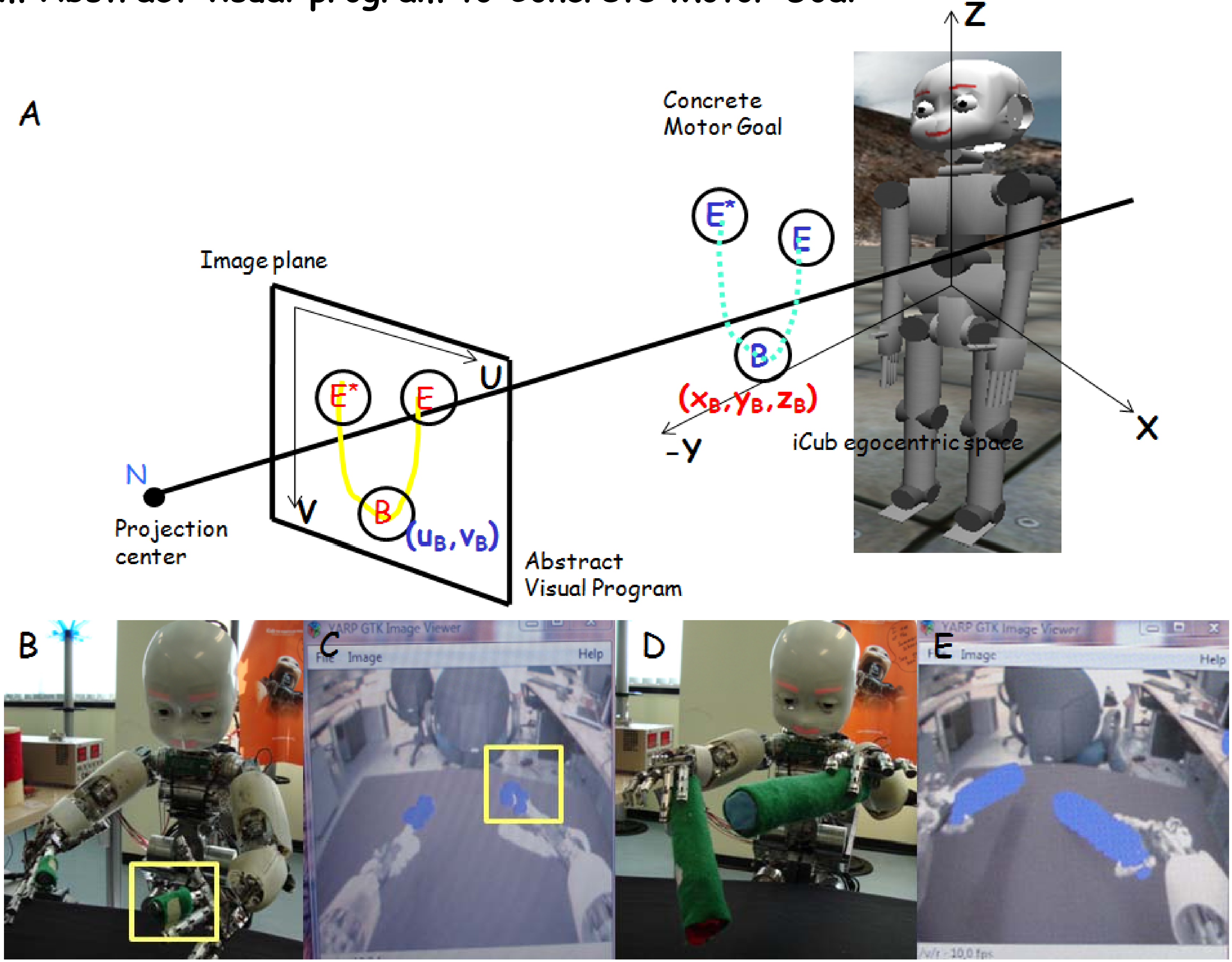
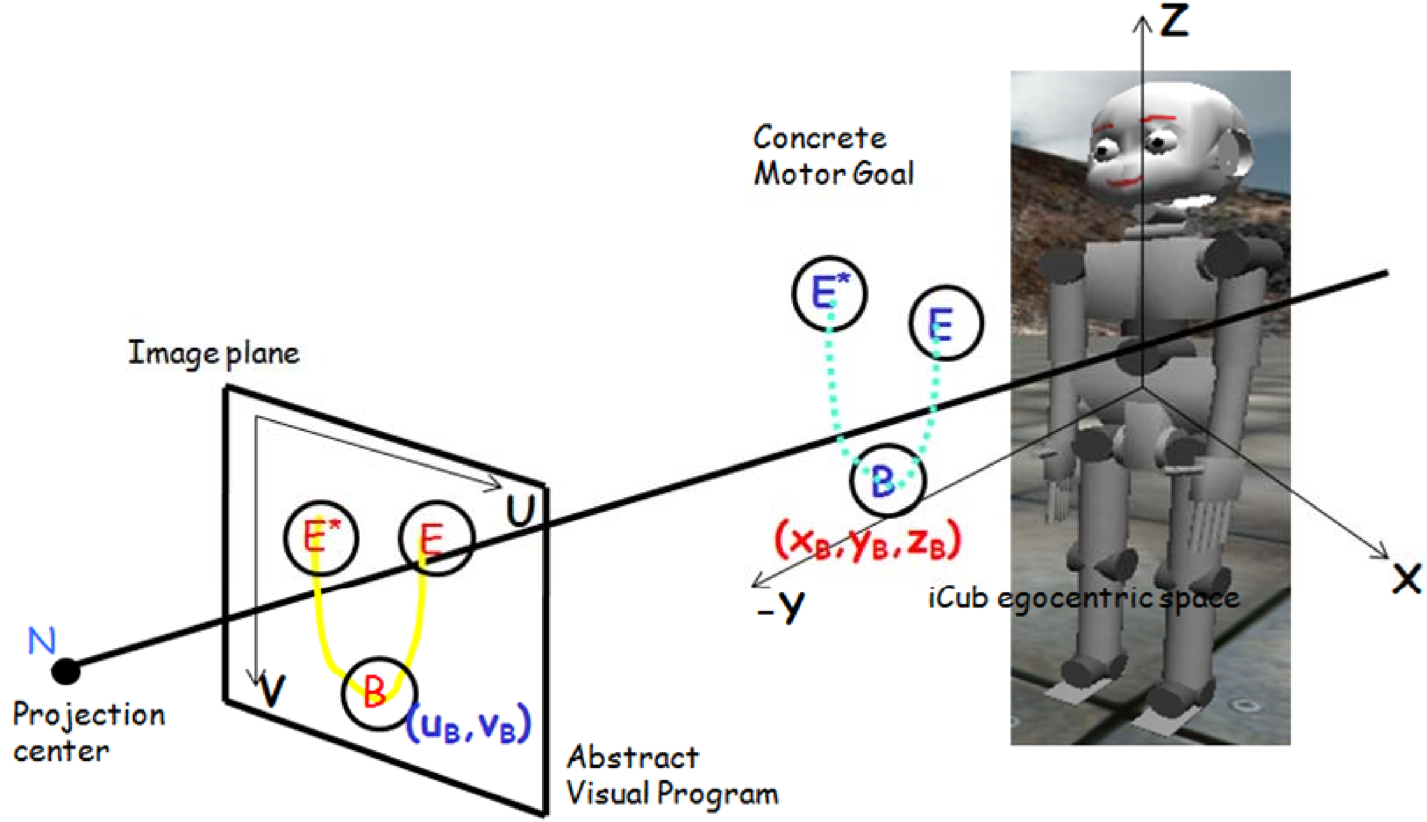


Shapes and Shapeing: Information flows

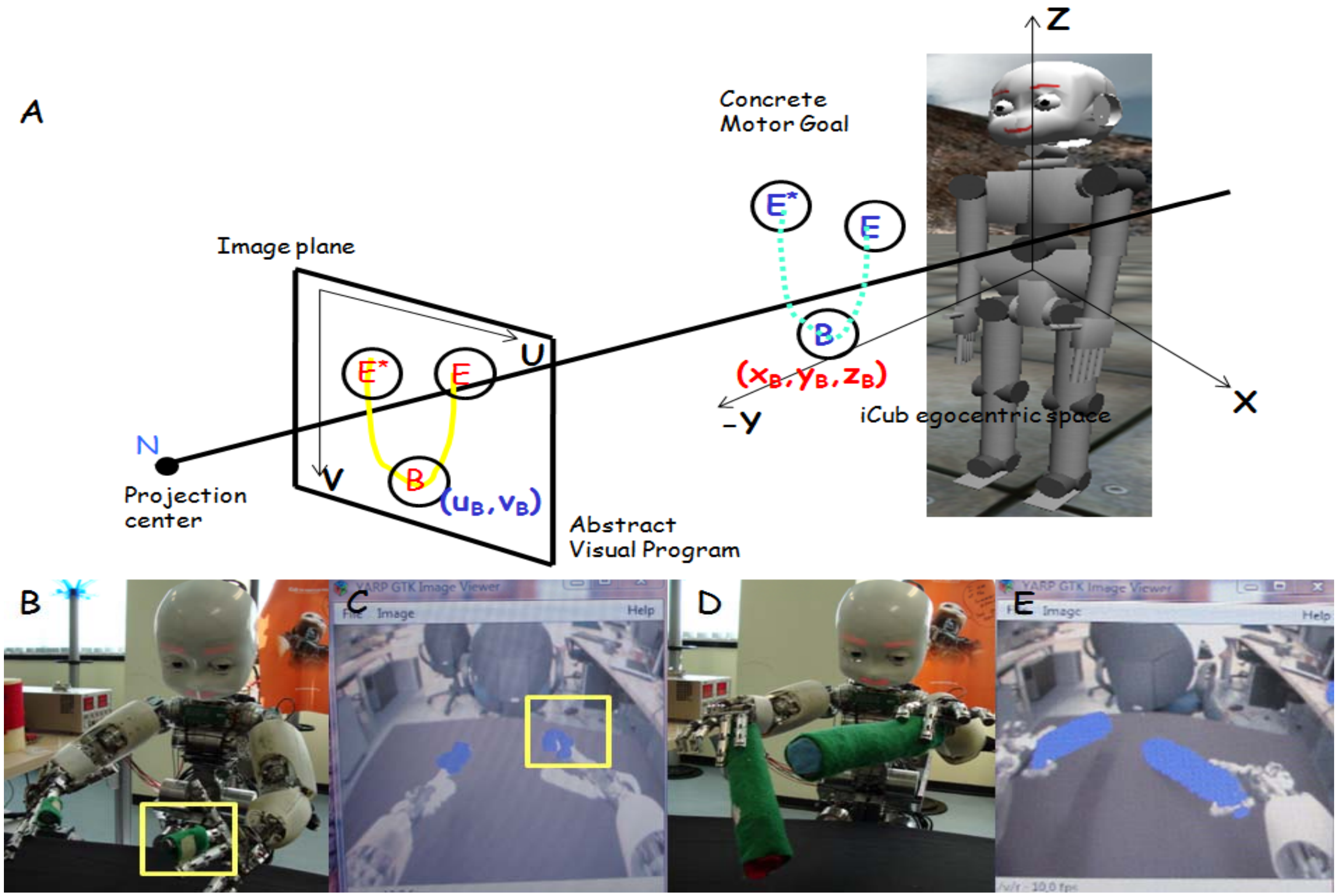


From Abstract visual program to Concrete Motor Goal





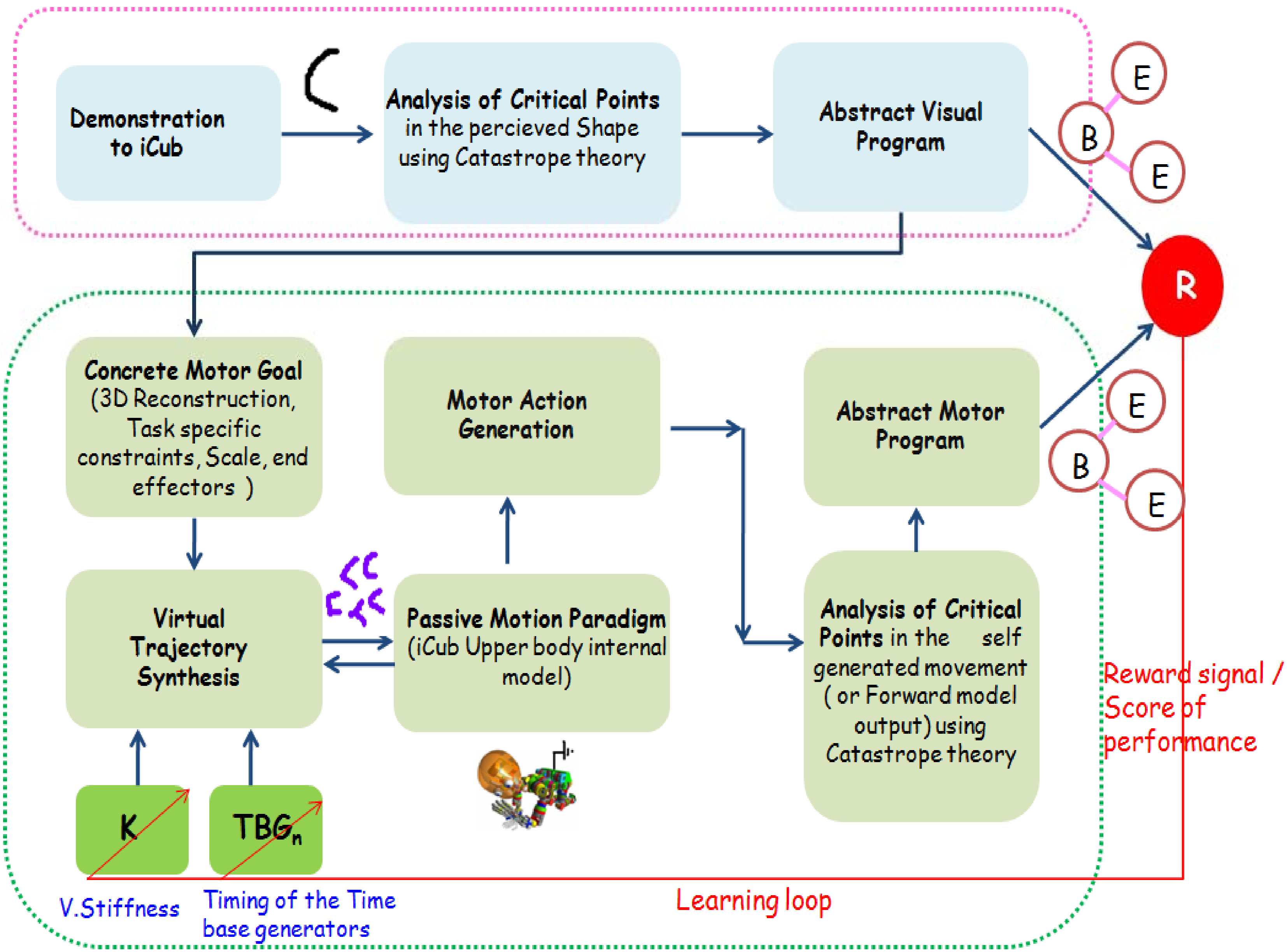
$$\begin{cases} u = \dfrac{L_1 x + L_2 y + L_3 z + L_4}{L_9 x + L_{10} y + L_{11} z + 1} \\ v = \dfrac{L_5 x + L_6 y + L_7 z + L_8}{L_9 x + L_{10} y + L_{11} z + 1} \end{cases}$$



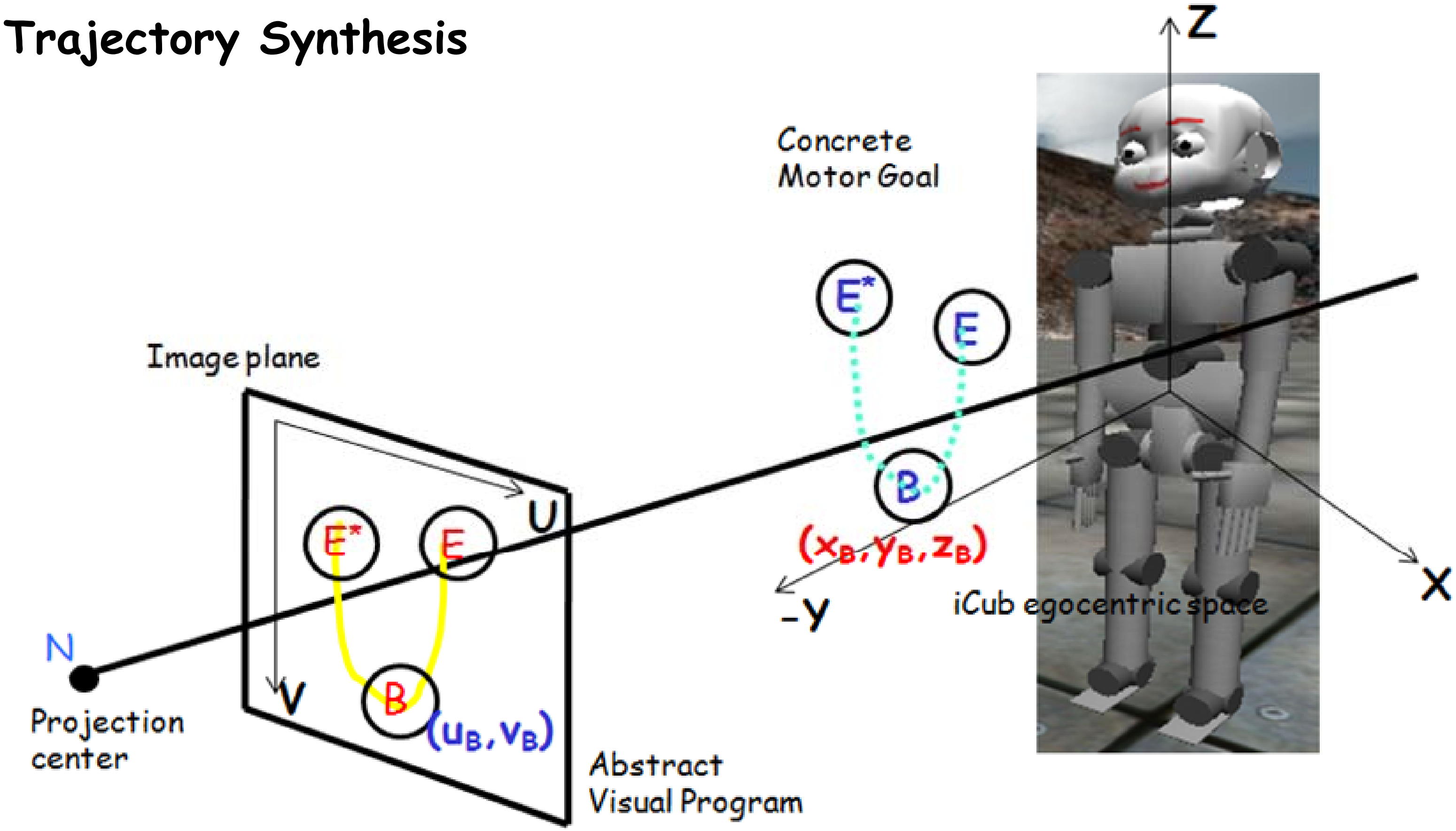
$$\begin{bmatrix} u_1 \\ v_1 \\ \cdots\cdot \\ u_N \\ v_N \end{bmatrix} = \begin{bmatrix} x_1 & y_1 & z_1 & 1 & 0 & 0 & 0 & 0 & -u_1x_1 & -u_1y_1 & -u_1z_1 \\ 0 & 0 & 0 & 0 & x_1 & y_1 & z_1 & 1 & -v_1x_1 & -v_1y_1 & -v_1z_1 \\ \cdots\cdots\cdots & & & & & & & & & & \\ x_N & y_N & z_N & 1 & 0 & 0 & 0 & 0 & -u_Nx_N & -u_Ny_N & -u_Nz_N \\ 0 & 0 & 0 & 0 & x_N & y_N & z_N & 1 & -v_Nx_N & -v_Ny_N & -v_Nz_N \end{bmatrix} \begin{bmatrix} L_1 \\ L_2 \\ \cdots \\ L_{11} \end{bmatrix}$$

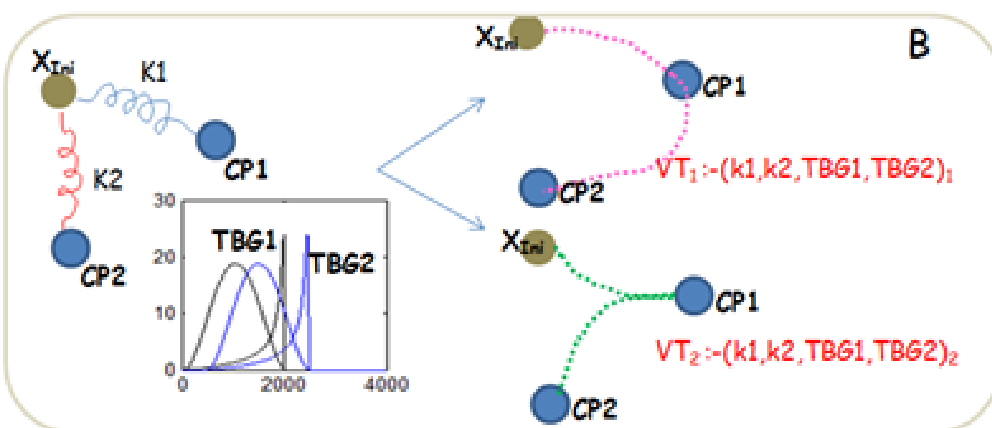
$$U = A \cdot L \quad \text{or} \quad L = \left[A^T A\right]^{-1} A^T \cdot U$$

Shapes and Shapeing: Information flows



Virtual Trajectory Synthesis



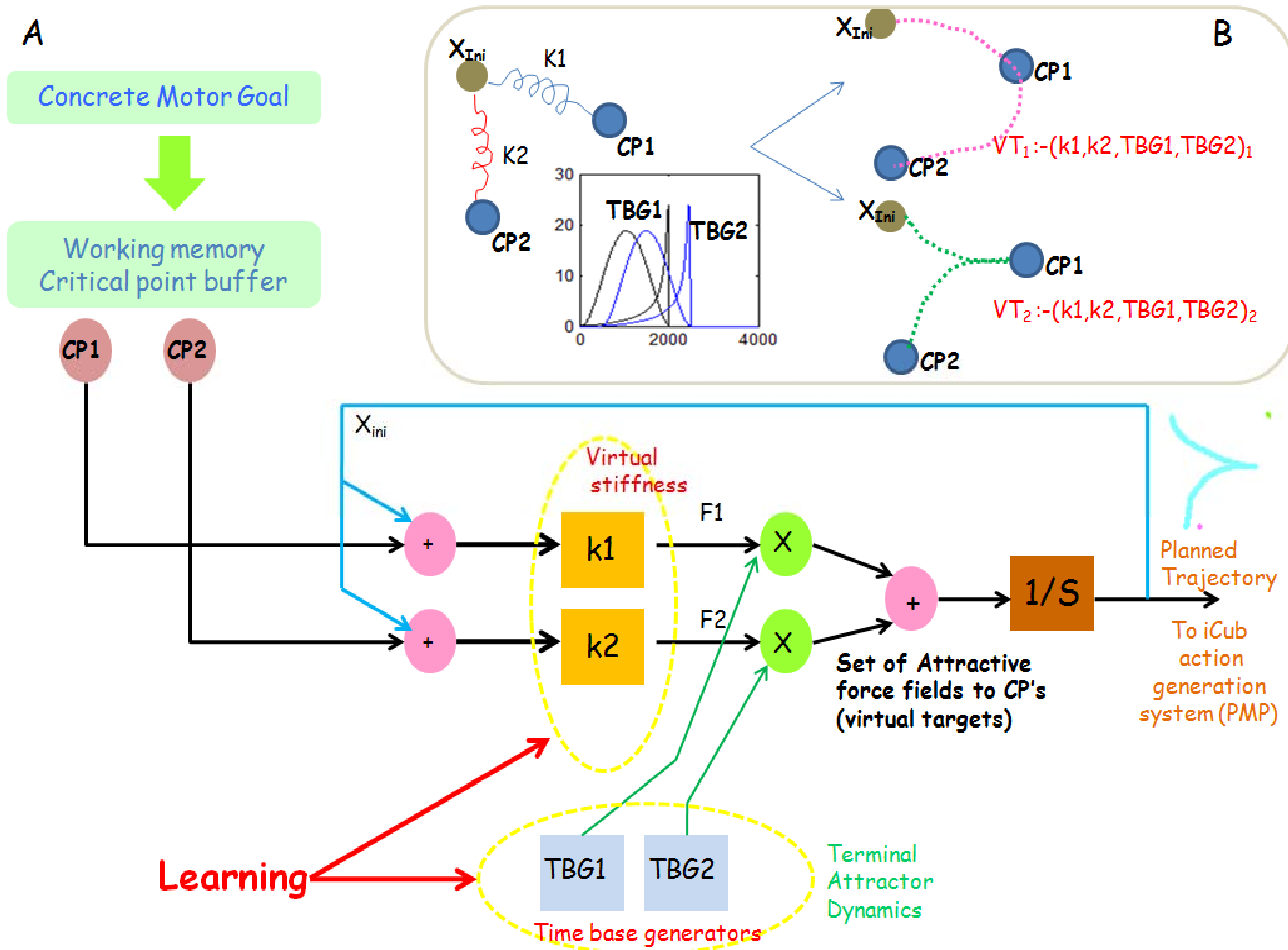


Discrete set of critical points

To a

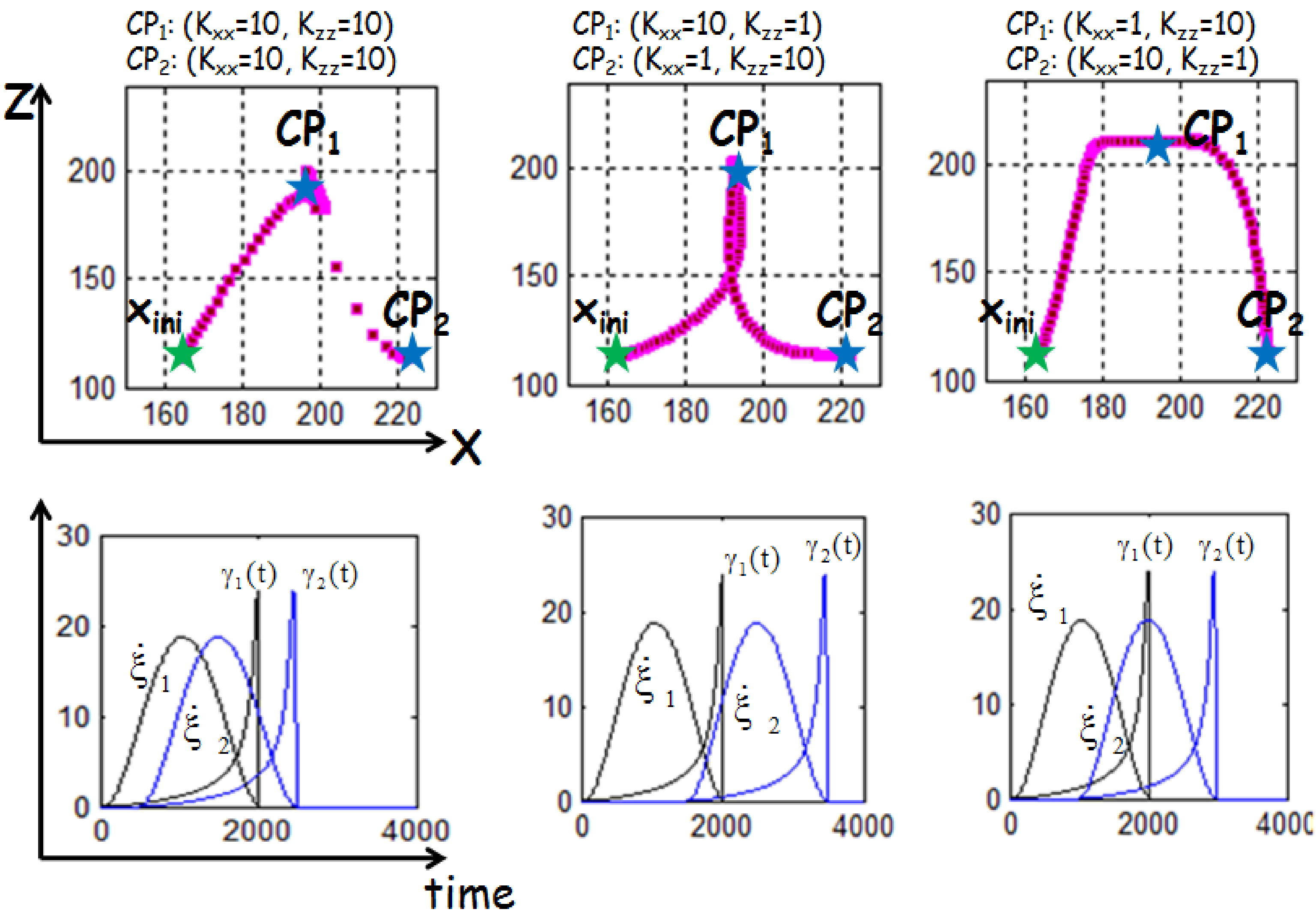
Continuous trajectory

From Concrete Motor Goal to Virtual Trajectory

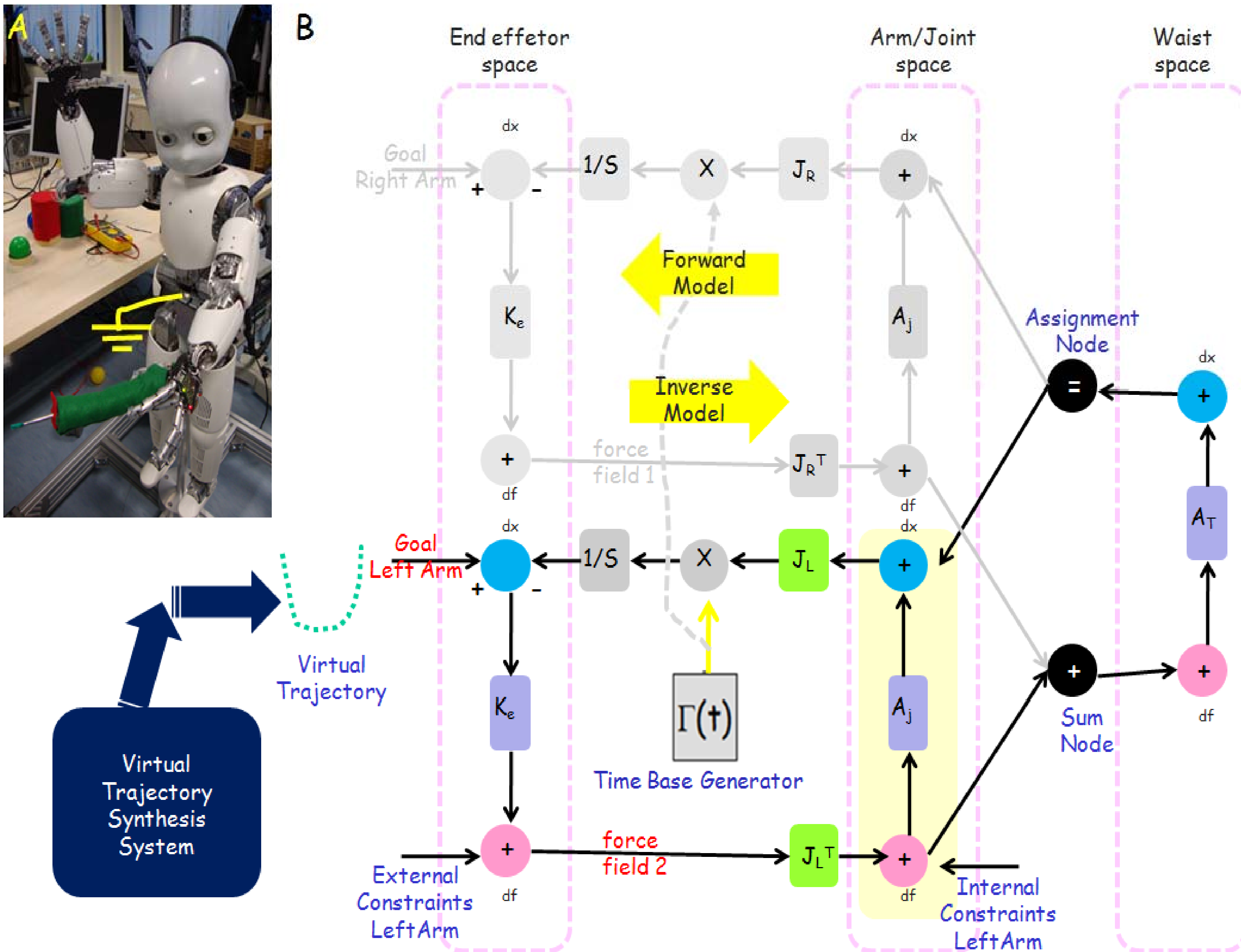


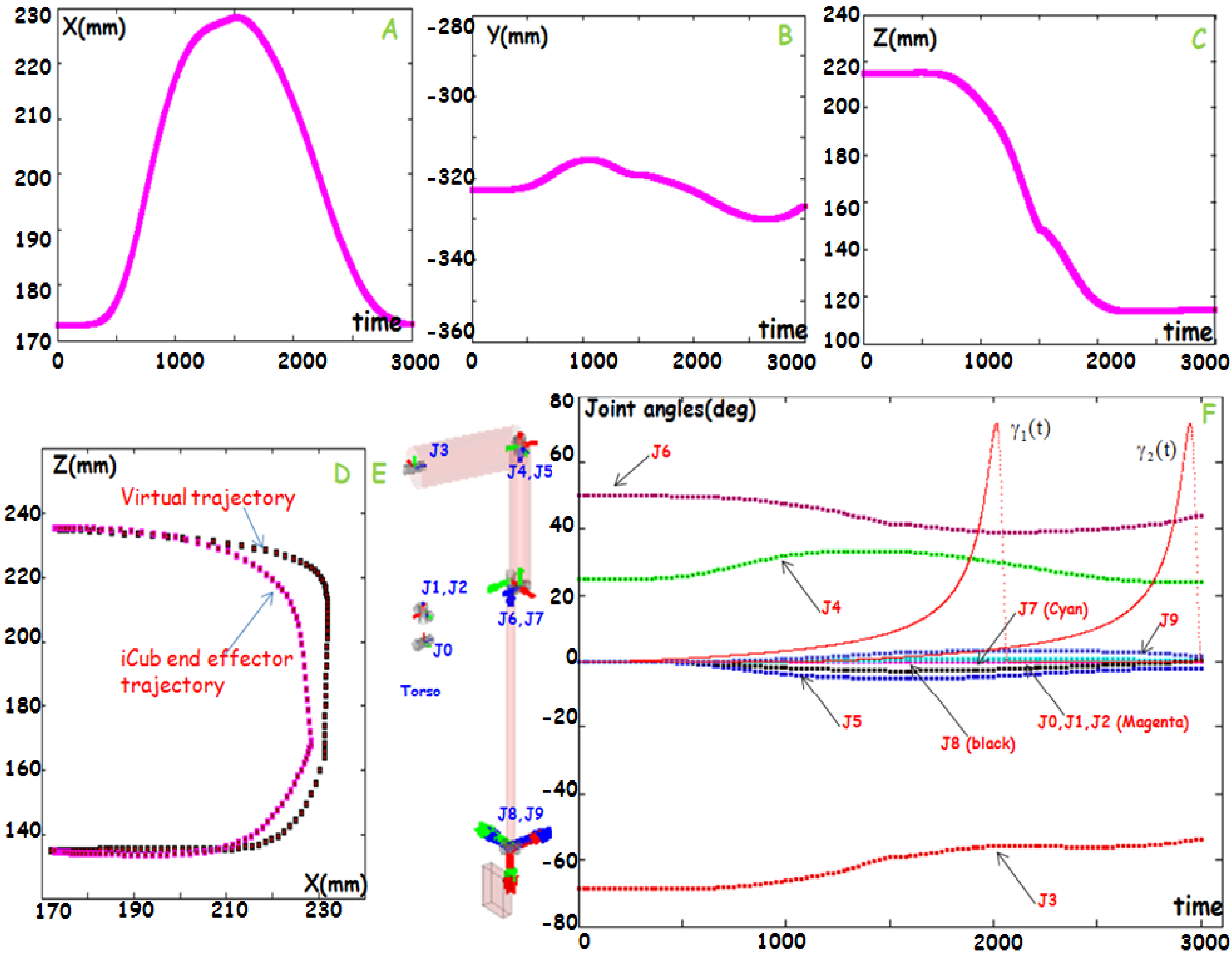
Virtual Trajectory Synthesis

Changing Stiffness and Timing to generate a range of Shapes



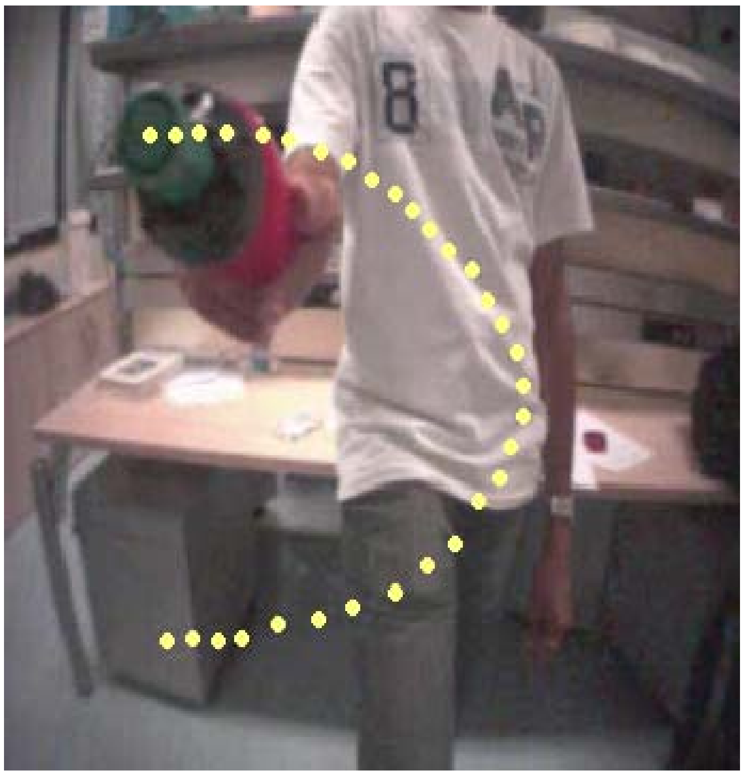
From Virtual Trajectory to Motor Action

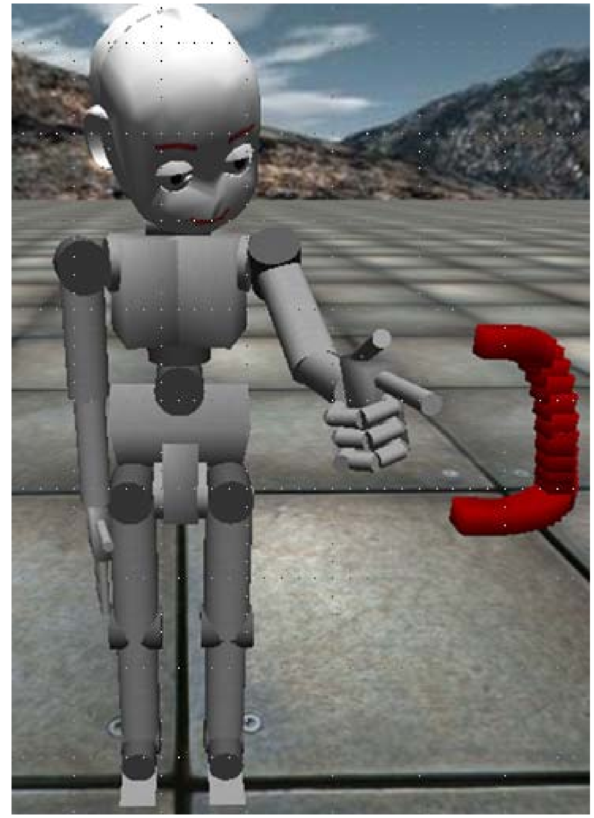




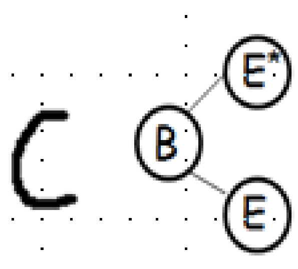
X(mm)
A
time
Y(mm)
B
time
Z(mm)
C
time
Z(mm)
D
Virtual trajectory
iCub end effector trajectory
X(mm)
E
J3
J4,J5
J1,J2
J6,J7
J0
Torso
J8,J9
Joint angles(deg)
F
J6
$\gamma_1(t)$
$\gamma_2(t)$
J4
J7 (Cyan)
J9
J5
J8 (black)
J0,J1,J2 (Magenta)
J3
time

Comparing abstract Motor and Visual representations to evaluate performance

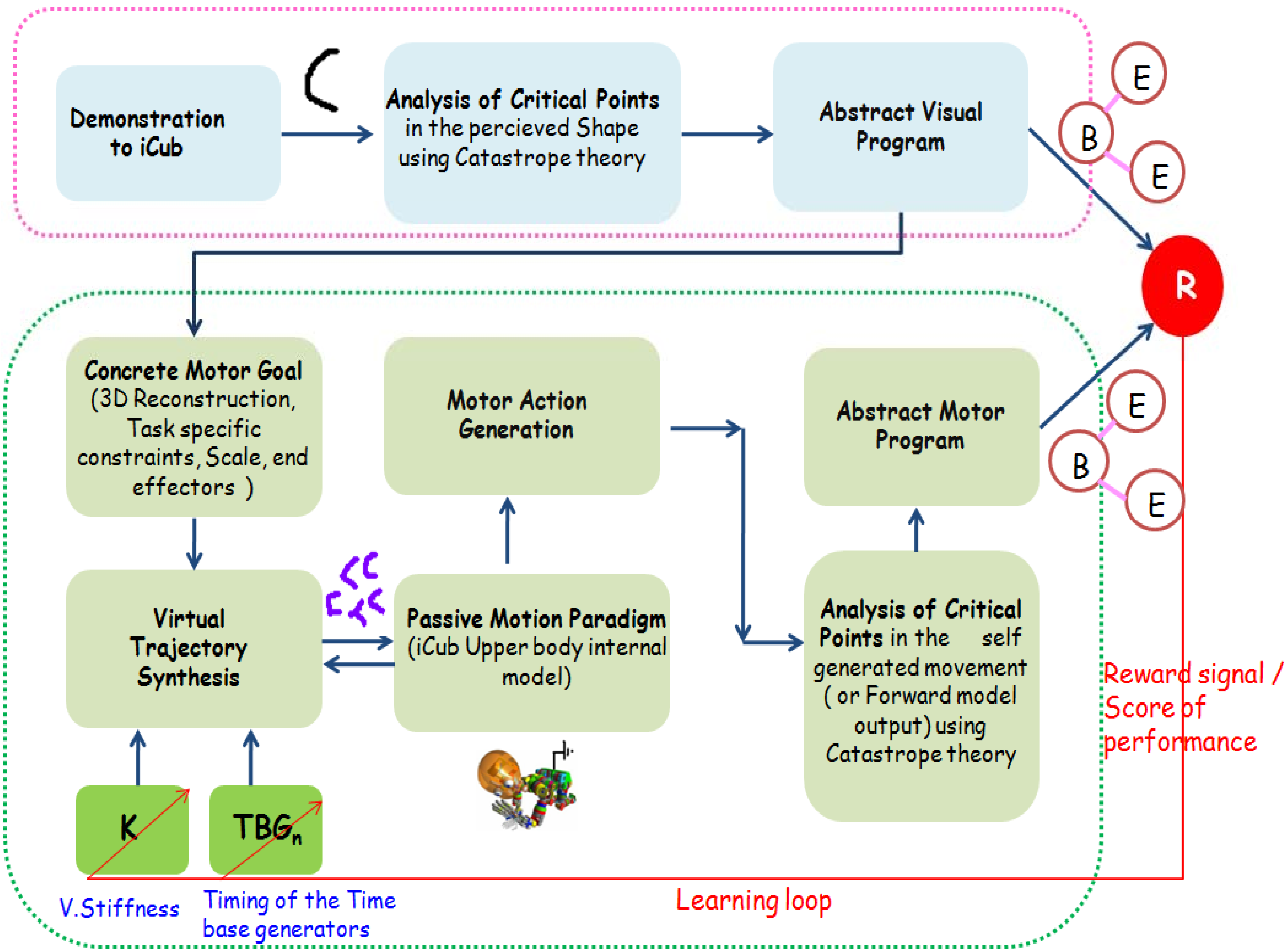




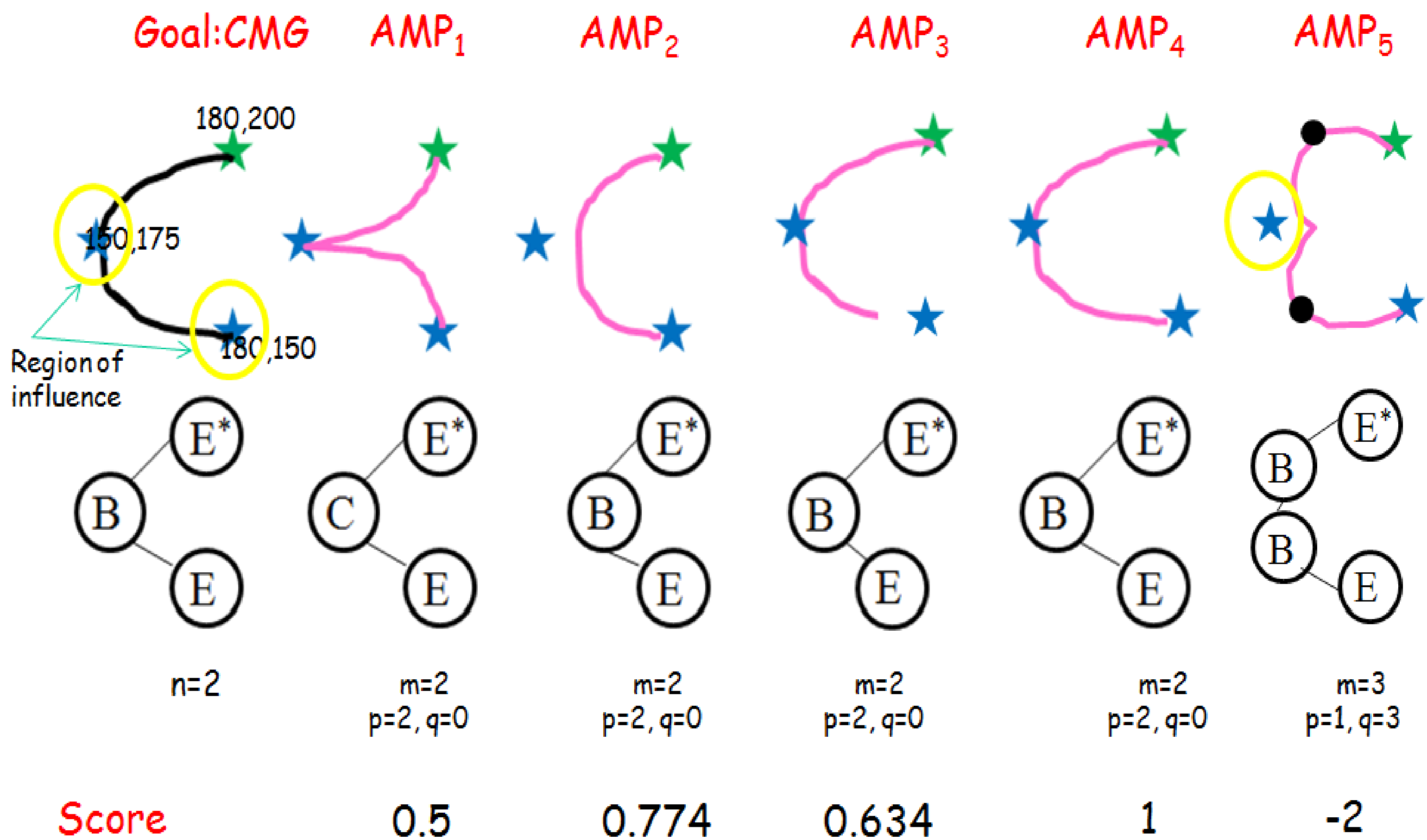
Do a Catastrophe theory analysis on SELF GENERATED Movement



Shapes and Shapeing: Information flows

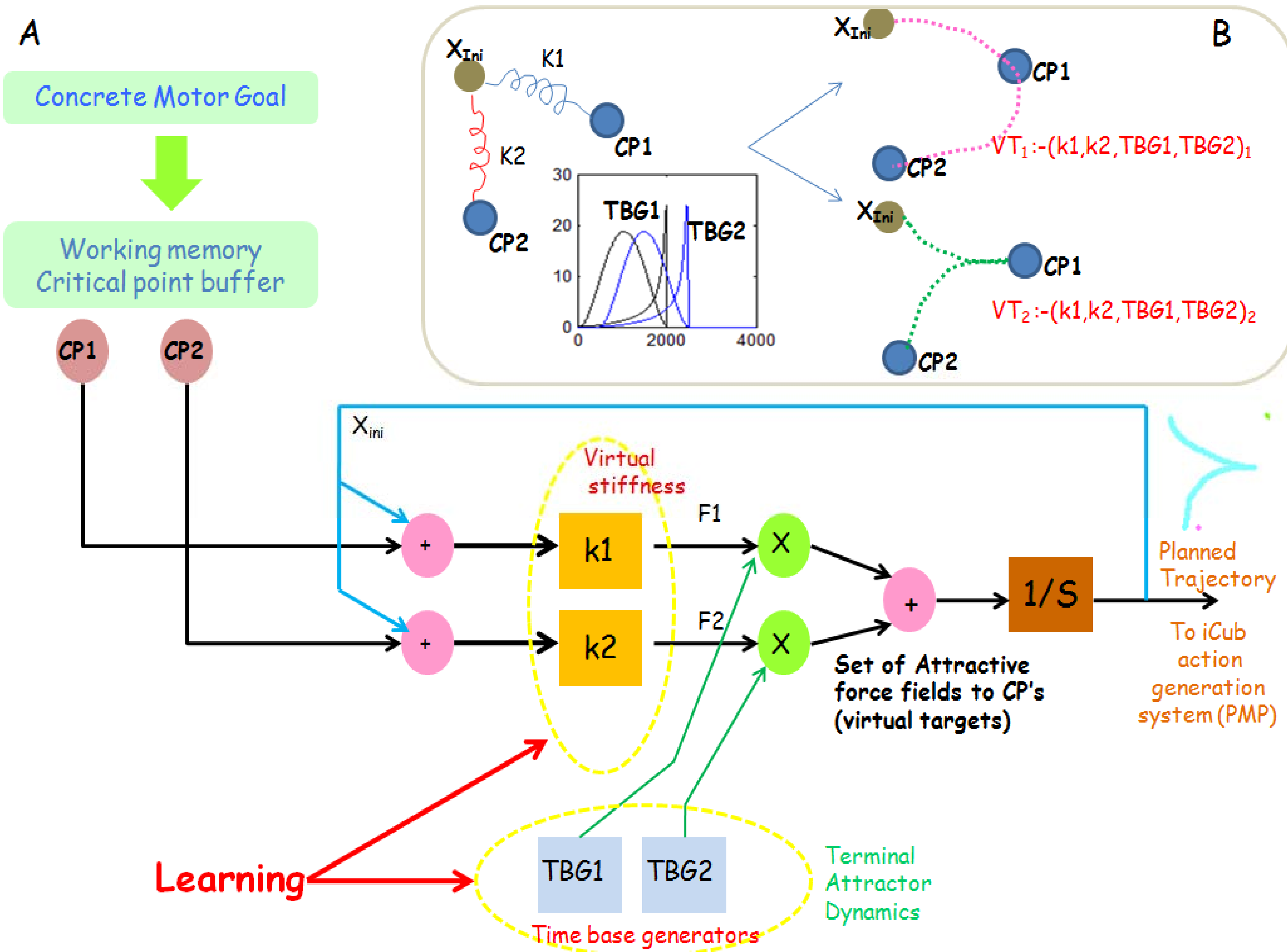


Comparing abstract Motor and Visual representations to evaluate performance

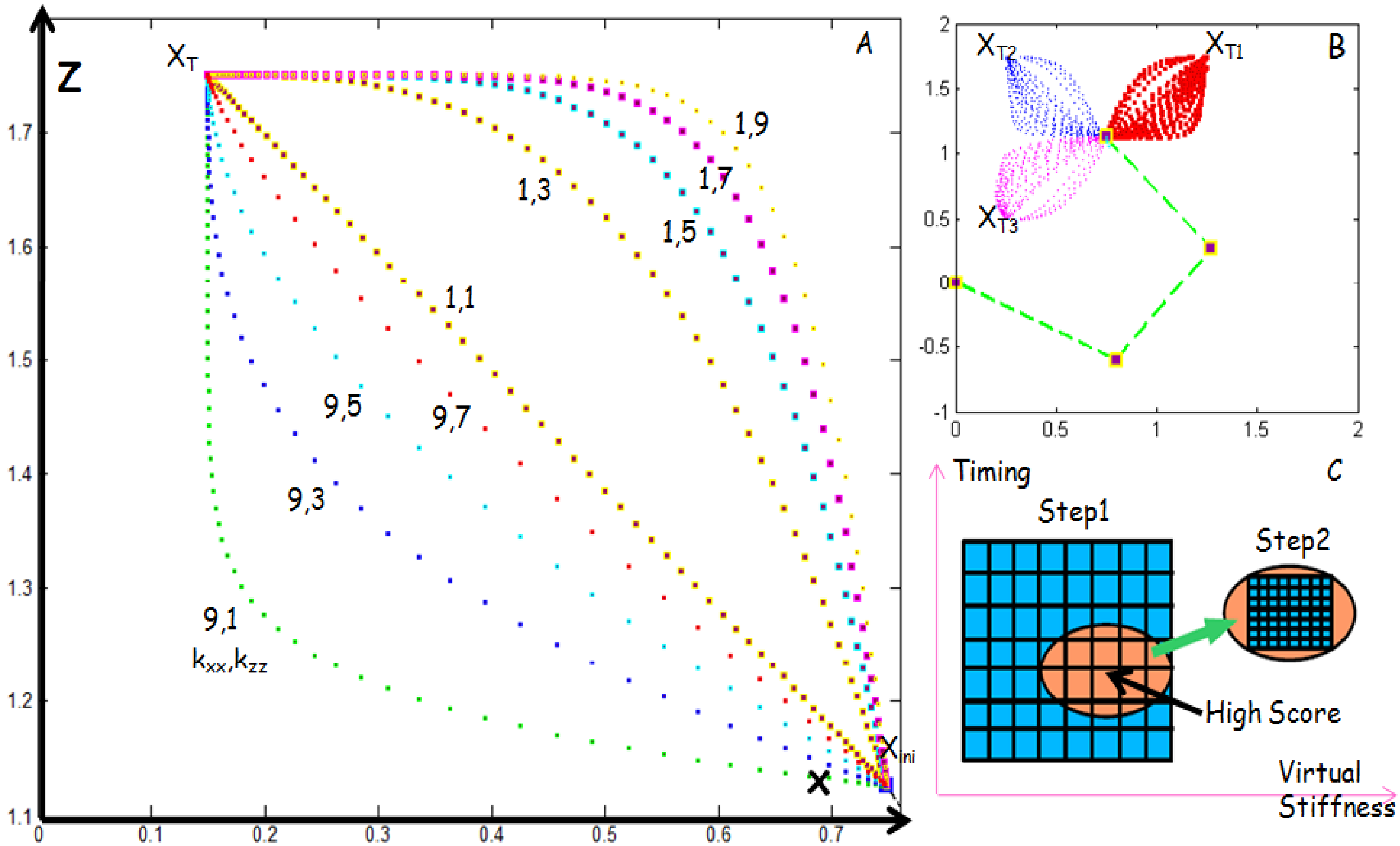


$$S = \frac{1}{p}\left(\sum_{CP=1}^{p} \Psi(CP_{S1}, CP_{S2}).dist(CP_{S1}, CP_{S2})\right) - q$$

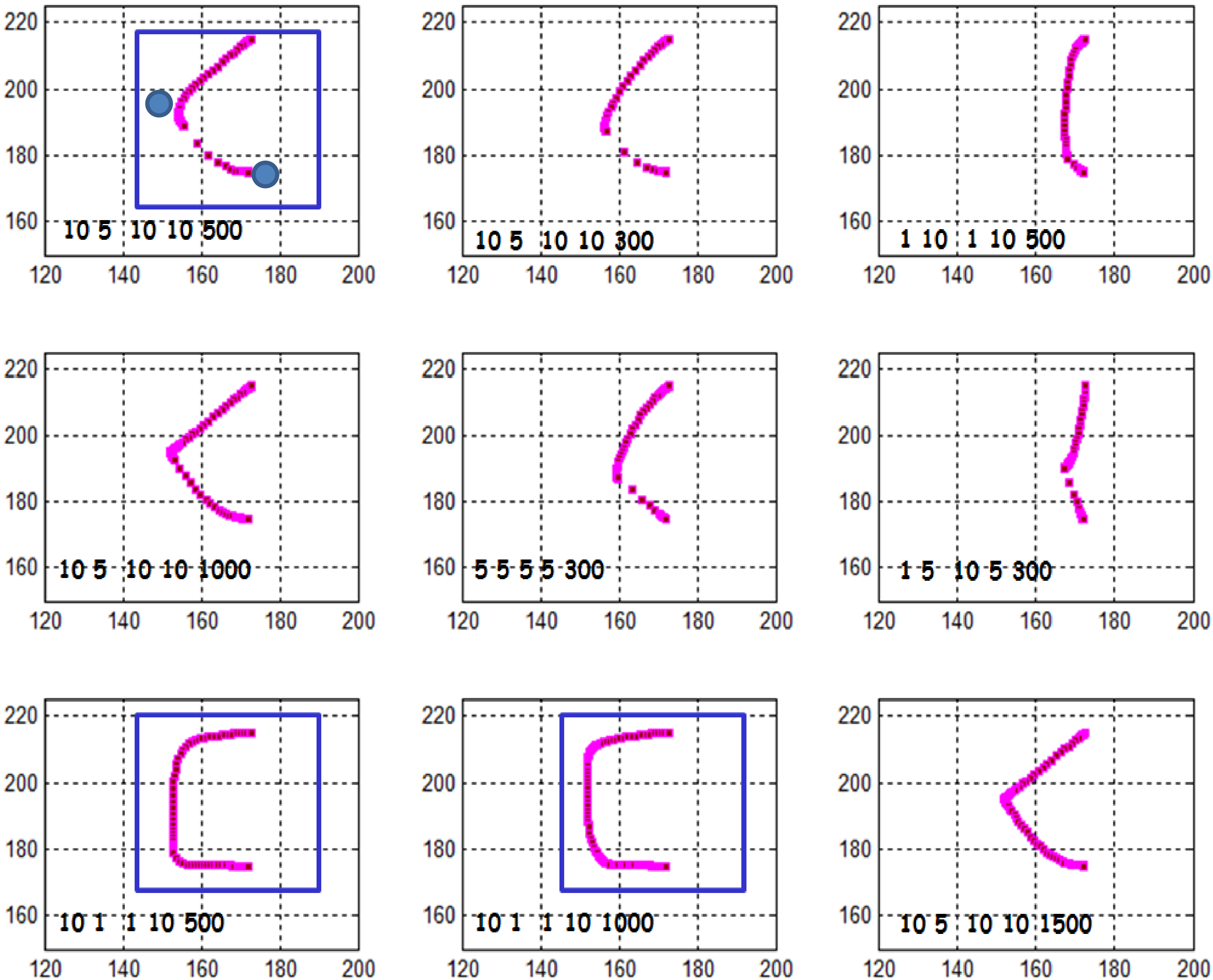
Learning to Shape

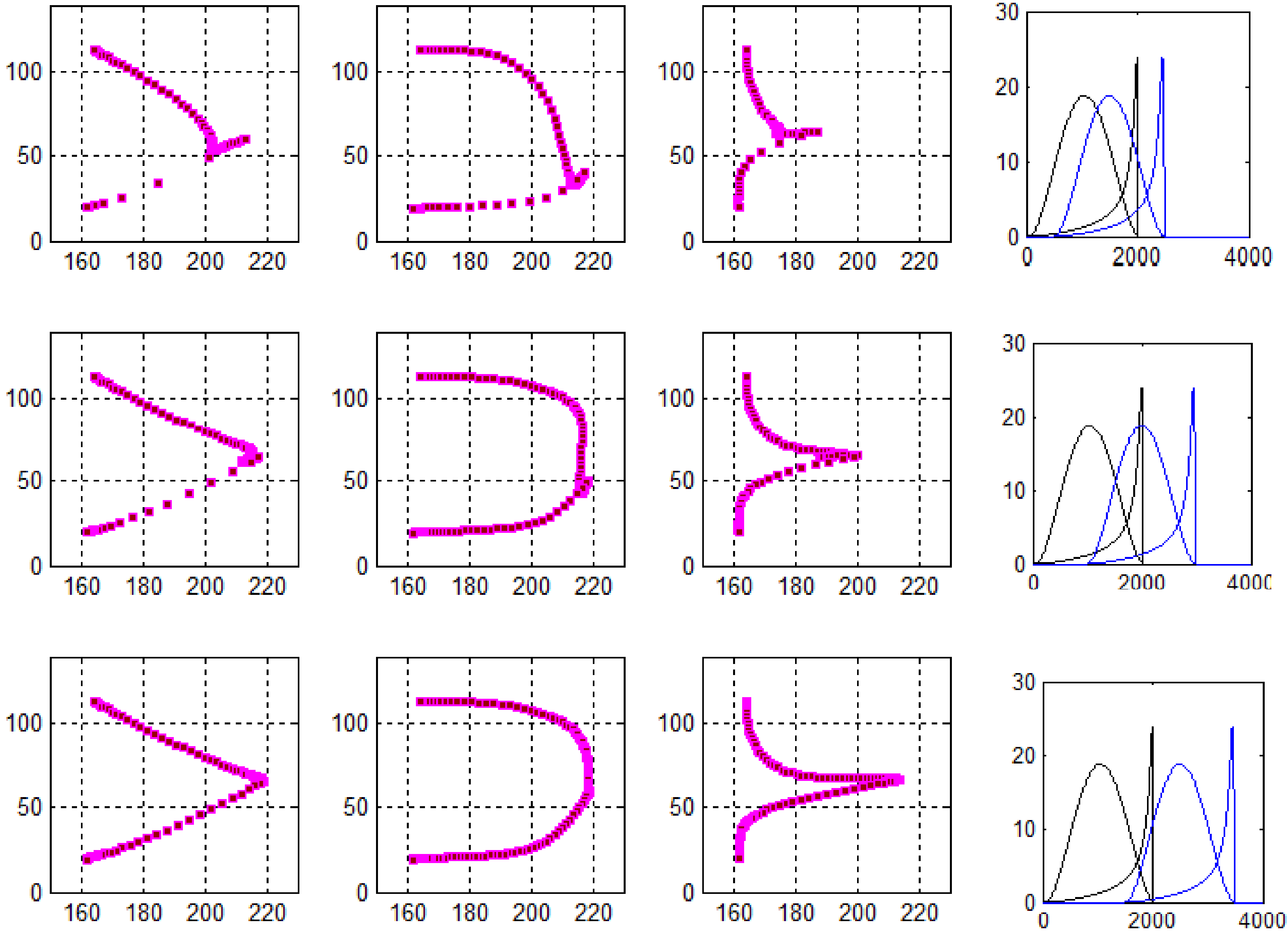


Learning to Shape: Trajectories between 2 Points in space

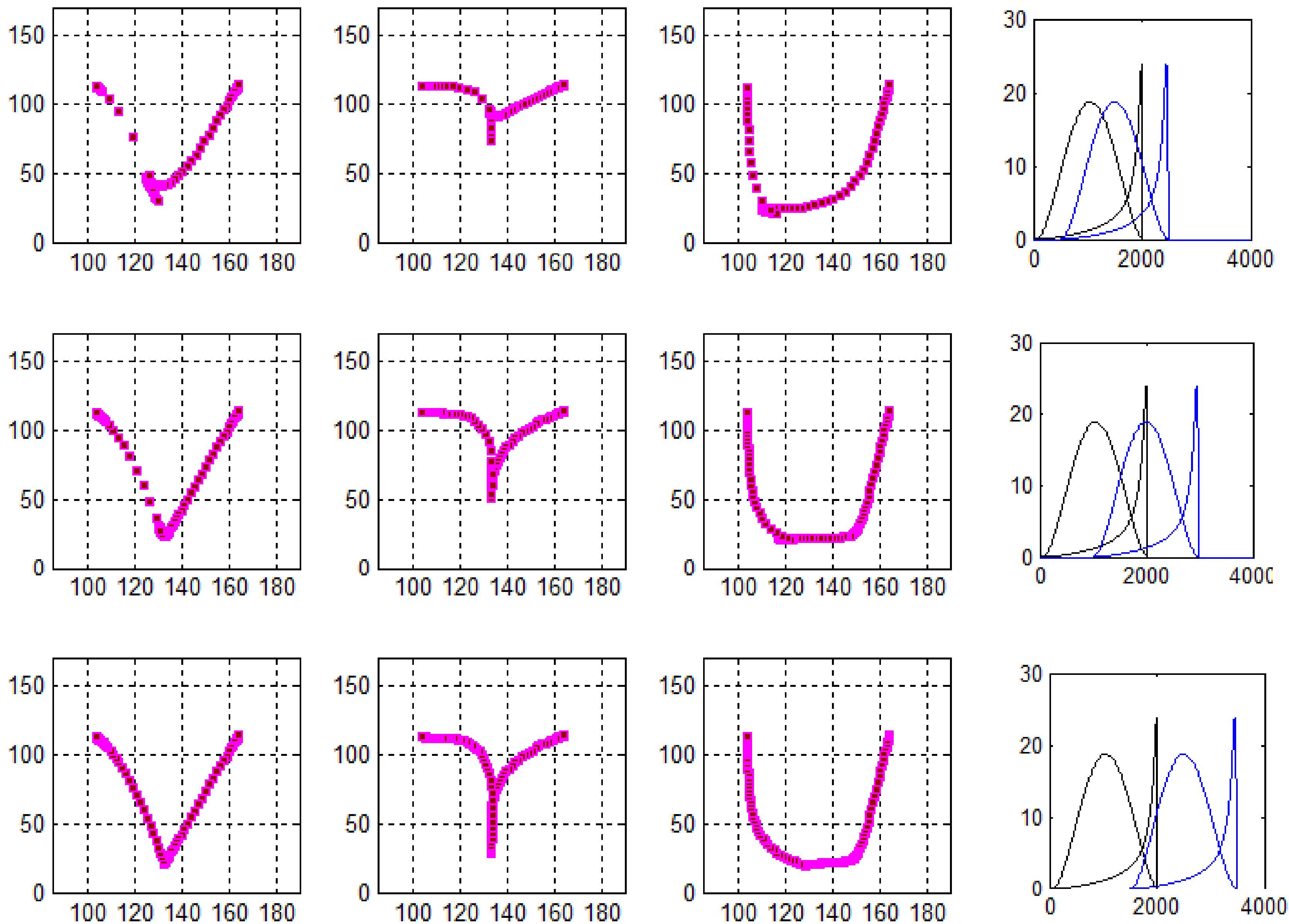


Examples of shapeing 'C'

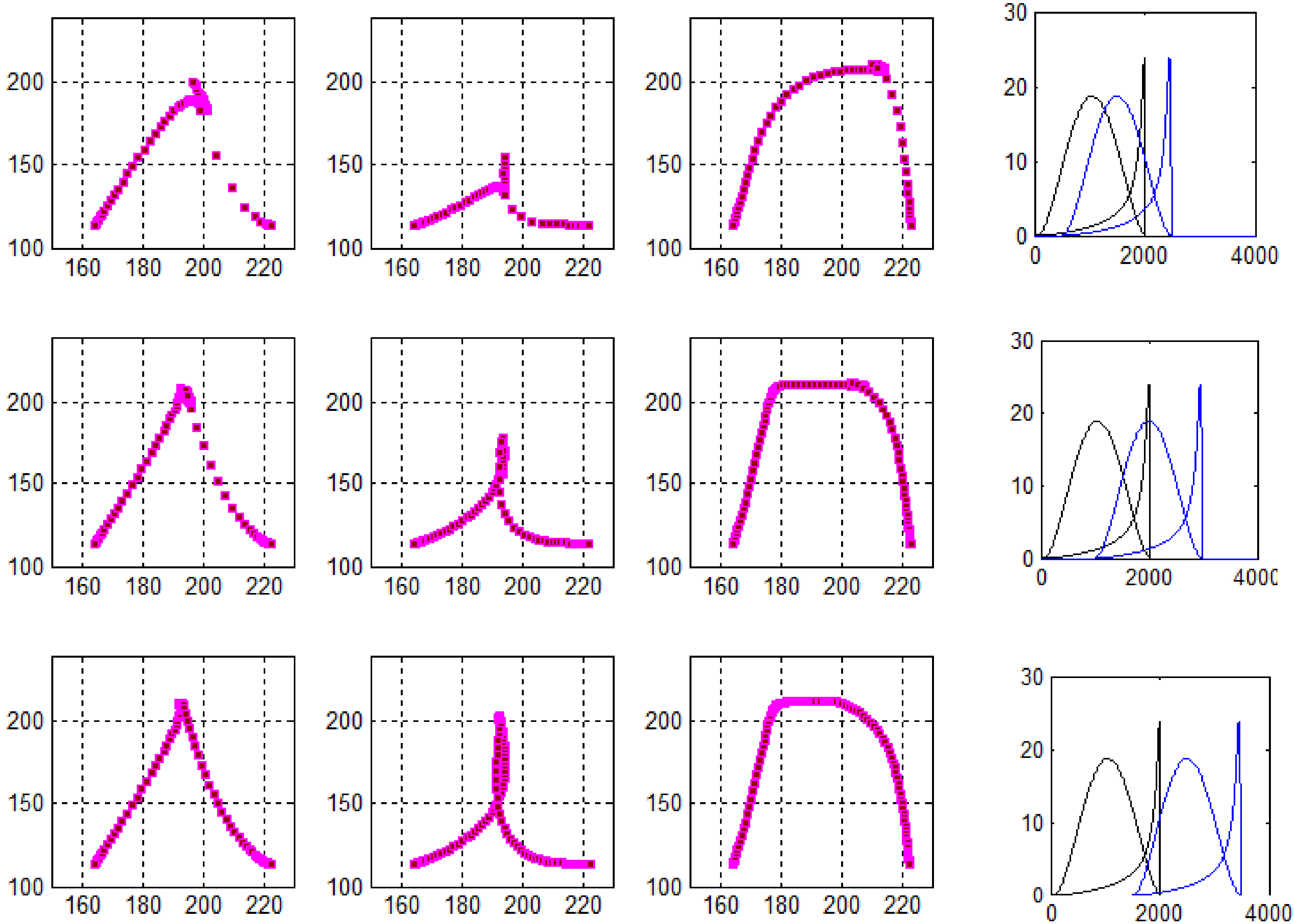




10 10 10 10 10 1 1 10 1 10 10 1



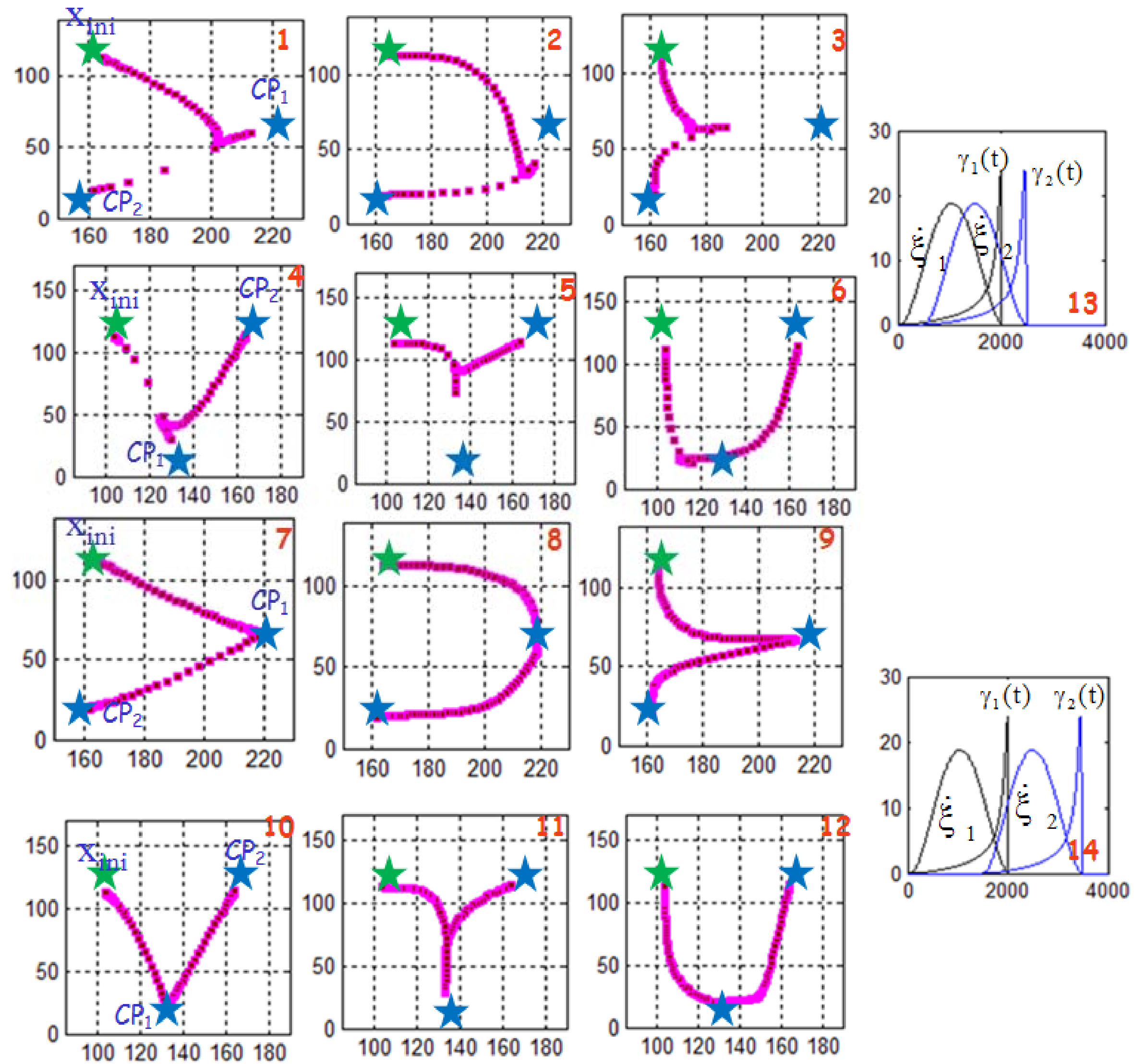
10 10 10 10 10 1 1 10 1 10 10 1



10 10 10 10   10 1 1 10   1 10 10 1

Learning to Shape: Underlying Principle ?????

Why some value of stiffness gives rise to some Shape



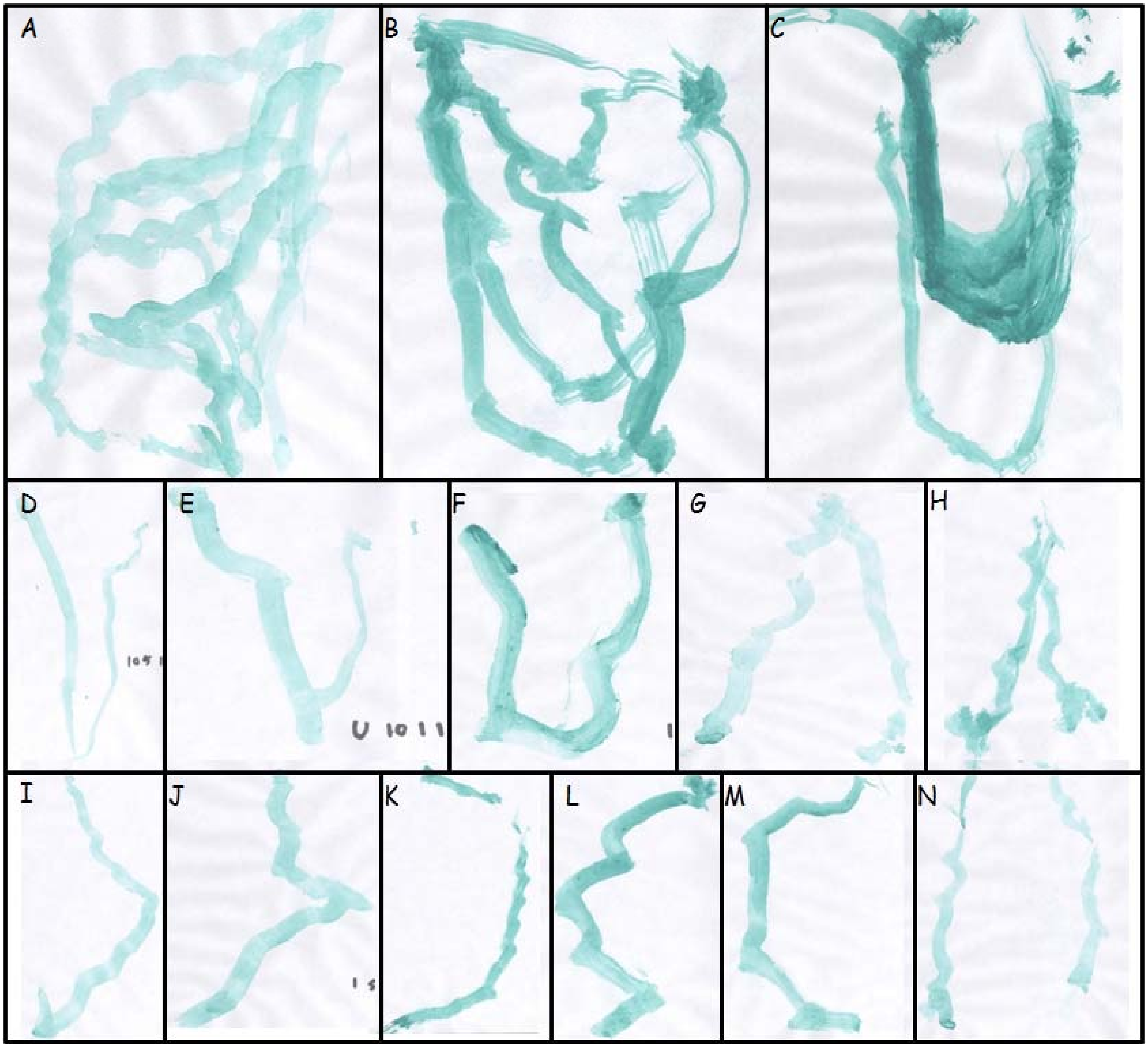
CP 1: (K xx=10, K zz=10) CP 2: (K xx=10, K zz=10)

CP 1: (K xx=10, K zz=1) CP 2: (K xx=1, K zz=10)

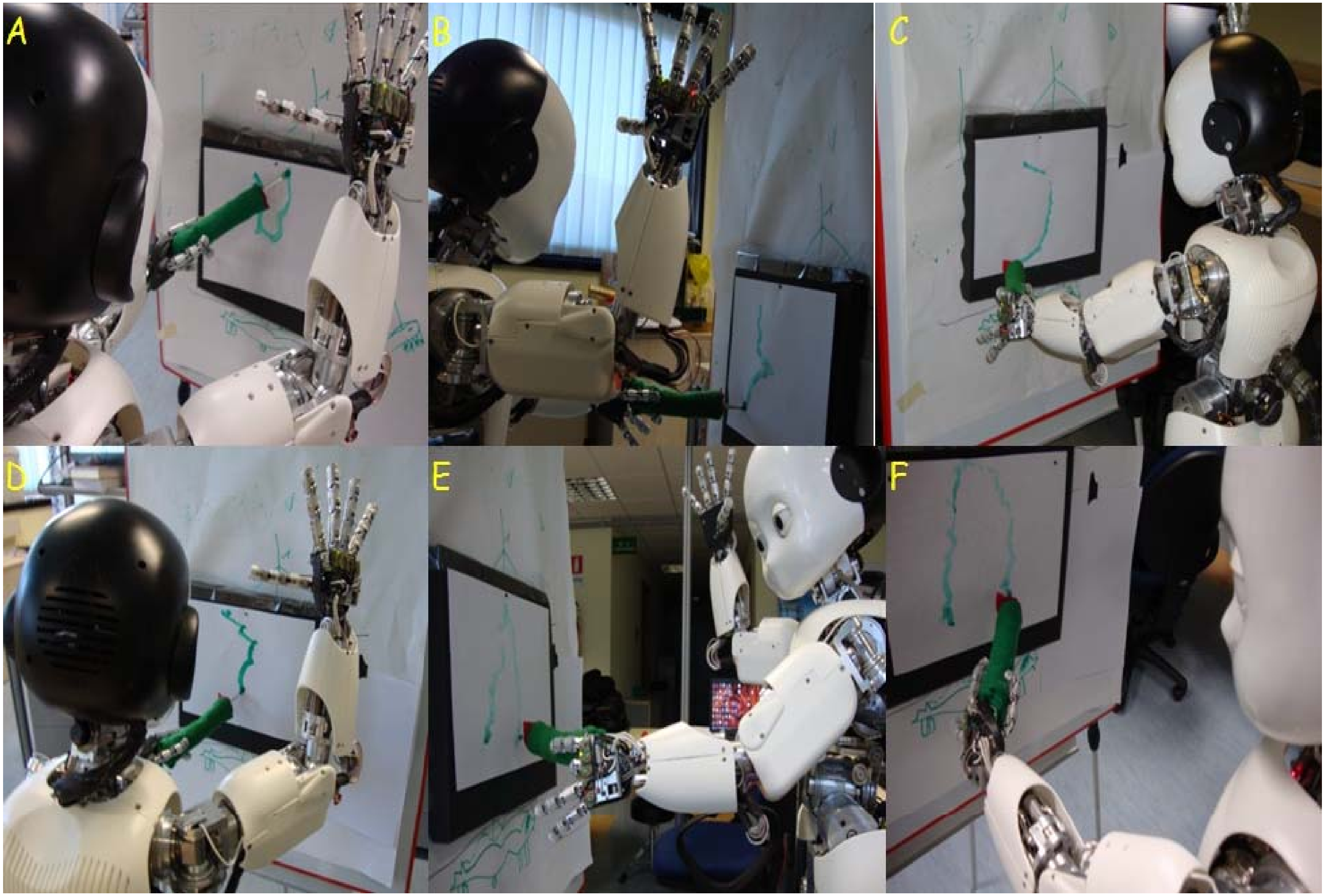
CP 1: (K xx=1, K zz=10) CP 2: (K xx=10, K zz=1)

iCubArt: First few steps

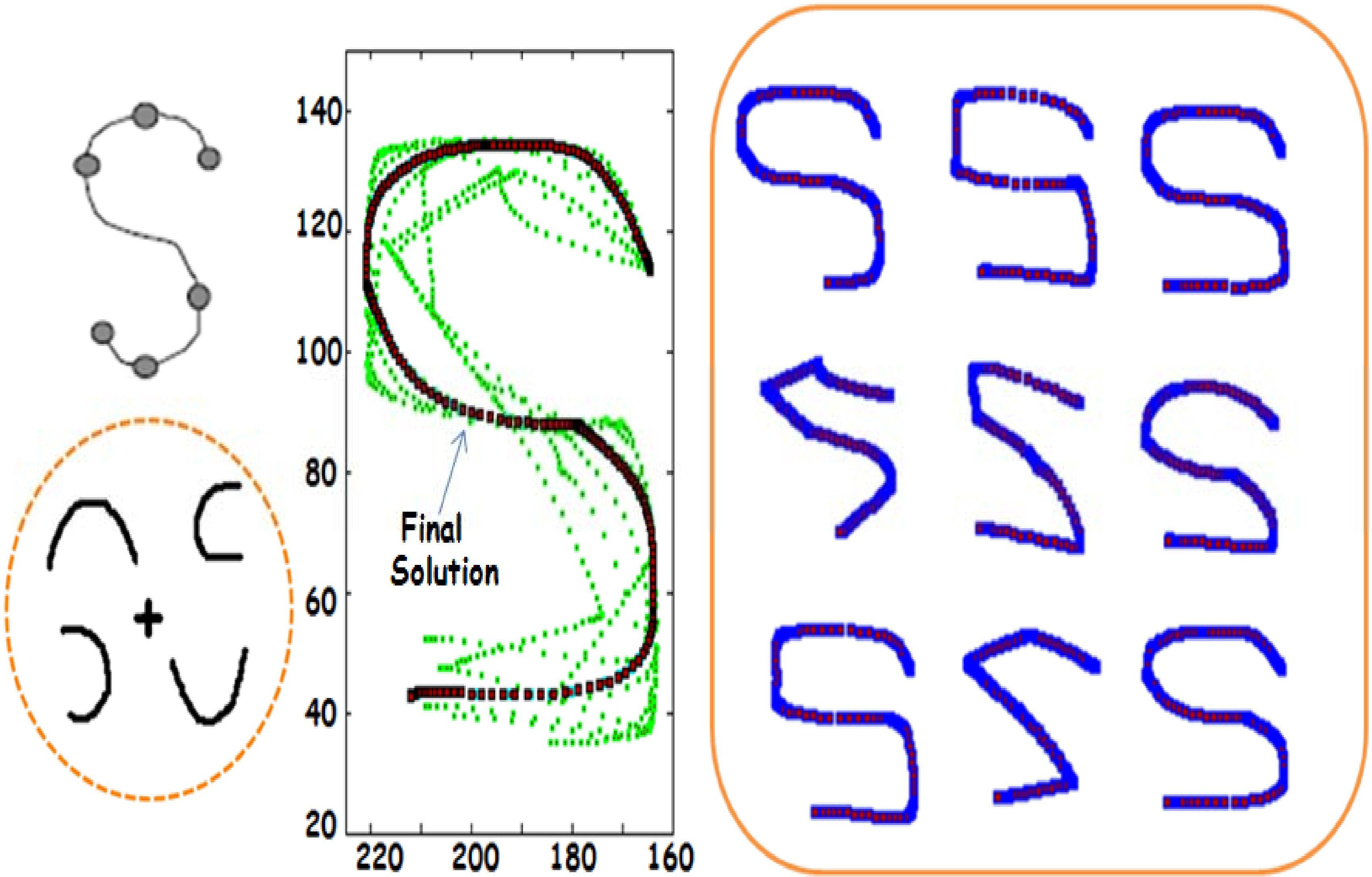
iCubArt: First drawings of iCub



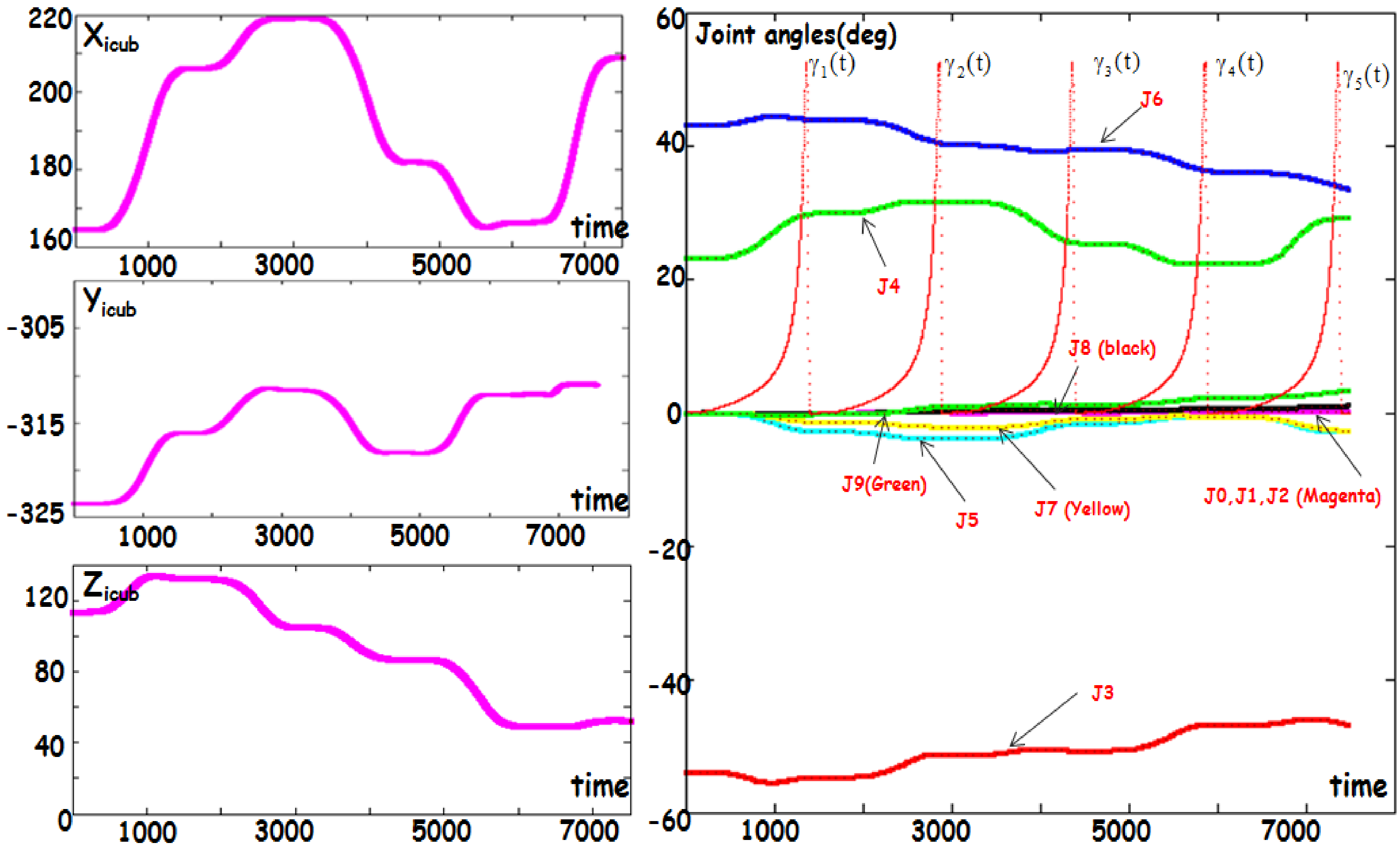
iCubArt: First drawings of iCub



Generalization during Compositional Synthesis



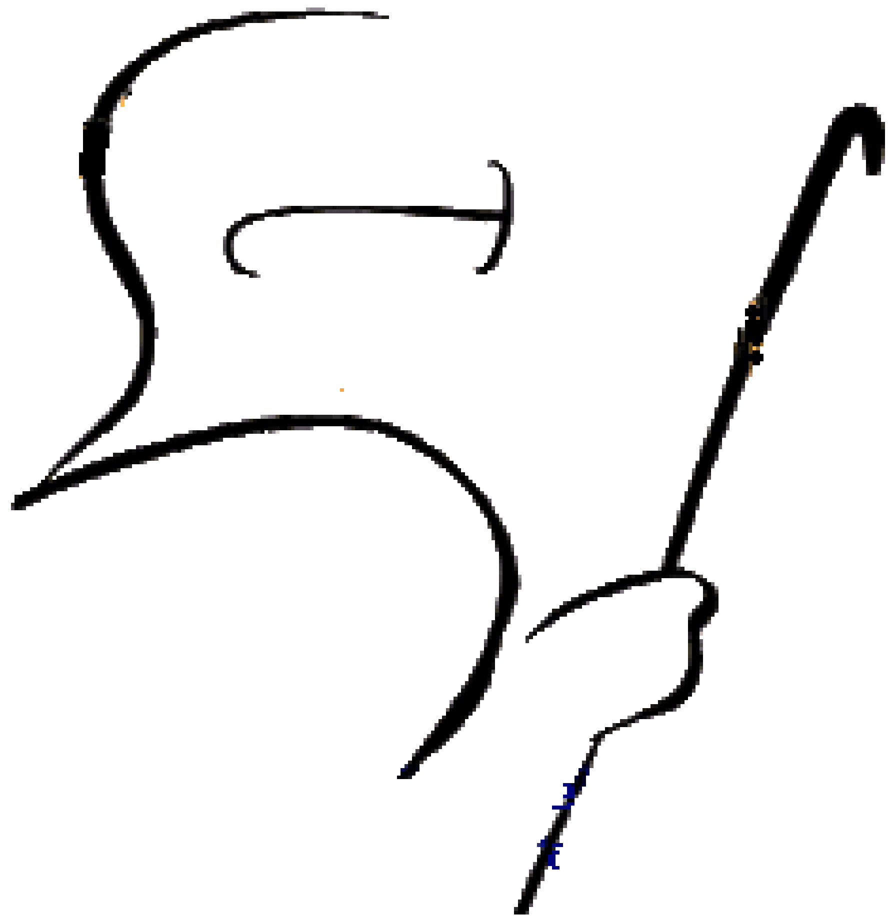
Generalization during Compositional Synthesis

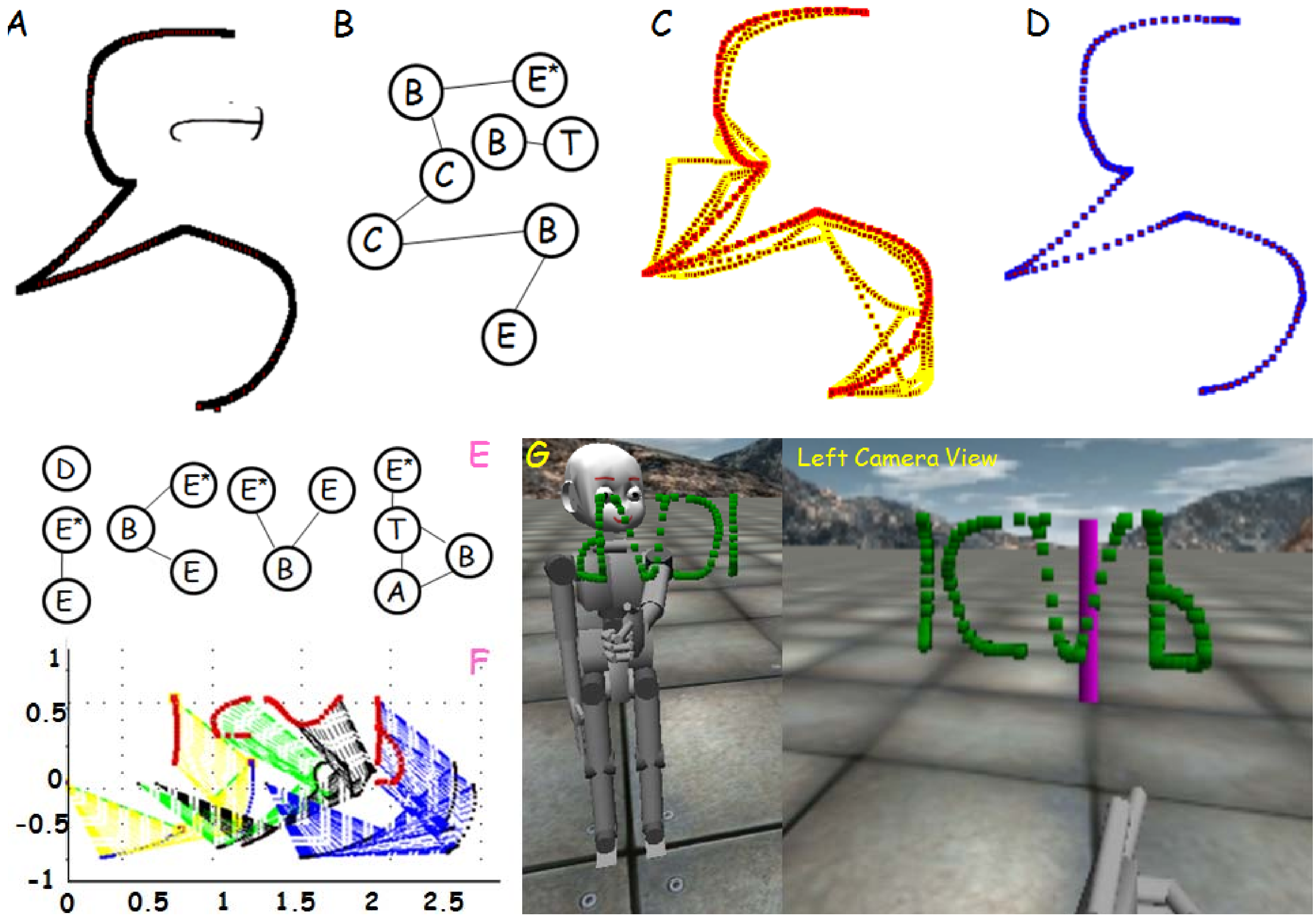


Generalization during Compositional Synthesis

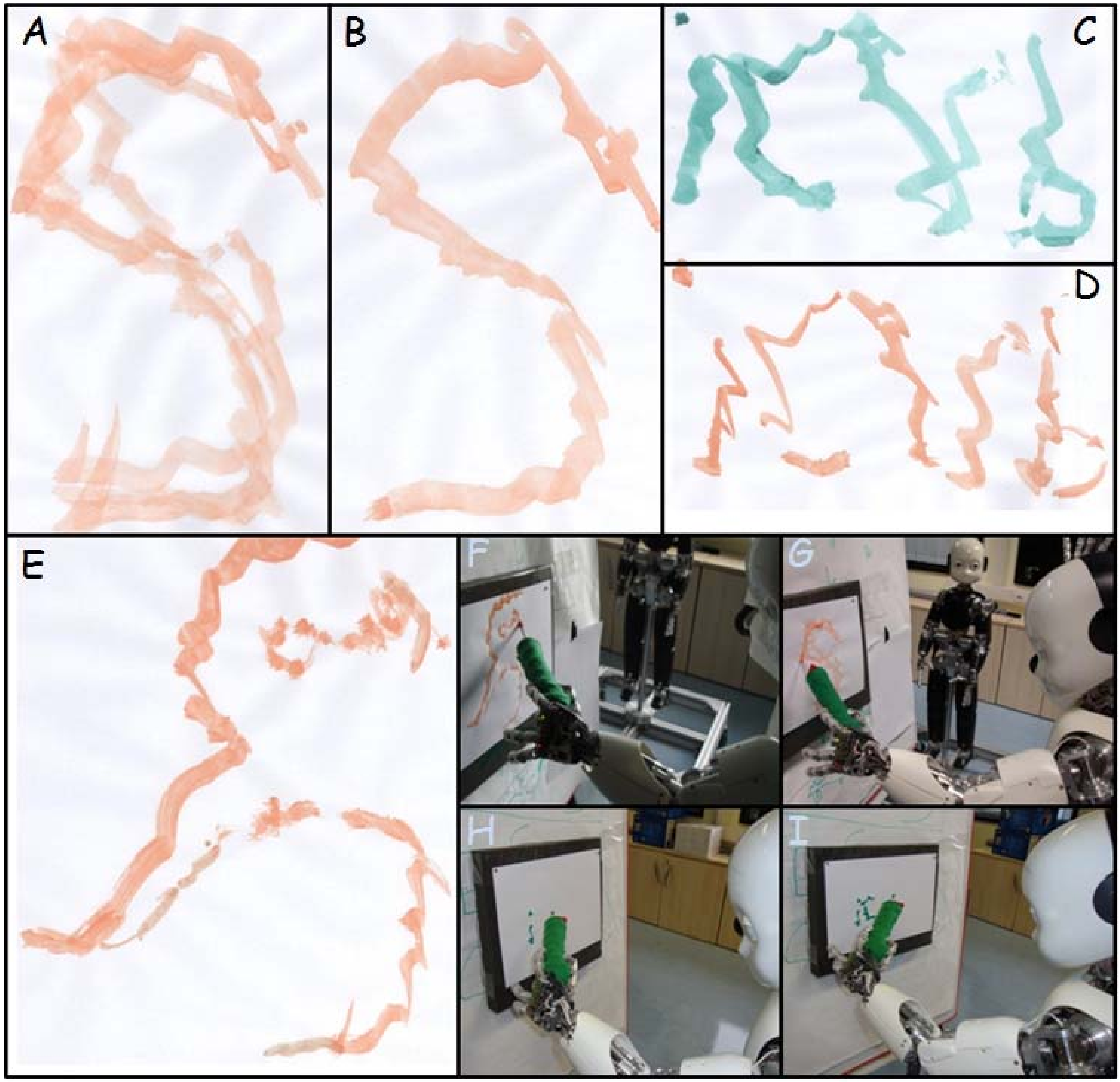
Since complex shapes can be 'decomposed' into combinations of primitive shape CP's using CT, inversely can the motor actions needed to create them be 'composed' using combinations of the corresponding 'learnt' primitive actions……….

The 'Shape' of Gandhi

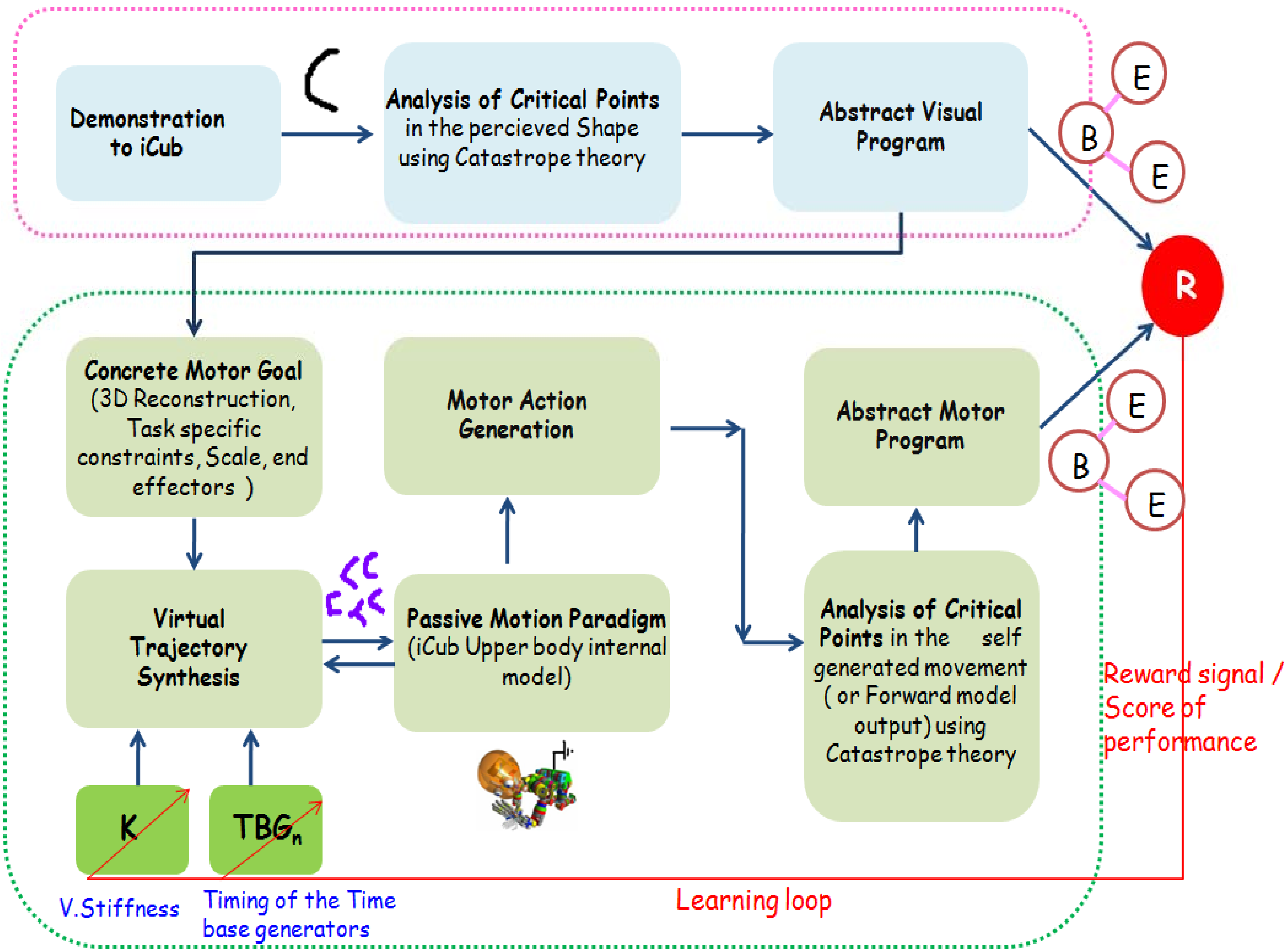



A
B
C
D
E
F
G
Left Camera View
B
E*
B
T
C
C
B
E
D
E*
E
B
E*
E
E*
E
B
E*
T
B
A
1
0.5
0
-0.5
-1
0
0.5
1
1.5
2
2.5

The 'Shape' of Gandhi



Shapes and Shapeing: Information flows



Open Questions ?

Are actions 'represented' ?

Computing through stiffness (physical/mental)?

Time, timing, sync and temporal order

Motor Control, Motor learning and Mental simulation of action

The 'Motivation -Exploration- Imagination-Introspection' Loop revisited

Socially Cognitive Humanoids: A minimal (brain based) neural architecture for imitation

Neuromotor rehabilitation: Robots teaching/assisting to draw ?

Shapes of   'Signals', Multimodal sensory resonance

Reaction diffusion systems and Valued goals?

iCubArt driven by iCubthought?

Thank You for your attention

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