


Chapter I
Four Basic Topics in AI

Content

Chapter 1 - Four Basic Topics:

1.1 COOPERATION:IntelligentAgents

1.2 Representation

1.3 Search

1.4 Learning

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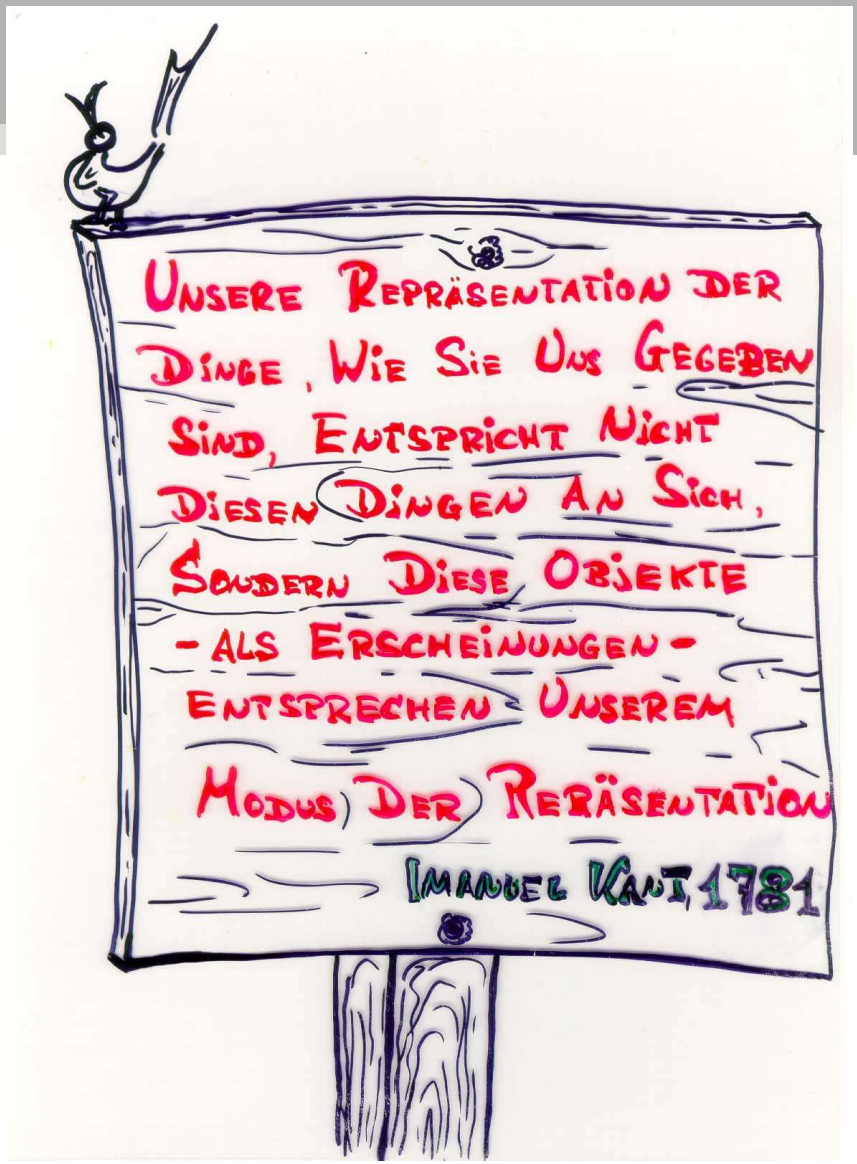

UNSERE REPRÄSENTATION DER
DINGE, WIE SIE UNS GEGEBEN
SIND, ENTSPRICHT NICHT
DIESEN DINGEN AN SICH,
SONDERN DIESE OBJEKTE
- ALS ERSCHEINUNGEN -
ENTSPRECHEN UNSEREM
MODUS DER REPRÄSENTATION
IMANUEL KANT 1781


The way, the presentation of matter is being revealed to us, does not correspond to matter itself, but those objects regarded as phenomena comply with our own mode of representation.

Imanuel Kant, 1781

1.2 Representation :

Geometric Intelligence Tests

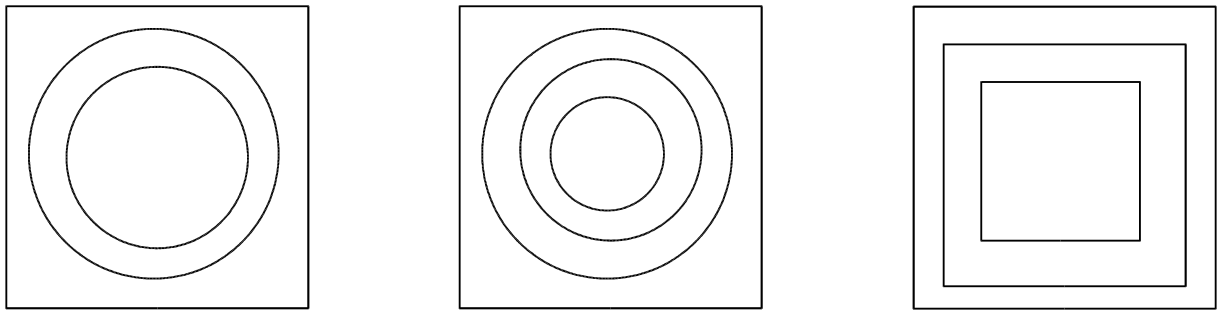
Thomas G. Evans:

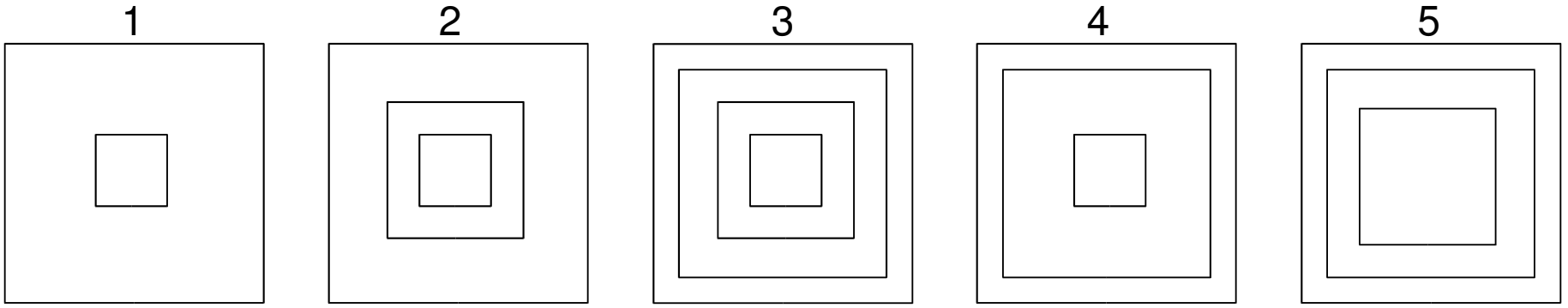
"A Program for the Solution of a Class of Geometric Analogy Intelligence Test-Questions"

(1963)

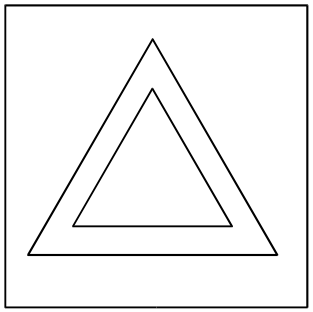
In: M. Minsky: "Semantic Information Processing"
The MIT-Press, 1968

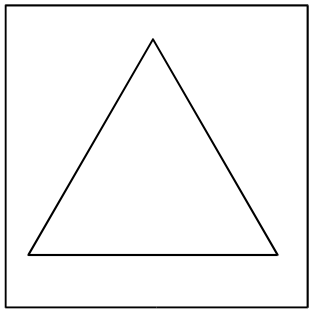
Analogy Intelligence Test (I)

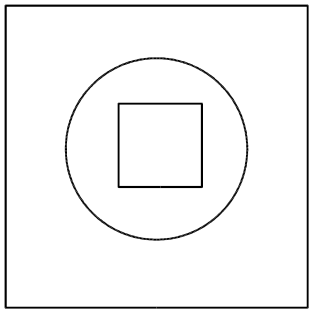


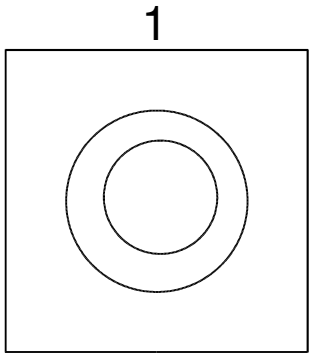


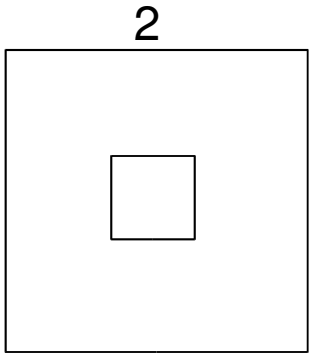
Analogy Intelligence Test (II)

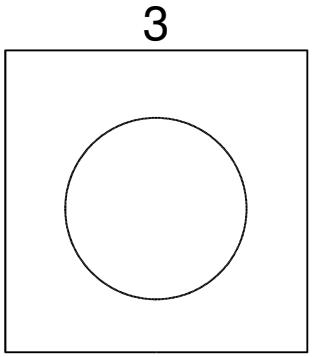


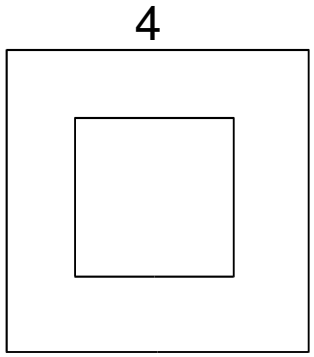


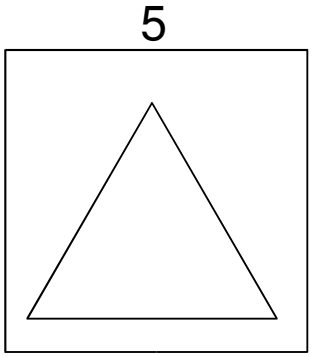






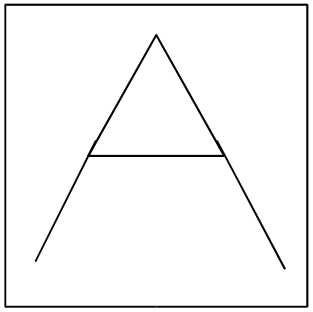






Analogy Intelligence Test (III)

A



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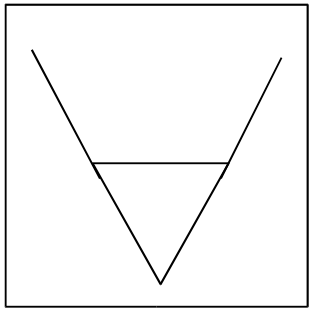

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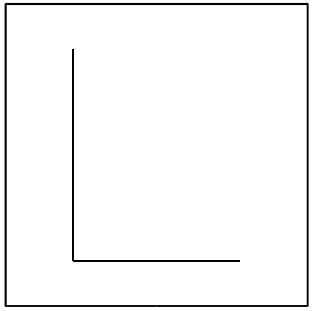

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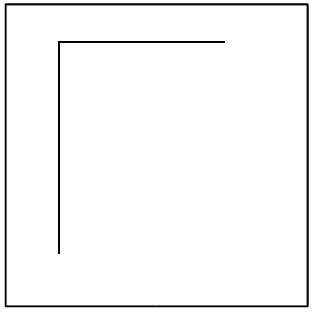

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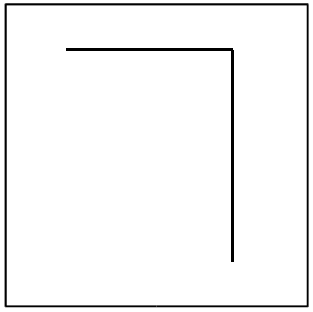

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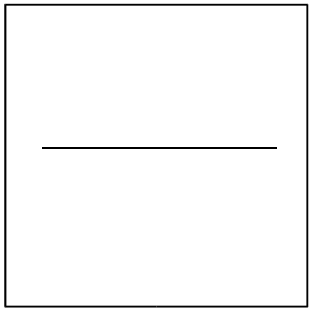

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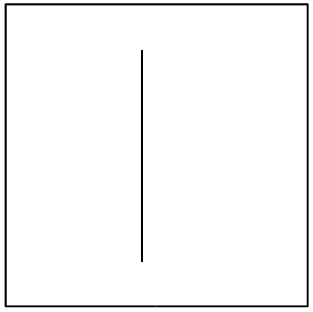

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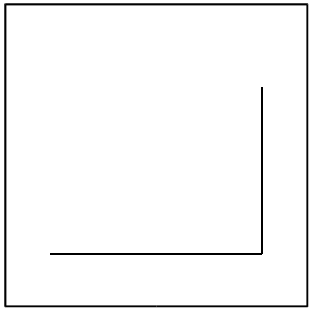

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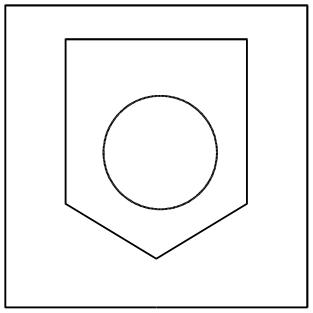
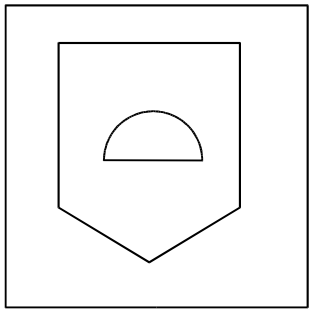
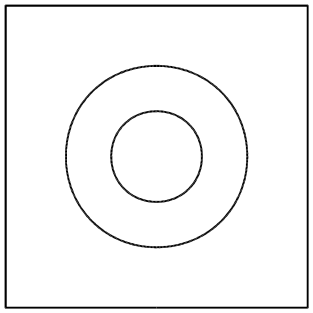
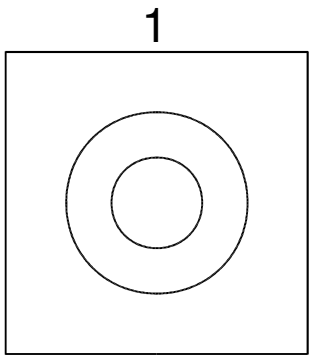
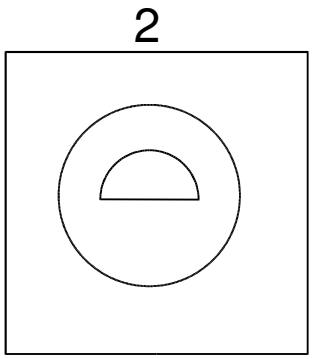
Analogy Intelligence Test (IV)

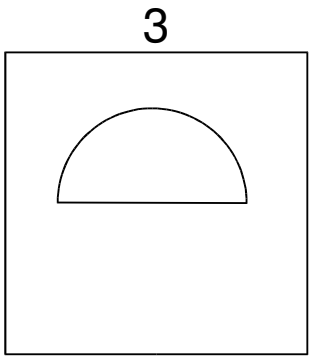


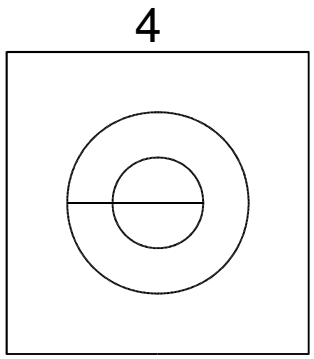


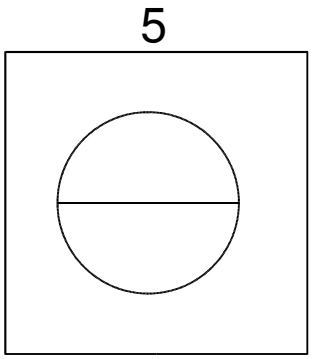












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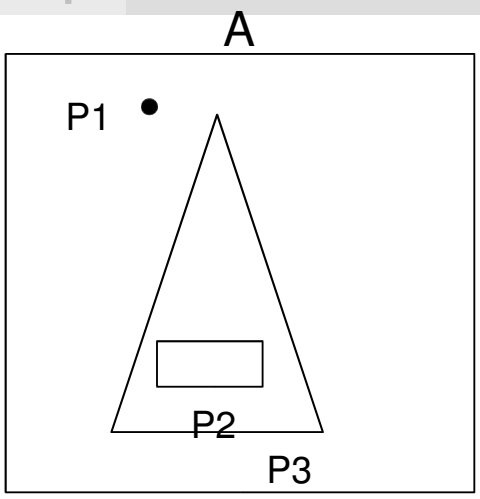
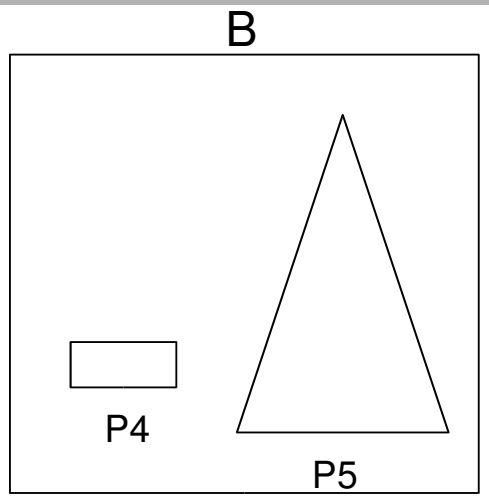
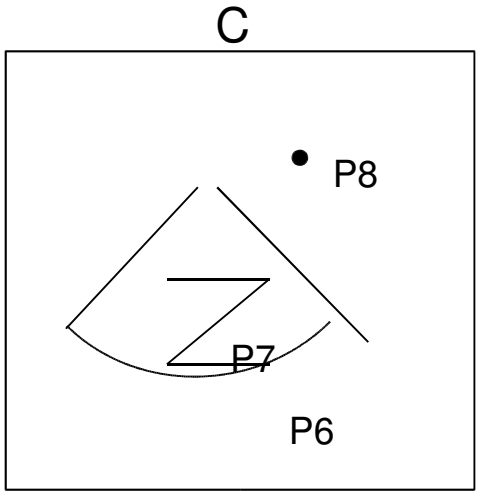
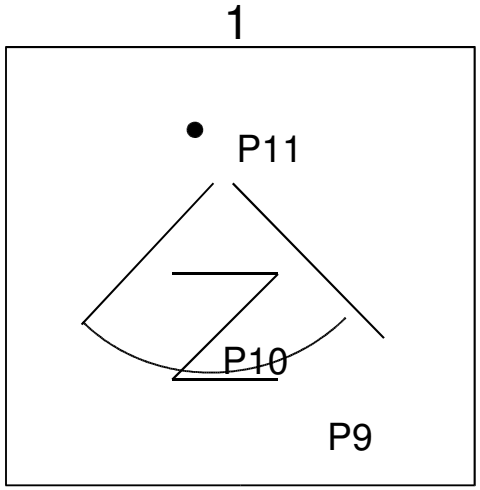
Geometric Analogy Problems: Our Example



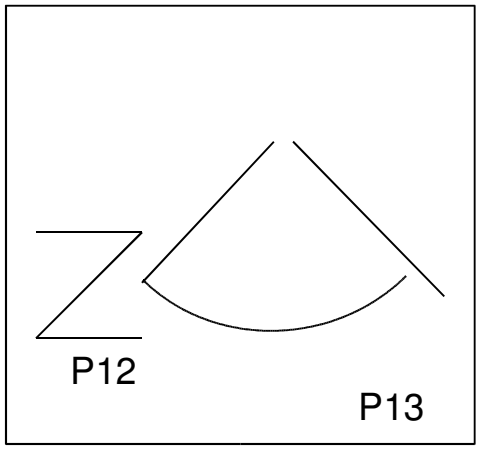






Geometric Analogy Problems: Our Example

2



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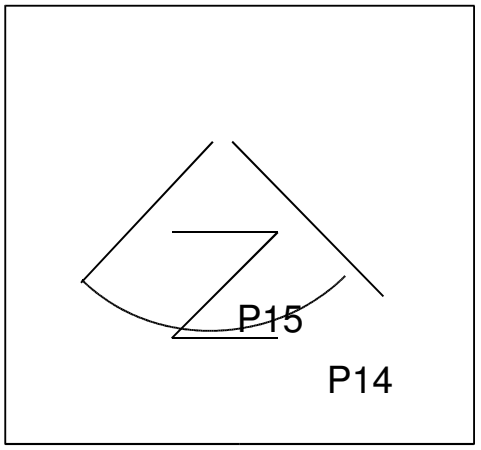

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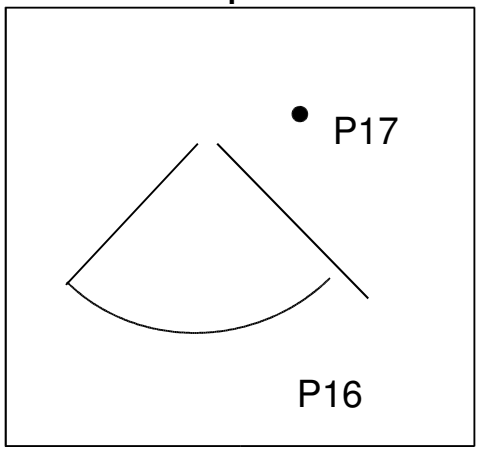

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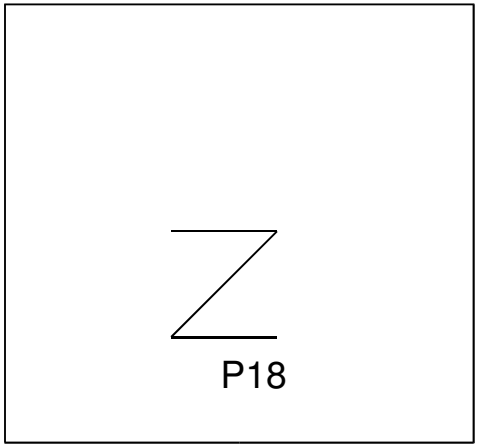
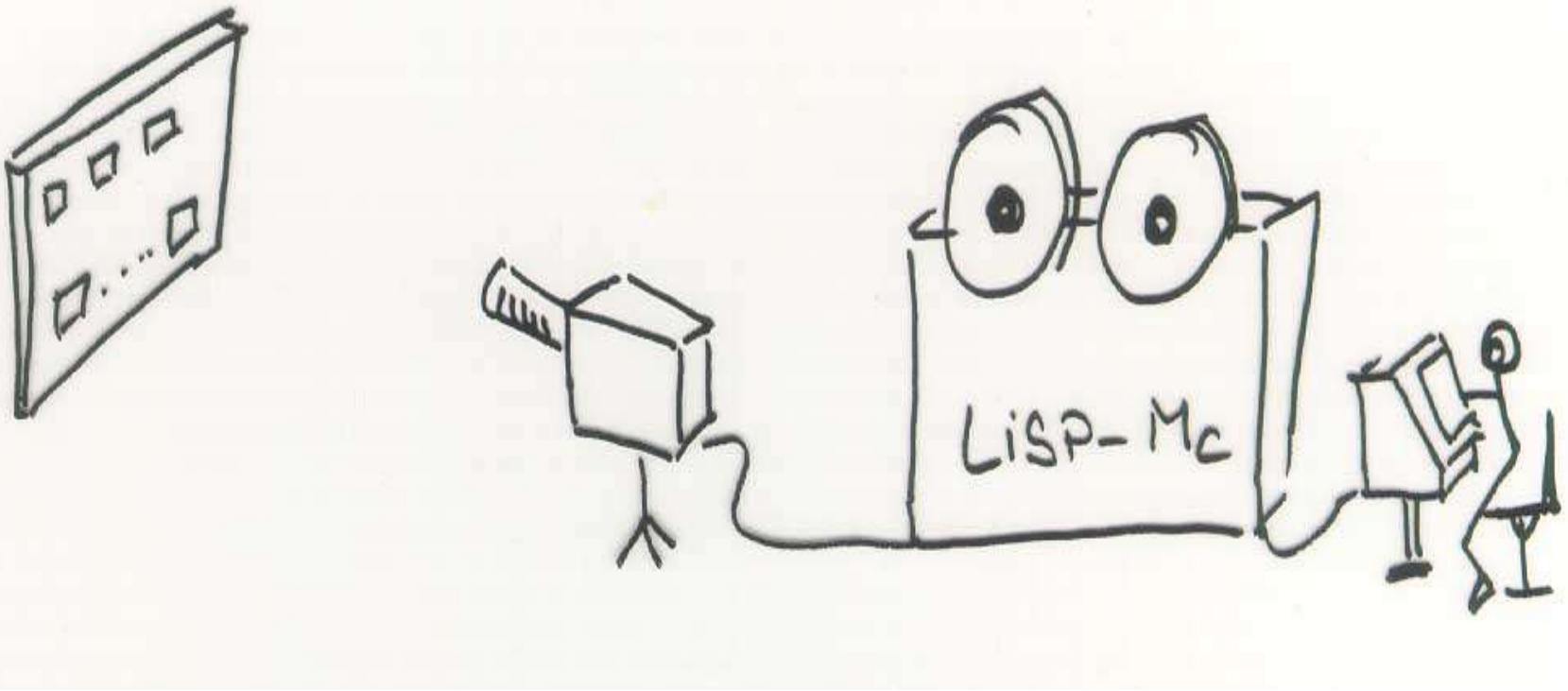


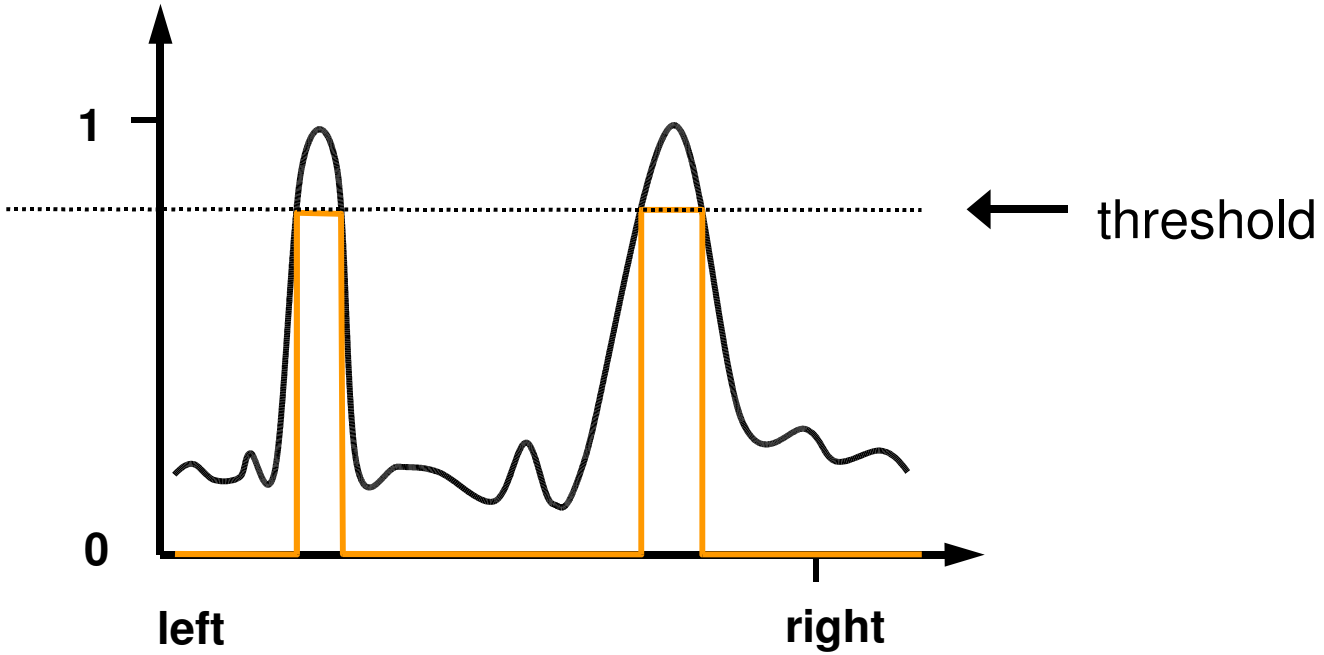
Steps of Representation: Setup



Steps of Representation: Rep^0 and Rep^1

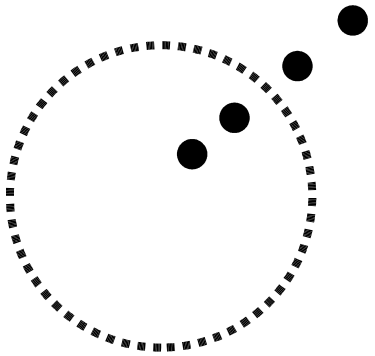
Rep^0: analogue signal

Rep^1: binary by threshold



Steps of Representation: Rep^2 and Rep^3

Rep^2: line finding



unit circle:

→ pixel offset

Rep^3: approximate line drawing

- $\min |\sum_i \overline{x}_i - \overline{y}_i|$
- sector of a circle (max ø)
- adjust edges

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First Symbolic Representation: Rep^4

Primitives:

PNT	:	point
SFI	:	simple closed figure
CFI	:	complex composed figure

Symbolic Representation: Example 1 (SFI)

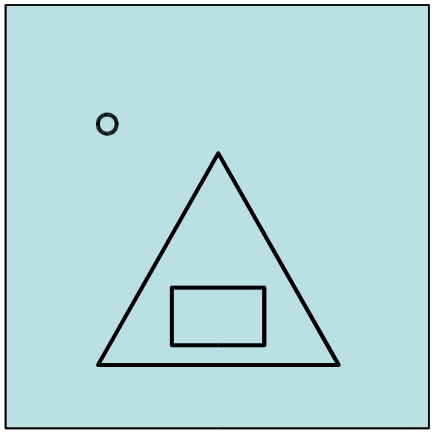
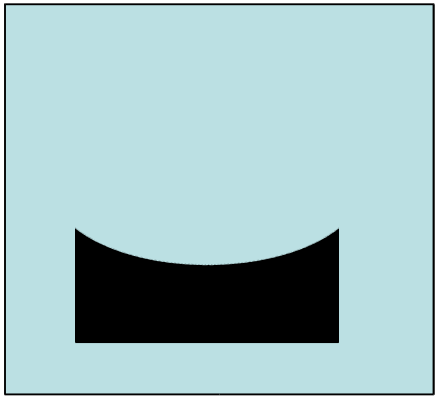


Figure A

```
(
(PNT(0.4 0.8))
(SFI((0.3 0.2) ∞ (0.7 0.2) ∞ (0.5 0.7) ∞ (0.3 0.2))
(SFI((0.4 0.3) ∞ (0.6 0.3) ∞ (0.6 0.4) ∞
                  (0.4 0.4) ∞ (0.4 0.3))
)
```

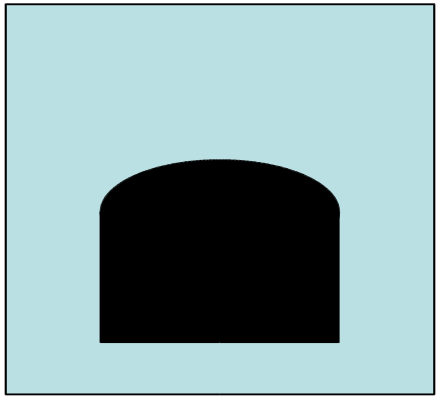
Symbolic Representation: Example 2 (SFI)



Concave

```
(
(SFI ((0.2 0.3)∞
      (0.8 0.3)∞
      (0.8 0.7)-1
      (0.2 0.7)∞
      (0.2 0.3))
)
```

Symbolic Representation: Example 3 (SFI)



Convex

```
(
(SFI ((0.2 0.3)∞
      (0.8 0.3)∞
      (0.8 0.7)+1
      (0.2 0.7)∞
      (0.2 0.3))
)
```

Symbolic Representation: Example 4 (CFI)

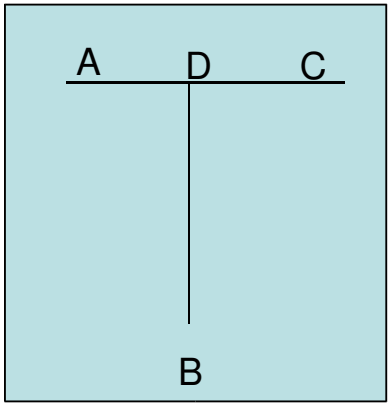


Figure I

```
(CFI ( (  A    (A ∞ D))
       (  B    (B ∞ D))
      (   C    (C ∞ A))
      (   D    (D ∞ A)(D ∞ B) (D ∞ C))
     )
)
```

Symbolic Representation: Example 5 (CFI)

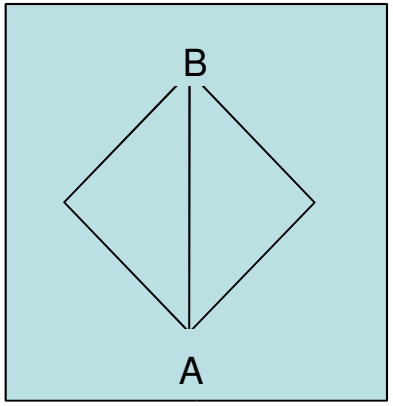


Figure II

```
(CFI (  (A  (A ∞ B ∞ (0.7 0.5) ∞ A)
            (A ∞ B)
            (A ∞ B ∞ (0.3 0.5) ∞ A)
        (B  (B ∞ A ∞ (0.3 0.5) ∞ B)
            (B ∞ A)
            (B ∞ A ∞ (0.7 0.5) ∞ A))
     )
)
```

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Symbolic Representation: Example 6 (CFI)

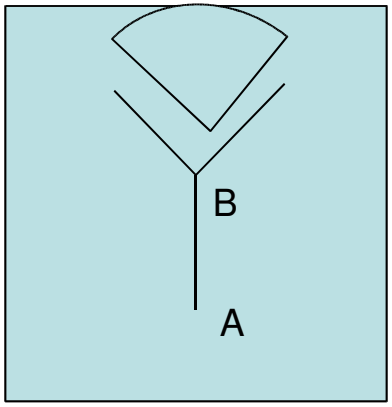
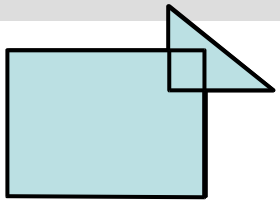


Figure III

```
(CFI   (   (A (A ∞ B))
           (   (B (B ∞ A)
                  (B ∞ (0.7 0.7)2.5(0.3 0.7)
                         ∞ B ))
           )
)
```

Separation



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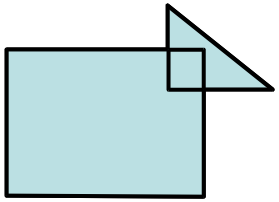

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Data Bank of “Prototypes”

OB1: Prototype Point

OB2: Prototype Triangle

OB3: Prototype Quadrangle

OB4: Prototype Square

…

etc. all in SFI representation

Transformation into a Prototype

Transformation into a Prototype with:

$$(\text{TRANS } \sigma_1\ \mu\ \theta\ \sigma_2\ ),$$

where:
- σ_1: reflection
- μ : scale
- θ : rotation
- σ_2 : reflection

values:
- $\sigma_1, \sigma_2 \in \{K, V, H\}$
- $0 < \mu < \infty$
- $-\pi < \theta < \pi$

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Representation of Relation

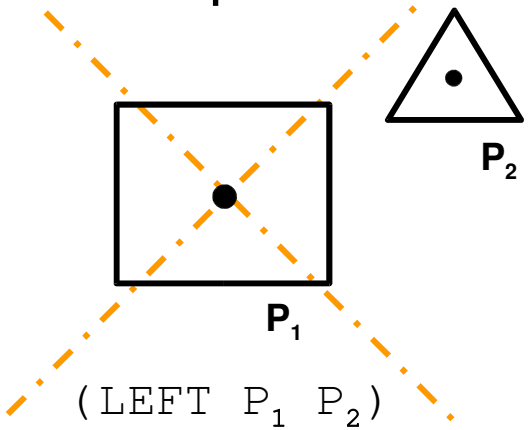
1. Defining the representation language

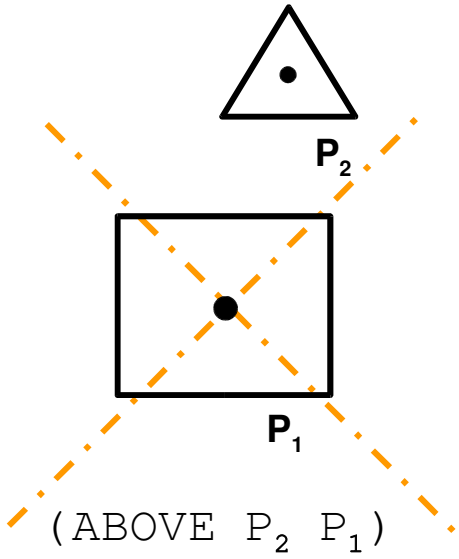
ABOVE
BELOW
LEFT
RIGHT
INSIDE

} "Primitives"

2. Redundancy / adequacy

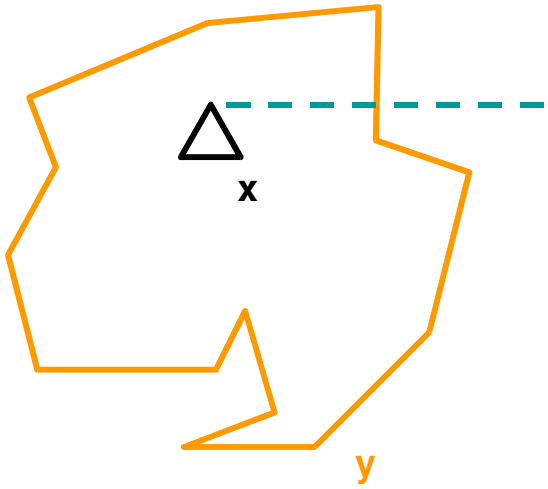
3. How to compute?





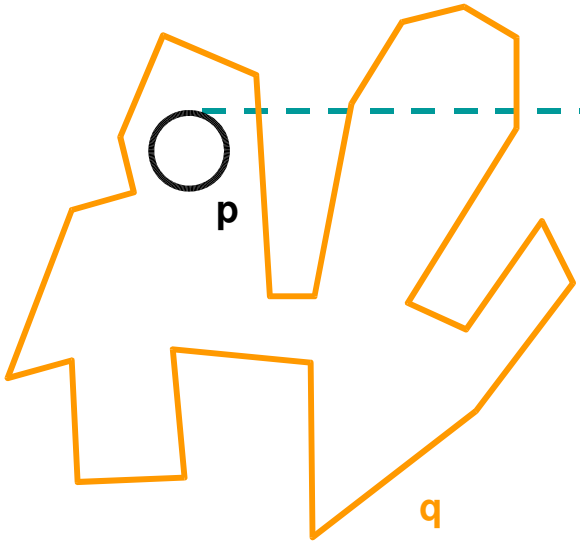
Computation of "Inside"

Example 1



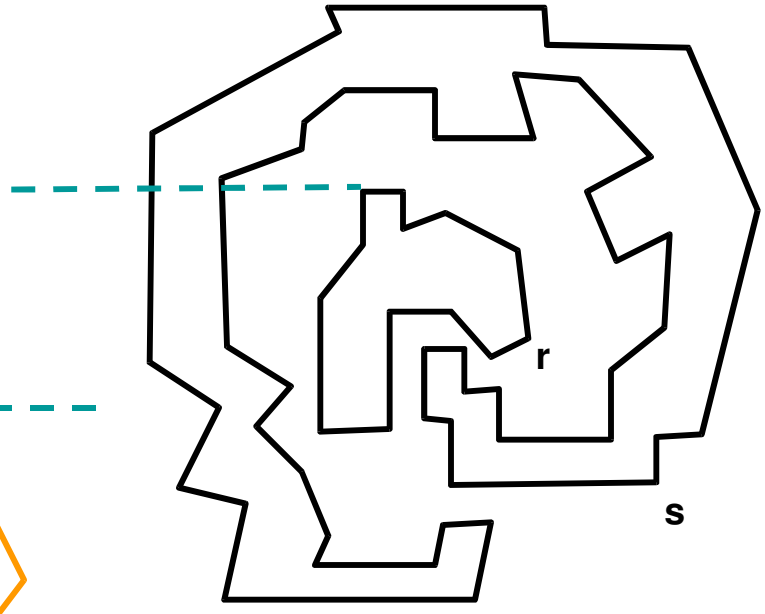
x Inside y

p Inside q



Example 2

Example 3



no Inside relationship

Final Symbolic Representation: Rep 5

```
(FIG-A     (CONSITS-OF P1 P2 P3)
           (RELATIONS   (INSIDE P2 P3)
                        (ABOVE P1 P3)
                        (ABOVE P1 P2)

           (SIM P1 OB1   (TRANS  K 1 0 K ))
           (SIM P2 OB3   (TRANS  K 1 0 K ))
           (SIM P3 OB2   (TRANS  K 1 0 K ))
 )
```

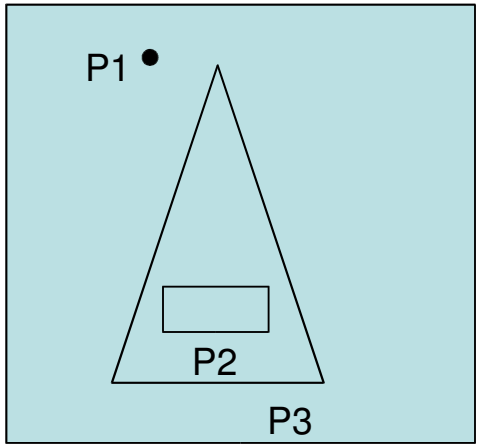


Figure A

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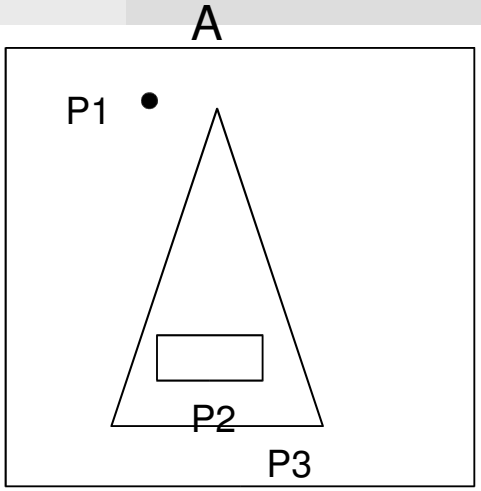
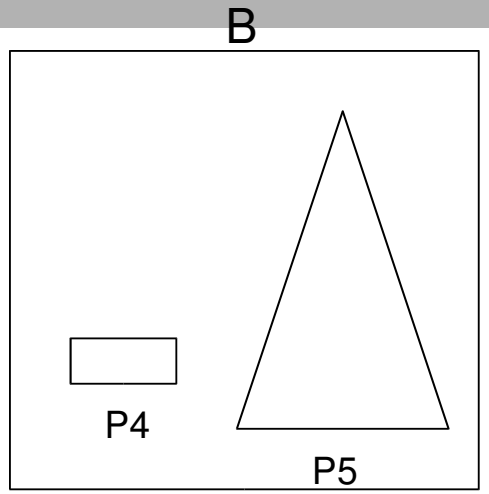
Rep 5: Examples





(1.) (FIG-A (CONSITS-OF P_1 P_2 P_3)
(RELATIONS (INSIDE P_2 P_3)
(ABOVE P_1 P_3)
(ABOVE P_1 P_2)))

2. (FIG-B (CONSISTS-OF P_4 P_5)
(RELATIONS (LEFT P_4 P_5)))

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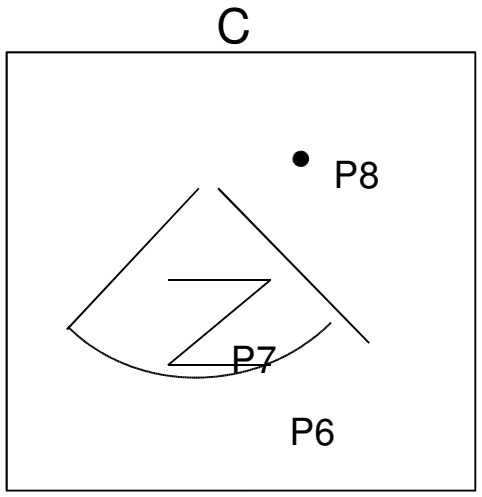
Rep 5: Examples



3.(FIG-C (CONSITS-OF P_6 P_7 P_8)

(RELATIONS (INSIDE P_7 P_6)

(ABOVE P_8 P_6)

(ABOVE P_8 P_7)))

Rep 5: Examples

4.(SIM-A-B (SIM P_2 P_4: (TRANS K 1.0 ∞ K)
(TRANS K 1.0 π K)
(SIM P_3 P_5: (TRANS K 1.0 ∞ K)))

5. (SIM-A-C (SIM P_1 P_8:(TRANS K 1.0 ∞ K)))

6. (SIM - B- C NIL)

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Rep 5: Examples

7.(FIG-1 (CONSITS-OF P_9 P_{10} P_{11})
(RELATIONS (INSIDE P_{10} P_9)
(ABOVE P_{11} P_9)
(ABOVE P_{11} P_{10})))

8.(FIG-2 (CONSITS-OF P_{12} P_{13})
(RELATIONEN (LEFT P_{12} P_{13})))

9.(FIG-3 (CONSITS-OF P_{14} P_{15})
(RELATIONEN (INSIDE P_{15} P_{14})))

10.(FIG-4 (CONSITS-OF P_{16} P_{17})
(RELATIONS (ABOVE P_{17} P_{16})))

11.(FIG-5 (CONSITS-OF P_{18})
(RELATIONS NIL))

Rep 5: Examples

12.(SIM-C-1 (SIM P_6 P_9: (TRANS K 1.0 0.0 K))
(SIM P_7 P_{10}: (TRANS K 1.0 0.0 K))
(SIM P_8 P_{11}: (TRANS K 1.0 0.0 K)))

13.(SIM-C-2 (SIM P_6 P_{13}: (TRANS K 1.0 0.0 K))
(SIM P_7 P_{12}: (TRANS K 1.0 0.0 K)
(TRANS K $-\pi$ 0.0 K)))

14.(SIM-C-3 (SIM P_6 P_{14} : (TRANS K 1.0 0.0 K))
(SIM P_7 P_{15} : (TRANS K 1.0 0.0 K))
(TRANS K $-\pi$ 0.0 K)))

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Rep 5: Examples

15.(SIM-C-4 (SIM P_6 P_{16} :(TRANS K 1.0 0.0 K))
(SIM P_8 P_{17} :(TRANS K 1.0 0.0 K)))

16.(SIM-C-5 (SIM P_7 P_{18} : (TRANS K 1.0 0.0 K))
(TRANS K $-\pi$ 0.0 K)))

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Unification and Matching

```
f (x, g (a, y ))
f (b, g (a, b ))
```

---

substitution: $\sigma = \{x \leftarrow b,\ y \leftarrow b\}$

in general:

$$\sigma = \{x_1 \leftarrow t_1, x_2 \leftarrow t_2, \ldots, x_n \leftarrow t_n\}$$

structural description:

$$\mathbf{D_1}$$

$$\mathbf{D_2}$$

unifier: σ

$$\Rightarrow \sigma\ \mathbf{D_1} \stackrel{?}{=} \sigma\ \mathbf{D_2}$$

matcher: μ

$$\Rightarrow \mu\ \mathbf{D1} \stackrel{?}{=} \mathbf{D2}$$

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Matching - Rules

ADD, REMOVE, MATCH

Rules

Example: A → B in figure 5-1

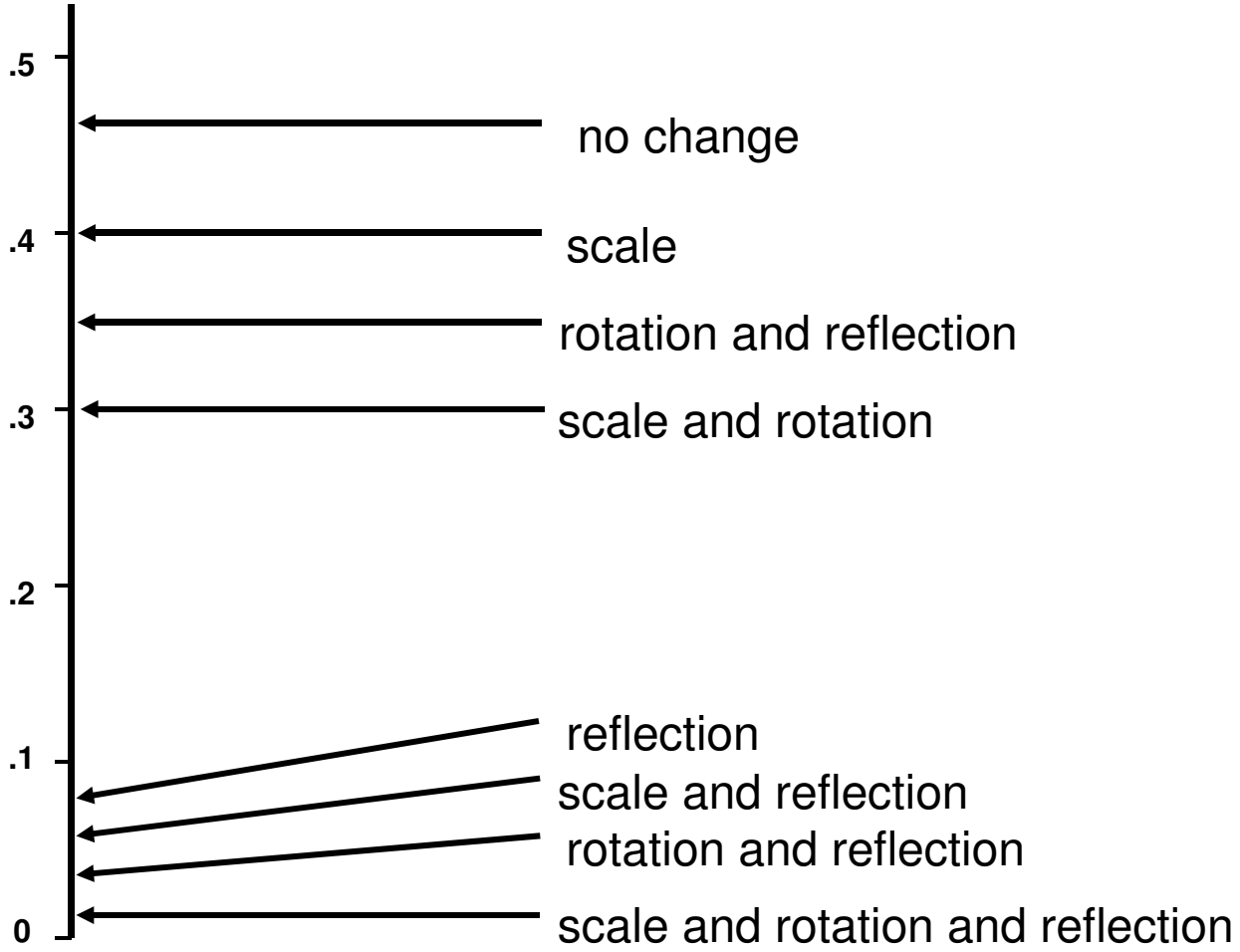
```
(REMOVE x1   ((ABOVE   x1    x3)
              (ABOVE     x1   x3)
              (SIM OB3   x1   (TRANS   K   1.0   0.0 K))
             ))

(MATCH   x2   FROM    ((INSIDE    x2   x3)
                       (ABOVE     x1   x2)
                       (SIM       OB2  x2   (TRANS    K   1.0   0.0   K))
              TO       ((LEFT      x2   x3)
                       (SIM    OB2    x2   (TRANS   K   1.0   0.0   K))
              WITH    (TRANS   K   1.0   0.0   K))
```

Matching – Rules: Example (cont.)

```
(MATCH  x3   FROM    ((INSIDE  x2     x3)
                      (ABOVE   x1     x3)
                      (SIM     OB1    x3   (TRANS   ....  )
               TO     ((LEFT    x2     x3)
                      (SIM     OB1    x3  (TRANS ... )))
               WITH    (TRANS  K  1.0   0.0  K))
```

Evaluation


.5
.4
.3
.2
.1
0
no change
scale
rotation and reflection
scale and rotation
reflection
scale and reflection
rotation and reflection
scale and rotation and reflection

Generalized Answer

Answer A-B-C-2:

```
(REMOVE  x1    WITH    ((ABOVE   x1  x3)
                        (ABOVE   x1  x2)
                        (SIM   OB3   x1  (TRANS  ...))
                       ))

(MATCH   x2    FROM    ((INSIDE  x2  x3)
                        ( ABOVE  x1 x2))
               TO      ((LEFT  x2  x3)
               WITH    (TRANS  K  1.0  0.0  K ))

(MATCH   x3    FROM    ((INSIDE   x2  x3)
                        ( ABOVE   x1  x3)
               TO      ((LEFT   x2  x3)
               WITH     (TRANS  K  1.0  0.0  K))
)
```

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Summary

- Strength: IQ
- Weaknesses:
  - Deficiencies of Representation
  - “Linear control flow” instead of an Agenda
  - Actual implementation

Conclusion:

Computational Intelligence

Relevance of the Representation