

# CAPUT V

## LECTIO SIGNORUM

Clavis/keys see `vocos_III_clavis_c.tex`.

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### CAP 1: 5 01 PLA

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- 5 01 1.  $\lceil P \in \text{Pla} : \Lambda p . p \in P . \leftrightarrow . \forall \lceil x . y \rceil . \lceil x . y \rceil \in \lceil \text{Int} . \text{Int} \rceil . \wedge . p = \lceil x . y \rceil \rceil$
- 5 01 2.  $\lceil \Lambda a \in \text{Rea} . \Lambda b \in \text{Rea} : \text{Dst } a \ b \geq 0 . \wedge : \text{Dst } a \ b = a - b . \vee . \text{Dst } a \ b = b - a \rceil$
- 5 01 3.  $\lceil \Lambda p \in P : f \ p = \lceil b . c . d \rceil . \wedge . \lceil b . c . d \rceil \in \lceil \text{Num} . \text{Num} . \text{Num} \rceil . \wedge . 0 \leq b \leq 11111111 . \text{Etc} \rceil$
- 5 01 4.  $\lceil \Lambda A . A \subset P . \rightarrow . A \in \text{Agg} \rceil$
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### CAP 2: 5 02 SCA

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- 5 02 1.  $\lceil Q \in \text{Pla} : \Lambda \lceil x . y \rceil \in Q . g \lceil x . y \rceil . = \text{Cca} . f \lceil x / 10 . y / 10 \rceil \rceil$
- 5 02 2.  $\lceil \Lambda p \in Q : g \ p = \lceil b . c . d \rceil . \rightarrow . h \ p . = \text{Cca} . (b + c + d) / 11 \rceil$
- Ha Vul  $\rightarrow$
- 5 02 3.  $\lceil \Lambda t . t \subset Q . \wedge . \text{Car } t = 1000 \ 1000 : \Lambda p \in t . \Lambda q \in t :$   
 $\text{Dst } (h' \ p) \ (h' \ q) \geq \text{Dst } (h \ p) \ (h \ q) . \wedge . \text{Dst } (h' \ p) \ (h' \ q) \leq 10 \ \text{Dst } (h \ p) \ (h \ q) \rceil$
- 5 02 4.  $\lceil \Lambda p \in Q : \Lambda q . \text{Dst } p \ q \leq 111 . \wedge . \text{Dst } (h' \ p) \ (h' \ q) \text{Pau} > 0 . \rightarrow . k \ p . = \text{Cca} . h' \ q \rceil$
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### CAP 3: 5 03 MUT

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- 5 03 1.  $\lceil \text{Car } (\hat{p} . k \ p < m) = \text{Car } (\hat{p} . k \ p > m) . \text{Put} . m = 101100 \rceil$
- 5 03 2.  $\lceil u \in \text{Int} : u \leq m - m / 11 < u + 1 . \text{Put} . u = 11101 \rceil$
- 5 03 3.  $\lceil v \in \text{Int} : v \leq m + m / 11 < v + 1 . \text{Put} . v = 111010 \rceil$
- $v \leq u \rightarrow$
- 5 03 4.  $\lceil u = 110010 . v = 10010110 \rceil$
- 5 03 5.  $\lceil \Lambda p \in Q . \text{Mut } k \ p = \sup (\hat{d} . \forall q . \text{Dst } p \ q = 1 . \wedge . d = \text{Dst } (k \ p) \ (k \ q)) \rceil$
- 5 03 6.  $\lceil \Lambda p : p \in A . \leftrightarrow : \text{Mut } k \ p > v . \forall : \text{Mut } k \ p > u . \wedge . \forall w \in \text{Via} . \text{Ini } w = p . \wedge . \text{Mut } k \ (\text{Fin } w) > v . \wedge . \Lambda r \in w . \text{Mut } k \ r > u \rceil$
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### CAP 4: 5 04 COR

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- 5 04 1.  $\lceil \Lambda p : p \in B . \leftrightarrow : p \in A . \vee . \forall q \in A . \forall r \in A . \text{Dst } p \ q \leq 11 . \wedge . \text{Dst } p \ r \leq 11 . \wedge . \text{Dst } q \ r \leq 11 \rceil$
- 5 04 2.  $\lceil R \in \text{Pla} : \Lambda \lceil x . y \rceil \in Q . \lceil x + 10100 . y + 10100 \rceil \in R \rceil$
- 5 04 3.  $\lceil \Lambda p \in R : p \in B . \rightarrow . e \ p = 0 : p \notin B . \rightarrow . e \ p = 11111111 \rceil$
- 5 04 4.  $\lceil n : \Lambda \lceil x . y \rceil \in R . y \leq n . \wedge . \forall \lceil x . y \rceil \in R . y = n \rceil$
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**CAP 5: 5 05** COG

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5 05 1.  $\lceil \text{Ha Dat Hb e} \rceil$   
 5 05 2.  $\lceil \text{Ha Inq Hb} . ? \hat{\lceil} \lceil p . a . b . y \rceil : p \in R . \wedge . a \in \text{Num} . \wedge . b \in \text{Num} . \wedge . \text{Hb Cog y Apu p} \rceil$   
 5 05 3.  $\lceil \text{Hb Inq Ha} . S \rceil$   
 5 05 4.  $\lceil \wedge \lceil p . a . b . y \rceil \in S . \text{Put} .$   
 $L = \hat{\lceil} q . \vee \lceil i . j \rceil . q = p + \lceil i . j \rceil . \wedge . 0 \leq i < a . \wedge . 0 \leq j < b \rceil$   
 5 05 5.  $\lceil \wedge \lceil p . a . b . y \rceil \in S : p = \lceil x . y' \rceil . \rightarrow . p' = \lceil x - 10100 . n - y' - b - 10100 \rceil$   
 5 05 6.  $\lceil \wedge \lceil p . a . b . y \rceil \in S : a = 0 . \vee . b = 0 . \vee . \text{Car} ( L \cap B ) = 0 . \rightarrow . \text{Ha Sin} \lceil p . a . b . y \rceil$   
 5 05 7.  $\lceil \text{Ha Enu S} . \text{Car S} = 1011001000001 \rceil$

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**CAP 6: 5 06** REP

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5 06 1.  $\lceil S' \subset S \rceil$  6 05 6  
 5 06 2.  $\lceil \wedge p \in R : \vee \lceil p'' . a . b . y \rceil \in S' . p \in L . \wedge . p \in B . \rightarrow . c p = 0 :$   
 $\neg \vee \lceil p'' . a . b . y \rceil \in S' . p \in L . \wedge . p \in B . \rightarrow . c p = 11111111 \rceil$   
 5 06 3.  $\lceil \text{Ha Dat Hb c} \rceil$   
 5 06 4.  $\lceil \text{Ha Inq Hb} . ? \hat{\lceil} \lceil p . a . b . y \rceil : \text{Hb Cog y Apu p} \rceil$   
 5 06 5.  $\lceil \text{Hb Inq Ha} . S'' \rceil$

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**CAP 7: 5 07** ORD

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5 07 1.  $\lceil \text{Car} ( \hat{\lceil} b . \vee \lceil p . a . b . y \rceil \in S'' : b < q ) = \text{Car} ( \hat{\lceil} b . \vee \lceil p . a . b . y \rceil \in S'' : b > q ) \rceil$   
 $\wedge \lceil p . a . b . y \rceil \in S'' . \lceil p' . a' . b' . y' \rceil \in S'' :$   
 $\left[ \begin{array}{l} 5 07 2. \lceil \lceil p . a . b . y \rceil \text{Ise} \lceil p' . a' . b' . y' \rceil . \leftrightarrow . \text{Dst} ( \text{Ctr L} ) ( \text{Ctr L}' ) < 11 \ q / 101 \rceil \\ 5 07 3. \lceil \text{Car} ( \hat{\lceil} d . d < r ) = \text{Car} ( \hat{\lceil} d . d > r ) : \\ d \in \hat{\lceil} d' . \vee \lceil p . a . b . y \rceil . \vee \lceil p' . a' . b' . y' \rceil . \lceil p . a . b . y \rceil \text{Ise} \lceil p' . a' . b' . y' \rceil . \wedge . \\ p = \lceil x . z \rceil . \wedge . p' = \lceil x' . z' \rceil . \wedge . d' = x' - x . \wedge . 0 < d' \leq 11 \ a \rceil \\ 5 07 4. \lceil \text{Car} ( \hat{\lceil} d . d < s ) = \text{Car} ( \hat{\lceil} d . d > s ) : \\ d \in \hat{\lceil} d' . \vee L . \vee L' . \neg L \text{Ise} L' . \wedge . d' = \text{Dst} ( \text{Ctr L} ) ( \text{Ctr L}' ) \rceil \\ 5 07 5. \lceil t = \text{Ctr L} . \wedge L' . \neg L' \text{Ise} L . \rightarrow . \text{Ctr L}' > \text{Ctr L} : w = \inf ( \hat{\lceil} x . \vee \lceil \lceil x . z \rceil . a . b . y \rceil \in S'' ) \rceil \\ 5 07 6. \lceil \wedge \lceil p . a . b . y \rceil \in S'' : p = \lceil x . z \rceil . \rightarrow . \vee \lceil i . j \rceil \in \lceil \text{Int} . \text{Int} \rceil . T \lceil i . j \rceil = y : \\ i \leq ( \text{Ctr L} - t ) / s < i + 1 . \wedge . j \leq ( x - w ) / r < j + 1 \rceil \\ \wedge \lceil i . j \rceil : T \lceil i . j \rceil = y . \wedge . T \lceil i . j \rceil = y' . \wedge . y \neq y' : \\ \left[ \begin{array}{l} 5 07 7. \lceil T \lceil i . j + 1 \rceil = y' \rceil \end{array} \right]$

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**CAP 8: 5 08** ECC

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5 08 1.  $\lceil \text{Ha Dat Hb T} . \text{Ecc} \rceil$

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「 Fin Caput V 」

Source: `edgeAndSilhouetteIntersection0cr.py`, branch **E**. `algorithm2e[ruled,vlined]`.

see Silhouette Function — CAPUT VI, *Multiplicatio Umbrae*:

`vocos_II_multiplicatio_umbrae_c_alg2e.tex`

The key to every text, sign, numeral:

`vocos_III_clavis_c.tex`

## CAPUT VI

### MULTIPLICATIO UMBRAE

$$\lceil a \cdot b = 0 \cdot \leftrightarrow \cdot a = 0 \cdot \vee \cdot b = 0 \rceil$$

$$1 \ 14 \ 5$$

The key is vocos\_III\_clavis\_c.tex.

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#### CAP 1: 6 01 ISE

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6 01 1.  $\lceil Ha \text{ Dat } Hb \text{ k} : Ha \text{ Dat } Hc \text{ k} \rceil \quad 5 \ 02 \ 4$   
 6 01 2.  $\lceil A \subset Q \cdot \wedge \cdot B \subset Q \rceil$   
 6 01 3.  $\lceil Ha \text{ Inq } Hc \cdot ? \hat{p} \cdot p \in Q \cdot \wedge \cdot \forall Hd \in Hom \cdot \forall w \in Via \cdot p \in w \cdot \wedge \cdot Hd \text{ Dat } w \rceil$   
 6 01 4.  $\lceil Hc \text{ Sci} \cdot Qia : \forall Hd \in Hom \cdot \forall t \in Tem \cdot t \text{ Ant } Nnc \cdot \wedge \cdot Hd \text{ Inq } Hc \rceil$

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#### CAP 2: 6 02 PRB

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6 02 1.  $\lceil U \in Pla : \sup (\hat{x} \cdot \forall \lceil x \cdot y \rceil \in U) = 1000000000 \cdot \vee \cdot \sup (\hat{y} \cdot \forall \lceil x \cdot y \rceil \in U) = 1000000000 : \wedge \lceil x \cdot y \rceil \in U \cdot g' \lceil x \cdot y \rceil = Cca \cdot g \lceil x / z \cdot y / z \rceil \rceil$   
 6 02 2.  $\lceil \wedge p \in U \cdot g'' p \cdot = Cca \cdot g' p - \lceil 1101000 \cdot 1110100 \cdot 1111010 \rceil \rceil$   
 6 02 3.  $\lceil Hc \text{ Anl } g'' \cdot Hc \text{ Cpu } Prb \cdot Hc \text{ Inq } Ha \text{ Prb} \rceil$   
 6 02 4.  $\lceil \wedge p \in Q \cdot Prb \text{ p} \in Rea \cdot \wedge \cdot 0 \leq Prb \text{ p} \leq 1 \rceil$   
 6 02 5.  $\lceil D = \hat{p} \cdot Prb \text{ p} \leq z' : E = \hat{p} \cdot Prb \text{ p} > z' : Put \cdot n = Car \text{ D} \cdot o = Car \text{ E} \cdot d = Dst (\text{Ctr } D) (\text{Ctr } E) : \wedge z'' \in Rea \cdot n \text{ o } d \text{ d} \geq n' \text{ o}' d' d' \rceil$   
 6 02 6.  $\lceil B = \hat{p} \cdot Prb \text{ p} > z' \rceil$   
 6 02 7.  $\lceil B' \subset B : \wedge p \in B \cdot \forall q \in B' \cdot Dst \text{ p } q \leq 10 \cdot \wedge \cdot \wedge p \in B' \cdot Car (\hat{q} \cdot q \in B' \cdot \wedge \cdot Dst \text{ p } q = 1) \leq 10 \rceil$

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#### CAP 3: 6 03 VIA

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6 03 1.  $\lceil \wedge w \in Via \cdot w \subset B' : \wedge p \in w \cdot \wedge q \in w \cdot q \text{ Pst } p \cdot \wedge \cdot \neg \vee r \in w \cdot r \text{ Pst } p \cdot \wedge \cdot q \text{ Pst } r : \rightarrow \cdot Dst \text{ p } q = 1 \rceil$   
 6 03 2.  $\lceil \wedge w \in Via \cdot \wedge p \in w \cdot p = \lceil x \cdot y \rceil \cdot \rightarrow \cdot Ha \text{ Dat } Hb \lceil w \cdot p \cdot x \cdot y \rceil \rceil$

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#### CAP 4: 6 04 CCA

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6 04 1.  $\lceil B'' = \hat{p} \cdot \forall q \in B' \cdot Dst \text{ p } q \leq s \rceil$   
 6 04 2.  $\lceil s = 0 \cdot \rightarrow \cdot B'' = B' \rceil$

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**CAP 5: 6 05 LEX**

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- 6 05 1.  $\lceil \bigwedge p \in Q : p \in A . \rightarrow . i\ p = 1 : p \notin A . \rightarrow . i\ p = 0 \rceil$   
 6 05 2.  $\lceil \bigwedge p \in Q : p \in B'' . \rightarrow . j\ p = 1 : p \notin B'' . \rightarrow . j\ p = 0 \rceil$   
 6 05 3.  $\lceil \bigwedge p \in Q . c\ p = i\ p\ j\ p \rceil$   
 6 05 4.  $\lceil \bigwedge p \in Q . c\ p = 0 . \leftrightarrow . i\ p = 0 . \vee . j\ p = 0 \rceil$  1 14 5  
 6 05 5.  $\lceil C = \hat{\lceil} p . c\ p = 1 : C = A \cap B'' \rceil$   
 6 05 6.  $\lceil \bigwedge \lceil p . a . b . y \rceil \in S . \text{Put} . n = \text{Car} ( L \cap A ) . k = \text{Car} ( L \cap C ) . e = k / n \rceil$   
 6 05 7.  $\lceil \lceil p . a . b . y \rceil \in S' . \leftrightarrow : k \geq 1 . \wedge . n > 0 . \wedge . e \geq 0 : \text{Put} . k \text{ Sat} \rceil$   
 6 05 8.  $\lceil \bigwedge \lceil p . a . b . y \rceil \in S . k = 0 . \rightarrow . \text{Ha Sin} \lceil p . a . b . y \rceil \rceil$
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**CAP 6: 6 06 ENU**

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- 6 06 1.  $\lceil \text{Ha Enu } S . \text{Car } S = 1011001000001 \rceil$   
 6 06 2.  $\lceil \text{Ha Enu} ( \hat{\lceil} p . a . b . y \rceil . \lceil p . a . b . y \rceil \in S . \wedge . k = 0 ) . \text{Car} = 1010011011001 \rceil$   
 6 06 3.  $\lceil \text{Car } S' = 101101000 \rceil$   
 6 06 4.  $\lceil \bigwedge \lceil p . a . b . y \rceil \in S' : n = \text{Cca } 1010101 . k = \text{Cca } 100 \rceil$   
 6 06 5.  $\lceil n \text{ Mul} > k : e \text{ Pau} > 0 : \sup ( \hat{\lceil} e . \vee \lceil p . a . b . y \rceil \in S' ) \text{ Mul} < 1 \rceil$
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**CAP 7: 6 07 COR**

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- 6 07 1.  $\lceil K = \hat{\lceil} p . \vee \lceil p' . a . b . y \rceil \in S' . p \in L . \wedge . p \in A \rceil$   
 6 07 2.  $\lceil K \supset C \cap K . \wedge . K \neq C \cap K \rceil$   
 6 07 3.  $\lceil \text{Ha Dat Hb } K \rceil$  5 06 2
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**CAP 8: 6 08 ECC**

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- 6 08 1.  $\lceil \text{Ha Dat Hb } T . \text{Ecc} \rceil$  5 08 1
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「 Fin Caput VI 」

*vocos\_III\_clavis\_c.tex*

## CLAVIS

## THE KEY

to **CAPUT V**, *Lectio Signorum*  
and **CAPUT VI**, *Multiplicatio Umbrae*

Those two documents describe `edgeAndSilhouetteIntersection0cr.py` in Hans Freudenthal's own units of meaning and own operators in LINCOS.

## 1. Signa — the operators

| SIGN                          | READING                                                                     | SHOWN AT                      |                                                                    |
|-------------------------------|-----------------------------------------------------------------------------|-------------------------------|--------------------------------------------------------------------|
| $\lceil \quad \rceil$         | enclose a program text; and, between them, an ordered pair or an $n$ -tuple | LINCOS 1 00 0, 1 29 1         | the double duty is his                                             |
| $\Lambda$                     | for every                                                                   | LINCOS 1 18 3                 | an infinite conjunction                                            |
| $\vee$                        | there is at least one                                                       | LINCOS 1 18 8                 | an infinite disjunction                                            |
| $\hat{\phantom{x}}$           | the set of all ... such that                                                | LINCOS 1 29 3                 | “a circumflex over a vertical stroke before the letter”            |
| $\in \notin$                  | is in / is not in                                                           | LINCOS 1 17 2                 |                                                                    |
| $\subset \supset$             | is contained in / contains                                                  | LINCOS 1 25 1                 |                                                                    |
| $\cup \cap$                   | union / intersection                                                        | LINCOS 1 26 2                 |                                                                    |
| $\wedge \vee \neg$            | and / or / not                                                              | LINCOS 1 11 2, 1 09 1, 1 36 8 |                                                                    |
| $\rightarrow \leftrightarrow$ | if-then / if and only if                                                    | LINCOS 1 06 1, 1 11 2         |                                                                    |
| $= \neq > <$                  | the arithmetical relations                                                  | LINCOS 1 01 1–3, 1 10 2       |                                                                    |
| $\geq \leq$                   |                                                                             |                               |                                                                    |
| $+ - /$                       | added to, less, divided by                                                  | LINCOS 1 03 1, 1 13 1, 1 15 5 |                                                                    |
| <i>(nothing)</i>              | <b>multiplied by</b>                                                        | LINCOS 1 14 4                 | “we shall now adopt the habit of omitting the multiplication sign” |
| $?$                           | the interrogation: what is the ... such that                                | LINCOS 1 13 1, 3 01 2         |                                                                    |
| <b>sup inf</b>                | the least upper / greatest lower bound                                      | LINCOS 1 33 1                 | see §6                                                             |
| $\cdot : '  $                 | punctuation of 1, 3, 4 and 8 units                                          | LINCOS 1 05 0                 | the marks are additive; the stronger mark separates the more       |

The third row from the bottom is not an omission. Freudenthal drops the multiplication sign at 1 14 4 for the convenience of the reader, and never writes it again. Caput VI is named for an operation that does not occur in it as a mark: in `c p = i p j p` the whole apparatus of this project is the white space between `i p` and `j p`.

## 2. Numeri — the dyadic numerals

Numerals in Caput V and VI are dyadic throughout, after 1 02 1, where Freudenthal supersedes his ostensive numerals with “algorithmic ones, composed of syllables written 0 and 1 according to the rules of the dyadic positional system”. Every numeral that occurs in the two caputs:

| DYADIC        |      | WHAT IT COUNTS                                                  |
|---------------|------|-----------------------------------------------------------------|
| 10            | 2    | the factor every length is enlarged by (- <b>upscale 2</b> )    |
| 11            | 3    | three colours; three places of closing; three sign-widths       |
| 101           | 5    | the fifth part, in <b>11 q / 101</b> = 0.6 q                    |
| 111           | 7    | the width of the blur                                           |
| 1000          | 8    | the side of the square in which light is levelled               |
| 10100         | 20   | the margin of white added around the field                      |
| 11101         | 29   | the lower limen ( <b>129</b> )                                  |
| 101100        | 44   | the middle light of the whole field                             |
| 110010        | 50   | the fixed lower limen, used only if the field has no middle     |
| 111010        | 58   | the upper limen ( <b>h58</b> )                                  |
| 10010110      | 150  | the fixed upper limen                                           |
| 1010101       | 85   | places in the stroke of a typical sign                          |
| 100           | 4    | places of contact in a typical survivor                         |
| 11111111      | 255  | the greatest light                                              |
| 1101000       | 104  |                                                                 |
| 1110100       | 116  | the three middle lights of the collection the net was taught on |
| 1111010       | 122  |                                                                 |
| 1000000000    | 512  | the longest side the net is shown ( <b>sz512</b> )              |
| 101101000     | 360  | signs kept                                                      |
| 1010011011001 | 5337 | signs multiplied by nothing                                     |
| 1011001000001 | 5697 | signs found in the whole field                                  |

### 3. Verba Lexicon

| WORD           | FREUDENTHAL'S GLOSS                                                  | AT            | WHAT IT DOES HERE                                                                           |
|----------------|----------------------------------------------------------------------|---------------|---------------------------------------------------------------------------------------------|
| <i>Agg</i>     | "← L <i>aggregatum</i> " — sets, classes                             | LINCOS 1 24 0 | every mask is one                                                                           |
| <i>Anl</i>     | "← L <i>analyzat</i> " — analyses                                    | LINCOS 3 07 1 | the net's forward pass                                                                      |
| <i>Ant</i>     | "← L <i>ante</i> " — before                                          | LINCOS 2 01 6 | the teaching happened before now                                                            |
| <i>Apu</i>     | "← L <i>apud</i> " — the local "at"                                  | LINCOS 4 08 4 | the reader recognises a thing <i>at</i> a place                                             |
| <i>Car</i>     | the cardinal number of                                               | LINCOS 1 27 1 | every count in both caputs                                                                  |
| <i>Cca</i>     | "← L <i>circa</i> " — about, nearly                                  | LINCOS 3 19 1 | carries every approximation: the interpolation, the weighting of grey, the fractional means |
| <i>Cog</i>     | "← L <i>cognoscit</i> " — recognises                                 | LINCOS 3 15 1 | the whole of optical character recognition                                                  |
| <i>Cor</i>     | "← L <i>corpus</i> " — body                                          | LINCOS 4 18 5 | the two sides of a stroke made into one body                                                |
| <i>Cpu</i>     | "← L <i>computat</i> " — computes                                    | LINCOS 3 04 1 | what the net does                                                                           |
| <i>Ctr</i>     | "← L <i>centrum</i> " — mass centre                                  | LINCOS 4 20 4 | the centre of a box; the mean of a part (see §6)                                            |
| <i>Dat</i>     | "← L <i>dat</i> " — gives                                            | LINCOS 3 38 1 | every handing-over of a field                                                               |
| <i>Dst</i>     | "← L <i>distantia</i> " — distance                                   | LINCOS 4 01 1 | between places; and, by 5 01 2, between numbers                                             |
| <i>Ecc</i>     | "← L <i>ecce</i> = see"; "will always announce"                      | LINCOS 2 01 6 | announces the plate. It is the last word of both caputs                                     |
| <i>Enu</i>     | "← L <i>enumerat</i> " — counts                                      | LINCOS 3 03 1 | 5697; 5337; 360                                                                             |
| <i>Etc</i>     | and so on                                                            | LINCOS 1 16 4 | the second and third colour, unwritten                                                      |
| <i>Fin</i>     | the end of                                                           | LINCOS 2 01 6 | the end of a path; the end of a caput                                                       |
| <i>Ha Hb</i>   | the dramatis personae                                                | LINCOS 3 00 3 | <i>Ha</i> acts; <i>Hb</i> reads; <i>Hc</i> was taught; <i>Hd</i> is a human                 |
| <i>Hom</i>     | "← L <i>homo</i> " — man                                             | LINCOS 3 26 5 | occurs exactly once in each caput: the hands that drew the boundaries                       |
| <i>Ini</i>     | the beginning of                                                     | LINCOS 2 02 4 | the beginning of a path                                                                     |
| <i>Inq</i>     | "← L <i>inquit</i> " — says                                          | LINCOS 3 00 2 | every question and every answer                                                             |
| <i>Int</i>     | "← L <i>integer</i> "                                                | LINCOS 1 16 5 | the coordinates of a place                                                                  |
| <i>Ise</i>     | "← L <i>inter se</i> " — among themselves                            | LINCOS 3 28 2 | two signs standing on one line of writing                                                   |
| <i>Lap</i>     | "← L <i>lapis</i> " — rectangular block                              | LINCOS 4 05 3 | the four bounds of a sign                                                                   |
| <i>Lex</i>     | "← L <i>lex</i> " — law                                              | LINCOS 3 39 1 | the title of 6 05                                                                           |
| <i>Mul Pau</i> | "← L <i>multo, paulo</i> " — much, a little; adverbs hung on > and < | LINCOS 3 19 1 | the whole of 6 06 5: the survivor's contact is <i>a little</i> more than nothing            |
| <i>Mut</i>     | "← L <i>mutat</i> " — changes                                        | LINCOS 3 11 1 | the gradient. An edge is a place where the field changes                                    |
| <i>Nnc</i>     | "← L <i>nunc</i> " — now                                             | LINCOS 3 20 1 | the moment of the making                                                                    |
| <i>Num</i>     | the natural numbers                                                  | LINCOS 1 17 2 | lights                                                                                      |
| <i>Ord</i>     | ordered                                                              | LINCOS 1 33 1 | the title of 5 07                                                                           |

| WORD       | FREUDENTHAL'S GLOSS                      | AT                       | WHAT IT DOES HERE                                                                  |
|------------|------------------------------------------|--------------------------|------------------------------------------------------------------------------------|
| <i>Pla</i> | "← L <i>planum</i> " — planes            | LINCOS 4 01 7            | the picture. Not <i>Spa</i> : a picture is a plane, and has two coordinates        |
| <i>Prb</i> | "← L <i>probabilitas</i> " — probability | LINCOS 3 40 4            | what the taught net answers with, before any limen                                 |
| <i>Pst</i> | "← L <i>post</i> " — after               | LINCOS 2 02 2            | order along a path                                                                 |
| <i>Put</i> | "← L <i>puta</i> " — namely              | LINCOS 3 05 2            | binds a letter to what has just been said                                          |
| <i>Qia</i> | "← L <i>quia</i> " — because             | LINCOS 3 12 0            | why the net knows what it knows                                                    |
| <i>Rea</i> | "← L <i>numerus realis</i> "             | LINCOS 1 23 1            | probabilities, fractions, distances                                                |
| <i>Rep</i> | "← L <i>reperit</i> " — finds            | LINCOS 3 06 1            | the title of 5 06                                                                  |
| <i>Sat</i> | "← L <i>satis</i> " — enough             | LINCOS 3 29 8            | one place of contact is enough                                                     |
| <i>Sca</i> | "← L <i>scala</i> " — scale              | LINCOS 4 27              | the title of 5 02                                                                  |
| <i>Sci</i> | "← L <i>scit</i> " — knows               | LINCOS 3 13 0            | the net knows; nobody in either caput knows what was read                          |
| <i>Sin</i> | "← L <i>sine</i> " — omits               | LINCOS 3 11 2            | the discarding. 5337 signs are <i>Sin</i> 'd                                       |
| <i>Tem</i> | "← L <i>tempus</i> " — time              | LINCOS 2 02 5            | the moment the teaching happened                                                   |
| <i>Via</i> | "← L <i>via</i> " — the path function    | LINCOS 4 21 1            | the chain of places that joins a weak edge to a strong one; and the traced outline |
| <i>Vul</i> | "← L <i>vult</i> " — wishes              | LINCOS 3 29 2,<br>3 38 0 | the optional levelling of the light happens only if <i>Ha</i> wishes it            |

## 4. Caput V decoded — *Lectio Signorum*

| TEXT   | WHAT IT SAYS                                                                                                                                                                                            | IN THE SOURCE                                                                            |
|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| 5 01 1 | <i>P</i> is a plane, and its places are exactly the pairs of whole numbers.                                                                                                                             | the image is a lattice of pixels                                                         |
| 5 01 2 | The distance between two numbers is never negative, and is either their difference one way or the other.                                                                                                | absolute difference; needed because <i>Dst</i> is his only word for "how far apart"      |
| 5 01 3 | At every place <i>f</i> gives three numbers, each between 0 and 255.                                                                                                                                    | the colour image, three channels, 8 bits                                                 |
| 5 01 4 | Any collection of places is a set.                                                                                                                                                                      | <b>there is no word for "mask" because none is needed</b>                                |
| 5 02 1 | <i>Q</i> is a plane on which <i>g</i> at $\lceil x.y \rceil$ is <i>nearly</i> <i>f</i> at $\lceil x/2.y/2 \rceil$ .                                                                                     | <code>-upscale 2</code> ; <i>Cca</i> carries the cubic interpolation                     |
| 5 02 2 | Where <i>g</i> gives three numbers, <i>h</i> gives nearly their third part.                                                                                                                             | <code>cvtColor(BGR2GRAY)</code> ; <i>Cca</i> carries the channel weighting               |
| 5 02 3 | Only if <i>Ha</i> wishes: within each square of eight by eight places, differences in <i>h</i> ' are no smaller than in <i>h</i> and no more than twice as large.                                       | <code>-clahe, clipLimit=2.0, tileGridSize=(8,8)</code>                                   |
| 5 02 4 | For places within seven of <i>p</i> whose light differs from <i>p</i> 's only a little, <i>k</i> at <i>p</i> is nearly their light.                                                                     | <code>bilateralFilter(7,50,50)</code> — the blur that refuses to cross an edge           |
| 5 03 1 | <i>m</i> has as many places under it as over it. It is 44.                                                                                                                                              | the median grey of the whole field                                                       |
| 5 03 2 | <i>u</i> is the whole number just under $m - m/3$ . It is 29.                                                                                                                                           | the lower Canny threshold, <code>sigma=0.33</code>                                       |
| 5 03 3 | <i>v</i> is the whole number just under $m + m/3$ . It is 58.                                                                                                                                           | the upper Canny threshold                                                                |
| 5 03 4 | Should <i>v</i> not exceed <i>u</i> , then <i>u</i> is 50 and <i>v</i> is 150.                                                                                                                          | the fallback for a field with no middle to speak of                                      |
| 5 03 5 | The change of <i>k</i> at <i>p</i> is the greatest distance between its light and a neighbour's.                                                                                                        | the gradient magnitude                                                                   |
| 5 03 6 | <i>p</i> is an edge if its change exceeds <i>v</i> ; or if its change exceeds <i>u</i> and there is a path beginning at <i>p</i> , every place of which exceeds <i>u</i> , whose end exceeds <i>v</i> . | <b>Canny hysteresis</b> , stated with <i>Via</i> , <i>Ini</i> and <i>Fin</i>             |
| 5 04 1 | <i>p</i> is in <i>B</i> if it is in <i>A</i> , or if two places of <i>A</i> stand within three of <i>p</i> and within three of each other.                                                              | <code>MORPH_CLOSE</code> , ellipse 3: the two sides of a stroke are joined into one body |
| 5 04 2 | <i>R</i> is a plane holding <i>Q</i> shifted by twenty in both directions.                                                                                                                              | <code>copyMakeBorder(20)</code>                                                          |
| 5 04 3 | <i>e</i> is 0 on <i>B</i> and 255 off it.                                                                                                                                                               | <code>bitwise_not</code> : black strokes on white paper                                  |
| 5 04 4 | <i>n</i> is the greatest second coordinate in <i>R</i> .                                                                                                                                                | the height, needed at 5 05 5                                                             |
| 5 05 1 | <i>Ha</i> gives <i>Hb</i> the field <i>e</i> .                                                                                                                                                          | the bitmap is handed to the reader                                                       |
| 5 05 2 | <i>Ha</i> asks <i>Hb</i> : which are the $\lceil \text{place} . \text{width} . \text{height} . \text{thing} \rceil$ such that <i>Hb</i> recognises the thing at the place?                              | <code>image_to_boxes</code>                                                              |

| TEXT     | WHAT IT SAYS                                                                                                                                         | IN THE SOURCE                                                                                     |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| 5 05 3   | <i>Hb</i> answers <i>S</i> .                                                                                                                         |                                                                                                   |
| 5 05 4   | For each answer, <i>L</i> is the set of places inside the rectangle.                                                                                 | the box, as a set of places, so that it can be intersected                                        |
| 5 05 5   | The place is corrected: twenty off, and the second coordinate counted from the other end.                                                            | the reader counts <i>y</i> from the foot of the field; the margin is taken back off               |
| 5 05 6   | A sign with no width, no height, or no ink is omitted by <i>Ha</i> .                                                                                 |                                                                                                   |
| 5 05 7   | <i>Ha</i> counts <i>S</i> : 5697.                                                                                                                    |                                                                                                   |
| 5 06 1   | <i>S'</i> is a part of <i>S</i> , defined at 6 05 6.                                                                                                 | the survivors of the multiplication                                                               |
| 5 06 2   | <i>c</i> is 0 at the strokes of the surviving signs and 255 everywhere else.                                                                         | <code>render_survivors</code>                                                                     |
| 5 06 3–5 | <i>Ha</i> gives <i>Hb</i> that field and asks again; <i>Hb</i> answers <i>S''</i> .                                                                  | <b>the second reading</b> , from nothing                                                          |
| 5 07 1   | <i>q</i> has as many sign-heights under it as over it.                                                                                               | the median glyph height                                                                           |
| 5 07 2   | Two signs stand on one line when their centres are nearer than three fifths of <i>q</i> .                                                            | <code>group_lines</code> , tolerance $0.6 \times$ median height                                   |
| 5 07 3   | <i>r</i> has as many under it as over it among the steps from one sign to the next along a line, counting only steps shorter than three sign-widths. | the median advance: one column of the grid. The long steps are word-gaps and are thrown out first |
| 5 07 4   | <i>s</i> likewise among the distances between the centres of signs <i>not</i> on one line.                                                           | the median line pitch: one row of the grid                                                        |
| 5 07 5   | <i>t</i> is the centre of the topmost line; <i>w</i> the least first coordinate.                                                                     | the origin of the grid                                                                            |
| 5 07 6   | Every sign stands at the cell $\lceil i.j \rceil$ got by dividing by <i>s</i> and by <i>r</i> and taking the whole part.                             | the position on the monospace grid                                                                |
| 5 07 7   | Where two signs want one cell, the later one goes one to the right.                                                                                  | nothing that was read is ever written over                                                        |
| 5 08 1   | <i>Ha</i> gives <i>Hb</i> the grid. <b>Behold.</b>                                                                                                   | <code>_layout.txt</code> , printed entire                                                         |

#### 4.1 lincos and hysteresis explanation

To explain branch **E** one has to describe hysteresis.

5 03 6.  $\lceil \Lambda p : p \in A . \leftrightarrow : \text{Mut } k p > v . \vee : \text{Mut } k p > u . \wedge .$   
 $\vee w \in \text{Via} . \text{Ini } w = p . \wedge . \text{Mut } k ( \text{Fin } w ) > v . \wedge .$   
 $\Lambda r \in w . \text{Mut } k r > u \rceil$

|                                                  |                                                                             |
|--------------------------------------------------|-----------------------------------------------------------------------------|
| $\Lambda p : p \in A . \leftrightarrow :$        | for every <i>p</i> : <i>p</i> is an edge exactly when —                     |
| $\text{Mut } k p > v$                            | the field changes at <i>p</i> by more than the upper limen                  |
| $\vee :$                                         | or (a weaker separation than the one before it: what follows is one clause) |
| $\text{Mut } k p > u . \wedge .$                 | it changes by more than the lower limen, and                                |
| $\vee w \in \text{Via} .$                        | there is a path                                                             |
| $\text{Ini } w = p . \wedge .$                   | beginning at <i>p</i> , and                                                 |
| $\text{Mut } k ( \text{Fin } w ) > v . \wedge .$ | whose end changes by more than the upper limen, and                         |
| $\Lambda r \in w . \text{Mut } k r > u$          | every place of which changes by more than the lower limen                   |

### 5. Caput VI decoded — *Multiplicatio Umbrae*

| TEXT   | WHAT IT SAYS                                                                            | IN THE SOURCE                                                                         |
|--------|-----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| 6 01 1 | <i>Ha</i> gives <i>Hb</i> the field <i>k</i> , and gives <i>Hc</i> the field <i>k</i> . | <b>the axiom.</b> The same letter is the whole of it: one preparation, handed to both |
| 6 01 2 | <i>A</i> and <i>B</i> are both sets of places of the same <i>Q</i> .                    | the two masks are aligned by construction, not by correction                          |
| 6 01 3 | <i>Ha</i> asks <i>Hc</i> : which places lie on a path that some human gave?             | what the taught net is actually asked. Not <i>where does the light change</i>         |
| 6 01 4 | <i>Hc</i> knows, because at a time before now some human told it.                       | <code>hed_pretrained_bsds.caffemodel</code> : trained on human-drawn boundaries       |

| TEXT   | WHAT IT SAYS                                                                                                                                                | IN THE SOURCE                                                                                                                                      |
|--------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| 6 02 1 | $U$ is a plane whose greatest side is 512, on which $g'$ is nearly $g$ reduced.                                                                             | <b>-hed-size 512</b>                                                                                                                               |
| 6 02 2 | $g''$ is $g'$ less $\lceil 104.116.122 \rceil$ .                                                                                                            | the three channel means of the collection the net was taught on                                                                                    |
| 6 02 3 | $Hc$ analyses it, computes the probability, and tells $Ha$ .                                                                                                | one forward pass                                                                                                                                   |
| 6 02 4 | At every place the probability is a real between 0 and 1.                                                                                                   | <b>_silprob.png</b> , before any limen                                                                                                             |
| 6 02 5 | $D$ and $E$ are the parts under and over $z'$ ; $n$ and $o$ their sizes; $d$ the distance between their centres; and no other number makes $n$ odd greater. | <b>Otsu's method</b> , stated exactly: maximise $n_1 n_2 (\mu_1 - \mu_2)^2$ . The two multiplications and the squaring are the four juxtapositions |
| 6 02 6 | $B$ is the part over $z'$ .                                                                                                                                 | the binarised outline                                                                                                                              |
| 6 02 7 | $B'$ lies inside $B$ ; every place of $B$ has a place of $B'$ within two; and no place of $B'$ has more than two neighbours in $B'$ .                       | <b>-sil-thin</b> : the fat response is reduced to a line one place wide                                                                            |
| 6 03 1 | Along a path, consecutive places are neighbours.                                                                                                            |                                                                                                                                                    |
| 6 03 2 | $Ha$ gives out $\lceil \text{path} . \text{place} . x . y \rceil$ for every place of every path.                                                            | <b>_edgecoords.csv</b>                                                                                                                             |
| 6 04 1 | $B''$ is the set of places standing within $s$ of $B'$ .                                                                                                    | the band of tolerance around the outline                                                                                                           |
| 6 04 2 | $s$ is 0, so $B''$ is $B'$ .                                                                                                                                | <b>-touch 0</b> : no band was granted. Contact had to be literal                                                                                   |
| 6 05 1 | $i$ is 1 on $A$ and 0 off it.                                                                                                                               | the characteristic function of the strokes                                                                                                         |
| 6 05 2 | $j$ is 1 on $B''$ and 0 off it.                                                                                                                             | the characteristic function of the outline                                                                                                         |
| 6 05 3 | $c \text{ p} = i \text{ p} j \text{ p}$                                                                                                                     | <b>the multiplication.</b><br><b>cv2.bitwise_and.</b> There is no sign for it                                                                      |
| 6 05 4 | $c$ at $p$ is nothing exactly when $i$ is nothing or $j$ is nothing.                                                                                        | 1 14 5, unaltered, applied to two masks                                                                                                            |
| 6 05 5 | $C$ is where $c$ is 1; which is $A \cap B''$ .                                                                                                              | the contact                                                                                                                                        |
| 6 05 6 | $n$ is the size of the stroke in the box, $k$ the size of the contact, $e$ their quotient.                                                                  | <b>stroke_px, hit_px, hit_frac</b>                                                                                                                 |
| 6 05 7 | A sign survives exactly when $k$ is at least 1, $n$ more than 0, and $e$ at least 0 — namely, when the contact is <i>enough</i> .                           | <b>-min-hits 1, -min-frac 0</b>                                                                                                                    |
| 6 05 8 | A sign whose contact is nothing is omitted by $Ha$ .                                                                                                        | the annihilation, in one word: <i>Sin</i>                                                                                                          |
| 6 06 1 | $Ha$ counts $S$ : 5697.                                                                                                                                     | signs found                                                                                                                                        |
| 6 06 2 | $Ha$ counts those whose contact is nothing: 5337.                                                                                                           | <b>multiplied by zero, and gone</b>                                                                                                                |
| 6 06 3 | $S'$ has 360 members.                                                                                                                                       | 6.32 in the hundred                                                                                                                                |
| 6 06 4 | For a survivor, $n$ is nearly 85 and $k$ nearly 4.                                                                                                          | a contact of four places buys the survival of eighty-five                                                                                          |
| 6 06 5 | $n$ is <i>much</i> greater than $k$ ; $e$ is a <i>little</i> greater than nothing; the greatest $e$ is <i>much</i> less than one.                           | Freudenthal's adverbs <i>Mul</i> and <i>Pau</i> (3 19 1), doing the work a statistician would do with three decimals                               |
| 6 07 1 | $K$ is every place of every surviving sign's stroke.                                                                                                        |                                                                                                                                                    |
| 6 07 2 | $K$ contains more than the contact, and is not the contact.                                                                                                 | <b>the sign is kept whole, not clipped at the crossing</b>                                                                                         |
| 6 07 3 | $Ha$ gives $Hb \ K$ ; see 5 06 2.                                                                                                                           | handed back to Caput V for the second reading                                                                                                      |
| 6 08 1 | <b>Behold.</b>                                                                                                                                              |                                                                                                                                                    |

6 05 3.  $\lceil \Lambda \text{ p} \in \mathbb{Q} . c \text{ p} = i \text{ p} j \text{ p} \rceil$

|                                      |                                                |
|--------------------------------------|------------------------------------------------|
| $\Lambda \text{ p} \in \mathbb{Q} .$ | for every place of the prepared plane          |
| $c \text{ p} =$                      | the contact there is                           |
| $i \text{ p}$                        | one if a sign is written there, nothing if not |
| (no sign at all)                     | <b>multiplied by</b> — LINCOS 1 14 4           |
| $j \text{ p}$                        | one if the outline runs there, nothing if not  |

Freudenthal gives the receiver the consequence at 1 14 5, in the fourteenth section of his first chapter, before he has actors, before he has time, and long before he has space:

$$\lceil \mathbf{a} \mathbf{b} = 0 \ . \ \leftrightarrow \ . \ \mathbf{a} = 0 \ . \ \vee \ . \ \mathbf{b} = 0 \ \rceil$$

Read with *i* and *j* in place of *a* and *b*, that line is the entire behaviour of this machine. LINCOS has words for judging — *Ben* and *Mal*, good and bad, at 3 00 4, the fourth text of his chapter on behaviour. Neither occurs in Caput VI.

## 6. Quod non est Freudenthalis — the eleven departures

No word was coined. But eleven of his words are made to carry a little more than he made them carry, and one operator is assumed. They are listed here so that nothing passes as his that is not.

|                 | HIS                                                                                  | HERE                                                                                                                                                                                                    |
|-----------------|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Dst</i>      | the distance between two places, proportional to the delay of a signal LINCOS 4 01 1 | also the distance between two numbers — but defined on the spot, at 5 01 2, so that nothing is assumed                                                                                                  |
| <i>Ctr</i>      | the mass centre of a body LINCOS 4 20 4                                              | the centre of a rectangle, and the mean of a set of numbers. Left undefined, as he leaves mass centre to his fourth chapter                                                                             |
| <i>Ini Fin</i>  | the beginning and end of a stretch of time LINCOS 2 02 4, 2 01 6                     | the beginning and end of a path                                                                                                                                                                         |
| <i>Pst</i>      | after, of moments LINCOS 2 02 2                                                      | after, of places along a path                                                                                                                                                                           |
| <i>Ise</i>      | among themselves LINCOS 3 28 2                                                       | standing on one line of writing                                                                                                                                                                         |
| <i>Via</i>      | the path function of a moving body LINCOS 4 21 1                                     | a chain of neighbouring places. Nothing moves along it                                                                                                                                                  |
| <i>Lap</i>      | a rectangular block, in space LINCOS 4 05 3                                          | a rectangle, in a plane                                                                                                                                                                                 |
| <i>Apu</i>      | the local “at” LINCOS 4 08 4                                                         | at a place in a plane                                                                                                                                                                                   |
| <i>Prb</i>      | the probability of an event, in a game LINCOS 3 40 4                                 | the belief of a taught net that a boundary runs at a place                                                                                                                                              |
| <i>sup</i>      | —                                                                                    | he shows <i>inf</i> at 1 33 1 and not its twin. <i>sup</i> is assumed                                                                                                                                   |
| <i>Ha Hb Hc</i> | his dramatis personae, introduced among humans LINCOS 3 00 3                         | never once said to be <i>Hom</i> . At 4 00 0 he writes: “So far the members of the class <i>Hom</i> might be ghosts.” Only <i>Hd</i> , at 6 01 3–4, is a human, and <i>Hd</i> appears in the past tense |

## 7. Colophon

**Source of the language.** Hans Freudenthal, LINCOS: DESIGN OF A LANGUAGE FOR COSMIC INTERCOURSE, Part I, North-Holland Publishing Company, Amsterdam, 1960

**Source of the machine.** `edgeAndSilhouetteIntersection0cr.py`; the making of 2026-08-01-17-41-23, whose settings were `hed-sz512-throtsu-X-canny-l29-h58-tch0-silthin-up2`.

**The three documents.**

`vocos_I_lectio_signorum_c_alg2e.tex` — Caput V

`vocos_II_multiplicatio_umbrae_c_alg2e.tex` — Caput VI

`vocos_III_clavis_c.tex`