1 Notes

The following notations may be used within VoxML specifications to structure voxeme instances, subject to the definitions below.

- $\mathcal{E}$ — the minimal embedding space (MES)
- $\mathcal{E}_A$ — the axis A of the MES
- $loc(x)$ — location of object x
- $orient(x)$ — orientation of object x
- $vec(A)$ — vector denoted by (positive unless otherwise specified) axis A
- $opp(v)$ — opposite vector of v
- $reify(x, s)$ — relabel object x (can be a collection (c_1,...,c_n)) as symbol s
- $interior(x)$ — the interior surface (and volumetric enclosed space) of object x
- $exterior(x)$ — the exterior surface of object x
- $dimension(x)$ — the number of dimensions defining entity x
- $while(c, e)$ — operation e is executed as long as condition c is true
- $for(x \in y)$ — following operation is executed for each element x in collection y
- $def(x, y)$ — defines y as the value of x
- $as(i)$ — comparator, returns input i as generic symbol
- $align(A, B)$ – defines vector A as aligned (parallel) with vector B

2 Templates

(1)
$$\left[\begin{array}{l} \textbf{OBJECT} \\ \text{LEX} = \left[\begin{array}{l}\text{PRED} = \textbf{...} \\ \text{TYPE} = \textbf{...}\end{array}\right] \\ \text{TYPE} = \left[\begin{array}{l}\text{HEAD} = \textbf{...} \\ \text{COMPONENTS} = \textbf{...} \\ \text{CONCAVITY} = \textbf{...} \\ \text{ROTATSYM} = \{...\} \\ \text{REFLECTSYM} = \{...\} \\ \text{CONSTR} = \{...\}\end{array}\right] \\ \text{HABITAT} = \left[\begin{array}{l}\text{INTR} = ... \\ \text{EXTR} = ...\end{array}\right] \\ \text{AFFORD\_STR} = \left[\ \text{A}_n = H_{[\#]} \rightarrow [E(a_{1..n})]R(a_{1..n})\ \right] \\ \text{EMBODIMENT} = \left[\begin{array}{l}\text{SCALE} = \textbf{...} \\ \text{MOVABLE} = \textbf{...}\end{array}\right] \end{array}\right]$$

TYPE	physobj, artifact

HEAD	prismatoid, pyramid, wedge, parallelepiped, cupola, frustum, cylindroid, ellipsoid, hemiellipsoid, bipyramid, rectangular_prism, toroid, sheet

CONCAVITY	convex, flat, concave

ROTATSYM	X, Y, Z

REFLSYM	XY, XZ, YZ

SCALE	<agent, agent >agent

MOVABLE	true, false

DENSITY	1..7

(2)
$$\begin{bmatrix} \textbf{PROGRAM} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{...} \\ \text{TYPE} = \textbf{...} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{HEAD} = \textbf{...} \\ \text{ARGS} = \begin{bmatrix} \text{A}_1 = \textbf{x:a} \end{bmatrix} \\ \text{BODY} = \begin{bmatrix} \text{E}_n = E(a_{1..n}) \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

TYPE	process, transition_event

HEAD	state, process, transition, assignment, test

(3)
$$\begin{bmatrix} \textbf{ATTRIBUTE} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{...} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{SCALE} = \textbf{...} \\ \text{ARITY} = \textbf{...} \\ \text{ARG} = \textbf{x:a} \end{bmatrix} \end{bmatrix}$$

SCALE	nominal, binary, ordinal, interval, rational

ARITY	intransitive, transitive

(4)
$$\begin{bmatrix} \textbf{RELATION} \\ \text{LEX} = \left[\text{PRED} = \textbf{...} \right] \\ \text{TYPE} = \begin{bmatrix} \text{CLASS} = \textbf{...} \\ \text{VALUE} = \textbf{...} \\ \text{ARGS} = \left[\text{A}_n = \textbf{x:...} \right] \\ \text{CONSTR} = \textbf{...} \end{bmatrix} \end{bmatrix}$$

CLASS	config, force_dynamic

VALUE	values of QSR calculus in use

(5)
$$\begin{bmatrix} \textbf{FUNCTION} \\ \text{LEX} = \left[\text{PRED} = \textbf{...} \right] \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:a} \\ \text{REFERENT} = \textbf{x}{\rightarrow}... \\ \text{MAPPING} = \textbf{f(n):R} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{...} \\ \text{AXIS} = \textbf{...} \\ \text{ARITY} = \textbf{a}(\rightarrow\text{PARAM})^*[bool(p)]{:}condition \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

SPACE	world, object, pov

AXIS	+X, -X, +Y, -Y, +Z, -Z

3 Thesis Test Set

3.1 Objects

(6)
$$\begin{bmatrix} \textbf{block} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{block} \\ \text{TYPE} = \textbf{physobj, artifact} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{HEAD} = \textbf{rectangular\_prism[1]} \\ \text{COMPONENTS} = \textbf{nil} \\ \text{CONCAVITY} = \textbf{flat} \\ \text{ROTATSYM} = \{X, Y, Z\} \\ \text{REFLECTSYM} = \{XY, XZ, YZ\} \end{bmatrix} \\ \text{HABITAT} = \begin{bmatrix} \text{INTR} = {}_{[2]}\left[\text{CONSTR} = \{X = Y + Z\} \right] \\ \text{EXTR} = ... \end{bmatrix} \\ \text{AFFORD\_STR} = \left[\text{A}_1 = H_{[2]} \rightarrow [put(x, on([1]))] support([1], x) \text{A}_3 = H_{[2]} \rightarrow [grasp(x, [1])] \right] \\ \text{EMBODIMENT} = \begin{bmatrix} \text{SCALE} = {<}\textbf{agent} \\ \text{MOVABLE} = \textbf{true} \end{bmatrix} \end{bmatrix}$$

(7)
$$\left[\begin{array}{l}\textbf{ball}\\ \textsc{lex} = \left[\begin{array}{l}\textsc{pred} = \textbf{ball}\\ \textsc{type} = \textbf{physobj, artifact}\end{array}\right]\\ \textsc{type} = \left[\begin{array}{l}\textsc{head} = \textbf{ellipsoid[1]}\\ \textsc{components} = \textbf{nil}\\ \textsc{concavity} = \textbf{convex}\\ \textsc{rotatsym} = \{X, Y, Z\}\\ \textsc{reflectsym} = \{XY, XZ, YZ\}\end{array}\right]\\ \textsc{habitat} = \left[\begin{array}{l}\textsc{intr} = \ldots\\ \textsc{extr} = \ldots\end{array}\right]\\ \textsc{afford\_str} = \left[\begin{array}{l}\textsc{a}_1 = H \rightarrow [grasp(x, [1])]\\ \textsc{a}_1 = H \rightarrow [hold(x, [1])]lift(x, [1])\\ \textsc{a}_1 = H \rightarrow [roll(x, [1])]\end{array}\right]\\ \textsc{embodiment} = \left[\begin{array}{l}\textsc{scale} = <\textbf{agent}\\ \textsc{movable} = \textbf{true}\end{array}\right]\end{array}\right]$$

(8)
$$\left[\begin{array}{l}\textbf{plate}\\ \textsc{lex} = \left[\begin{array}{l}\textsc{pred} = \textbf{plate}\\ \textsc{type} = \textbf{physobj, artifact}\end{array}\right]\\ \textsc{type} = \left[\begin{array}{l}\textsc{head} = \textbf{sheet[1]}\\ \textsc{components} = \textbf{base, surface[1]}\\ \textsc{concavity} = \textbf{concave}\\ \textsc{rotatsym} = \{Y\}\\ \textsc{reflectsym} = \{XY, YZ\}\end{array}\right]\\ \textsc{habitat} = \left[\begin{array}{l}\textsc{intr} = {}_{[2]}\left[\begin{array}{l}\textsc{constr} = \{Y \ll X, Y \ll Z\}\\ \textsc{up} = align(Y, \mathcal{E}_Y)\\ \textsc{top} = top(+Y)\end{array}\right]\\ \textsc{extr} = {}_{[3]}\left[\textsc{up} = align(Y, \mathcal{E}_{\perp Y})\right]\end{array}\right]\\ \textsc{afford\_str} = \left[\begin{array}{l}\textsc{a}_1 = H_{[2]} \rightarrow [put(x, on([1]))]support([1], x)\\ \textsc{a}_2 = H_{[2]} \rightarrow [put(x, in([1]))]contain([1], x)\\ \textsc{a}_3 = H_{[2]} \rightarrow [grasp(x, [1])]\\ \textsc{a}_3 = H_{[2]} \rightarrow [grasp(x, [1])]lift(x, [1])\\ \textsc{a}_3 = H_{[2]} \rightarrow [slide(x, [1])]\\ \textsc{a}_3 = H_{[3]} \rightarrow [roll(x, [1])]\end{array}\right]\\ \textsc{embodiment} = \left[\begin{array}{l}\textsc{scale} = <\textbf{agent}\\ \textsc{movable} = \textbf{true}\end{array}\right]\end{array}\right]$$

(9)
$$\left[\begin{array}{l}\textbf{cup}\\ \textsc{lex} = \left[\begin{array}{l}\textsc{pred} = \textbf{cup}\\ \textsc{type} = \textbf{physobj, artifact}\end{array}\right]\\ \textsc{type} = \left[\begin{array}{l}\textsc{head} = \textbf{cylindroid[1]}\\ \textsc{components} = \textbf{surface, interior}\\ \textsc{concavity} = \textbf{concave}\\ \textsc{rotatsym} = \{Y\}\\ \textsc{reflectsym} = \{XY, YZ\}\end{array}\right]\\ \textsc{habitat} = \left[\begin{array}{l}\textsc{intr} = {}_{[2]}\left[\begin{array}{l}\textsc{constr} = \{Y > X, Y > Z\}\\ \textsc{up} = align(Y, \mathcal{E}_Y)\\ \textsc{top} = top(+Y)\end{array}\right]\\ \textsc{extr} = {}_{[3]}\left[\textsc{up} = align(Y, \mathcal{E}_{\perp Y})\right]\end{array}\right]\\ \textsc{afford\_str} = \left[\begin{array}{l}\textsc{a}_1 = H_{[2]} \rightarrow [put(x, on([1]))]support([1], x)\\ \textsc{a}_2 = H_{[2]} \rightarrow [put(x, in([1]))]contain([1], x)\\ \textsc{a}_3 = H_{[2]} \rightarrow [grasp(x, [1])]\\ \textsc{a}_4 = H_{[3]} \rightarrow [roll(x, [1])]\end{array}\right]\\ \textsc{embodiment} = \left[\begin{array}{l}\textsc{scale} = <\textbf{agent}\\ \textsc{movable} = \textbf{true}\end{array}\right]\end{array}\right]$$

(10)
$$\left[\begin{array}{l}\textbf{disc}\\ \text{LEX} = \left[\begin{array}{l}\text{PRED} = \textbf{disc}\\ \text{TYPE} = \textbf{physobj, artifact}\end{array}\right]\\ \text{TYPE} = \left[\begin{array}{l}\text{HEAD} = \textbf{cylindroid[1]}\\ \text{COMPONENTS} = \textbf{nil}\\ \text{CONCAVITY} = \textbf{flat}\\ \text{ROTATSYM} = \{Y\}\\ \text{REFLECTSYM} = \{XY, YZ\}\end{array}\right]\\ \text{HABITAT} = \left[\begin{array}{l}\text{INTR} = {}_{[2]}\left[\text{CONSTR} = \{X > Y, Z > Y\}\right]\\ \text{EXTR} = \left[\begin{array}{l}{}_{[3]}\left[\begin{array}{l}\text{CONSTR} = \{X([1]) \geqslant X(y : physobj),\\ \qquad Z([1]) \geqslant Z(y : physobj)\}\end{array}\right]\\ {}_{[4]}\left[\text{UP} = align(Y, \mathcal{E}_{\perp Y})\right]\end{array}\right]\end{array}\right]\\ \text{AFFORD\_STR} = \left[\begin{array}{l}\text{A}_1 = H_{[2]} \rightarrow [grasp(x, [1])]\\ \text{A}_2 = H_{[3]} \rightarrow [put([1], on(y)]close([1], y)\\ \text{A}_4 = H_{[4]} \rightarrow [roll(x, [1])]\end{array}\right]\\ \text{EMBODIMENT} = \left[\begin{array}{l}\text{SCALE} = <\textbf{agent}\\ \text{MOVABLE} = \textbf{true}\end{array}\right]\end{array}\right]$$

(11)
$$\left[\begin{array}{l}\textbf{spoon}\\ \text{LEX} = \left[\begin{array}{l}\text{PRED} = \textbf{spoon}\\ \text{TYPE} = \textbf{physobj, artifact}\end{array}\right]\\ \text{TYPE} = \left[\begin{array}{l}\text{HEAD} = \textbf{sheet[1]}\\ \text{COMPONENTS} = \textbf{handle[2], bowl[3]}\\ \text{CONCAVITY} = \textbf{concave}\\ \text{ROTATSYM} = nil\\ \text{REFLECTSYM} = \{YZ\}\end{array}\right]\\ \text{HABITAT} = \left[\begin{array}{l}\text{INTR} = {}_{[4]}\left[\begin{array}{l}\text{CONSTR} = \{Z > X, Z \gg Y\}\\ \text{UP} = align(Y, \mathcal{E}_Y)\\ \text{FRONT} = top(+Y)\end{array}\right]\\ \text{EXTR} = {}_{[5]}\left[\text{UP} = align(Y, \mathcal{E}_{\perp Y})\right]\end{array}\right]\\ \text{AFFORD\_STR} = \left[\begin{array}{l}\text{A}_1 = H_{[4]} \rightarrow [put(x, in([3]))]contain([3], x)\\ \text{A}_2 = H_{[4]} \rightarrow [grasp(x, [2])]\\ \text{A}_1 = H_{[4]} \rightarrow [put([1], in(x))]contain(x, [1])\\ \text{A}_1 = H_{[5]}, contain(x, [1]) \rightarrow [stir(x, [1])]\end{array}\right]\\ \text{EMBODIMENT} = \left[\begin{array}{l}\text{SCALE} = <\textbf{agent}\\ \text{MOVABLE} = \textbf{true}\end{array}\right]\end{array}\right]$$

(12)
$$\left[\begin{array}{l}\textbf{book}\\ \text{LEX} = \left[\begin{array}{l}\text{PRED} = \textbf{book}\\ \text{TYPE} = \textbf{physobj, artifactj}\end{array}\right]\\ \text{TYPE} = \left[\begin{array}{l}\text{HEAD} = \textbf{rectangular\_prism[1]}\\ \text{COMPONENTS} = \textbf{cover[2]+, page[3]+}\\ \text{CONCAVITY} = \textbf{flat}\\ \text{ROTATSYM} = \textbf{nil}\\ \text{REFLECTSYM} = \{XY\}\end{array}\right]\\ \text{HABITAT} = \left[\begin{array}{l}\text{INTR} = {}_{[4]}\left[\begin{array}{l}\text{UP} = align(Y, \mathcal{E}_Y)\\ \text{TOP} = front(+Y)\end{array}\right]\\ \text{EXTR} = \ldots\end{array}\right]\\ \text{AFFORD\_STR} = \left[\begin{array}{l}\text{A}_1 = H \rightarrow [grasp(x, [2]),\\ \qquad move(x, [2], away(from([3])))]open(x, [1])\\ \text{A}_2 = H \rightarrow [grasp(x, [2]),\\ \qquad move(x, [2], toward([3]))]close(x, [1])\end{array}\right]\\ \text{EMBODIMENT} = \left[\begin{array}{l}\text{SCALE} = <\textbf{agent}\\ \text{MOVABLE} = \textbf{true}\end{array}\right]\end{array}\right]$$

(13)
$$\left[\begin{array}{l}\textbf{blackboard}\\ \textsc{lex} = \left[\begin{array}{l}\textsc{pred} = \textbf{blackboard}\\ \textsc{type} = \textbf{physobj, artifactj}\end{array}\right]\\ \textsc{type} = \left[\begin{array}{l}\textsc{head} = \textbf{sheet[1]}\\ \textsc{components} = \textbf{board, surface[1], back, leg[2]+}\\ \textsc{concavity} = \textbf{flat}\\ \textsc{rotatsym} = \textbf{nil}\\ \textsc{reflectsym} = \{YZ\}\end{array}\right]\\ \textsc{habitat} = \left[\begin{array}{l}\textsc{intr} = [3]\left[\begin{array}{l}\textsc{up} = align(Y, \mathcal{E}_Y)\\ \textsc{top} = top(+Y)\\ \textsc{up} = align(Z, \mathcal{E}_Z)\\ \textsc{top} = front(+Z)\\ \textsc{constr}[2] = \{Y \gg X, Y \gg Z\}\end{array}\right]\\ \textsc{extr} = \ldots\end{array}\right]\\ \textsc{afford\_str} = \left[\begin{array}{l}\mathrm{A}_1 = H \rightarrow [grasp(x, [1])]\\ \mathrm{A}_1 = H_{[3]} \rightarrow [write(x, on([1])]\end{array}\right]\\ \textsc{embodiment} = \left[\begin{array}{l}\textsc{scale} = \textbf{agent}\\ \textsc{movable} = \textbf{true}\end{array}\right]\end{array}\right]$$

(14)
$$\left[\begin{array}{l}\textbf{bottle}\\ \textsc{lex} = \left[\begin{array}{l}\textsc{pred} = \textbf{bottle}\\ \textsc{type} = \textbf{physobj, artifact}\end{array}\right]\\ \textsc{type} = \left[\begin{array}{l}\textsc{head} = \textbf{cylindroid[1]}\\ \textsc{components} = \textbf{surface, interior}\\ \textsc{concavity} = \textbf{concave}\\ \textsc{rotatsym} = \{Y\}\\ \textsc{reflectsym} = \{XY, YZ\}\end{array}\right]\\ \textsc{habitat} = \left[\begin{array}{l}\textsc{intr} = [2]\left[\begin{array}{l}\textsc{constr} = \{Y > X, Y > Z\}\\ \textsc{up} = align(Y, \mathcal{E}_Y)\\ \textsc{top} = top(+Y)\end{array}\right]\\ \textsc{extr} = [3]\left[\textsc{up} = align(Y, \mathcal{E}_{\perp Y})\right]\end{array}\right]\\ \textsc{afford\_str} = \left[\begin{array}{l}\mathrm{A}_1 = H_{[2]} \rightarrow [put(x, on([1]))]support([1], x)\\ \mathrm{A}_2 = H_{[2]} \rightarrow [put(x, in([1]))]contain([1], x)\\ \mathrm{A}_3 = H_{[2]} \rightarrow [grasp(x, [1])]\\ \mathrm{A}_4 = H_{[3]} \rightarrow [roll(x, [1])]\end{array}\right]\\ \textsc{embodiment} = \left[\begin{array}{l}\textsc{scale} = <\textbf{agent}\\ \textsc{movable} = \textbf{true}\end{array}\right]\end{array}\right]$$

(15)
$$\left[\begin{array}{l}\textbf{grape}\\ \textsc{lex} = \left[\begin{array}{l}\textsc{pred} = \textbf{grape}\\ \textsc{type} = \textbf{physobj}\end{array}\right]\\ \textsc{type} = \left[\begin{array}{l}\textsc{head} = \textbf{ellipsoid[1]}\\ \textsc{components} = \textbf{fruit[1]}\\ \textsc{concavity} = \textbf{flat}\\ \textsc{rotatsym} = \{Y\}\\ \textsc{reflectsym} = \{XY, YZ\}\end{array}\right]\\ \textsc{habitat} = \left[\begin{array}{l}\textsc{intr} = \ldots\\ \textsc{extr} = [2]\left[\textsc{up} = align(Y, \mathcal{E}_{\perp Y})\right]\end{array}\right]\\ \textsc{afford\_str} = \left[\begin{array}{l}\mathrm{A}_1 = H \rightarrow [grasp(x, [1])]\\ \mathrm{A}_1 = H \rightarrow [hold(x, [1])]lift(x, [1])\\ \mathrm{A}_1 = H \rightarrow [slide(x, [1])]\\ \mathrm{A}_1 = H_{[2]} \rightarrow [roll(x, [1])]\end{array}\right]\\ \textsc{embodiment} = \left[\begin{array}{l}\textsc{scale} = <\textbf{agent}\\ \textsc{movable} = \textbf{true}\end{array}\right]\end{array}\right]$$

(16)
$$\begin{bmatrix}
\textbf{apple} & \\
\text{LEX} = & \begin{bmatrix} \text{PRED} = \textbf{apple} \\ \text{TYPE} = \textbf{physobj} \end{bmatrix} \\
\text{TYPE} = & \begin{bmatrix} \text{HEAD} = \textbf{ellipsoid[1]} \\ \text{COMPONENTS} = \textbf{fruit[1], stem, leaf} \\ \text{CONCAVITY} = \textbf{flat} \\ \text{ROTATSYM} = \{Y\} \\ \text{REFLECTSYM} = \{XY, YZ\} \end{bmatrix} \\
\text{HABITAT} = & \begin{bmatrix} \text{INTR} = \dots \\ \text{EXTR} = {}_{[2]}\begin{bmatrix} \text{UP} = align(Y, \mathcal{E}_{\perp Y}) \end{bmatrix} \end{bmatrix} \\
\text{AFFORD_STR} = & \begin{bmatrix} \text{A}_1 = H \rightarrow [grasp(x, [1])] \\ \text{A}_1 = H \rightarrow [hold(x, [1])]lift(x, [1]) \\ \text{A}_1 = H \rightarrow [slide(x, [1])] \\ \text{A}_1 = H_{[2]} \rightarrow [roll(x, [1])] \end{bmatrix} \\
\text{EMBODIMENT} = & \begin{bmatrix} \text{SCALE} = <\textbf{agent} \\ \text{MOVABLE} = \textbf{true} \end{bmatrix}
\end{bmatrix}$$

(17)
$$\begin{bmatrix}
\textbf{banana} & \\
\text{LEX} = & \begin{bmatrix} \text{PRED} = \textbf{banana} \\ \text{TYPE} = \textbf{physobj} \end{bmatrix} \\
\text{TYPE} = & \begin{bmatrix} \text{HEAD} = \textbf{cylindroid[1]} \\ \text{COMPONENTS} = \textbf{fruit[1], stem} \\ \text{CONCAVITY} = \textbf{convex} \\ \text{ROTATSYM} = \{Y\} \\ \text{REFLECTSYM} = \{YZ\} \end{bmatrix} \\
\text{HABITAT} = & \begin{bmatrix} \text{INTR} = \dots \\ \text{EXTR} = {}_{[2]}\begin{bmatrix} \text{UP} = align(Y, \mathcal{E}_{\perp Y}) \end{bmatrix} \end{bmatrix} \\
\text{AFFORD_STR} = & \begin{bmatrix} \text{A}_3 = H \rightarrow [grasp(x, [1])] \\ \text{A}_3 = H \rightarrow [hold(x, [1])]lift(x, [1]) \\ \text{A}_4 = H_{[2]} \rightarrow [slide(x, [1])] \end{bmatrix} \\
\text{EMBODIMENT} = & \begin{bmatrix} \text{SCALE} = <\textbf{agent} \\ \text{MOVABLE} = \textbf{true} \end{bmatrix}
\end{bmatrix}$$

(18)
$$\begin{bmatrix}
\textbf{table} & \\
\text{LEX} = & \begin{bmatrix} \text{PRED} = \textbf{table} \\ \text{TYPE} = \textbf{physobj, artifactj} \end{bmatrix} \\
\text{TYPE} = & \begin{bmatrix} \text{HEAD} = \textbf{sheet[1]} \\ \text{COMPONENTS} = \textbf{surface[1], leg[2]+} \\ \text{CONCAVITY} = \textbf{flat} \\ \text{ROTATSYM} = \{Y\} \\ \text{REFLECTSYM} = \{XY, YZ\} \end{bmatrix} \\
\text{HABITAT} = & \begin{bmatrix} \text{INTR} = {}_{[3]}\begin{bmatrix} \text{UP} = align(Y, \mathcal{E}_Y) \\ \text{TOP} = top(+Y) \\ \text{CONSTR[1]} = \{Y \ll X, Y \ll Z\} \\ \text{CONSTR[2]} = \{Y \gg X, Y \gg Z\} \end{bmatrix} \\ \text{EXTR} = \dots \end{bmatrix} \\
\text{AFFORD_STR} = & \begin{bmatrix} \text{A}_1 = H \rightarrow [grasp(x, [1])] \\ \text{A}_1 = H \rightarrow [hold(x, [1])]lift(x, [1]) \\ \text{A}_1 = H \rightarrow [slide(x, [1])] \\ \text{A}_1 = H_{[2]} \rightarrow [roll(x, [1])] \end{bmatrix} \\
\text{EMBODIMENT} = & \begin{bmatrix} \text{SCALE} = \textbf{agent} \\ \text{MOVABLE} = \textbf{true} \end{bmatrix}
\end{bmatrix}$$

(19)
$$\left[\begin{array}{l}\textbf{bowl}\\ \textsc{lex} = \left[\begin{array}{l}\textsc{pred} = \textbf{bowl}\\ \textsc{type} = \textbf{physobj, artifact}\end{array}\right]\\ \textsc{type} = \left[\begin{array}{l}\textsc{head} = \textbf{cylindroid[1]}\\ \textsc{components} = \textbf{base, interior}\\ \textsc{concavity} = \textbf{concave}\\ \textsc{rotatsym} = \{Y\}\\ \textsc{reflectsym} = \{XY, YZ\}\end{array}\right]\\ \textsc{habitat} = \left[\begin{array}{l}\textsc{intr} = {}_{[2]}\left[\begin{array}{l}\textsc{constr} = \{Y < X, Y < Z\}\\ \textsc{up} = align(Y, \mathcal{E}_Y)\\ \textsc{top} = top(+Y)\end{array}\right]\\ \textsc{extr} = {}_{[3]}\left[\textsc{up} = align(Y, \mathcal{E}_{\perp Y})\right]\end{array}\right]\\ \textsc{afford\_str} = \left[\begin{array}{l}\mathrm{A}_1 = H_{[2]} \rightarrow [put(x, on([1]))]support([1], x)\\ \mathrm{A}_2 = H_{[2]} \rightarrow [put(x, in([1]))]contain([1], x)\\ \mathrm{A}_3 = H_{[2]} \rightarrow [grasp(x, [1])]\\ \mathrm{A}_3 = H_{[2]} \rightarrow [grasp(x, [1])]lift(x, [1])\\ \mathrm{A}_3 = H_{[2]} \rightarrow [slide(x, [1])]\\ \mathrm{A}_3 = H_{[3]} \rightarrow [roll(x, [1])]\end{array}\right]\\ \textsc{embodiment} = \left[\begin{array}{l}\textsc{scale} = <\textbf{agent}\\ \textsc{movable} = \textbf{true}\end{array}\right]\end{array}\right]$$

(20)
$$\left[\begin{array}{l}\textbf{knife}\\ \textsc{lex} = \left[\begin{array}{l}\textsc{pred} = \textbf{knife}\\ \textsc{type} = \textbf{physobj, artifact}\end{array}\right]\\ \textsc{type} = \left[\begin{array}{l}\textsc{head} = \textbf{rectangular\_prism[1]}\\ \textsc{components} = \textbf{handle[2], blade}\\ \textsc{concavity} = \textbf{flat}\\ \textsc{rotatsym} = nil\\ \textsc{reflectsym} = \{XY\}\end{array}\right]\\ \textsc{habitat} = \left[\begin{array}{l}\textsc{intr} = {}_{[3]}\left[\begin{array}{l}\textsc{constr} = \{X > Y, X \gg Z\}\\ \textsc{front} = front(+X)\end{array}\right]\\ \textsc{extr} = \ldots\end{array}\right]\\ \textsc{afford\_str} = \left[\begin{array}{l}\mathrm{A}_1 = H_{[3]} \rightarrow [grasp(x, [1])]\\ \mathrm{A}_2 = H_{[3]} \rightarrow [grasp(x, [2]) \rightarrow grasp(x, [1])]\end{array}\right]\\ \textsc{embodiment} = \left[\begin{array}{l}\textsc{scale} = <\textbf{agent}\\ \textsc{movable} = \textbf{true}\end{array}\right]\end{array}\right]$$

(21)
$$\left[\begin{array}{l}\textbf{pencil}\\ \textsc{lex} = \left[\begin{array}{l}\textsc{pred} = \textbf{pencil}\\ \textsc{type} = \textbf{physobj, artifact}\end{array}\right]\\ \textsc{type} = \left[\begin{array}{l}\textsc{head} = \textbf{cylindroid[1]}\\ \textsc{components} = \textbf{shaft[1], eraser, nib}\\ \textsc{concavity} = \textbf{convex}\\ \textsc{rotatsym} = \{Z\}\\ \textsc{reflectsym} = \{XZ, YZ\}\end{array}\right]\\ \textsc{habitat} = \left[\begin{array}{l}\textsc{intr} = {}_{[4]}\left[\begin{array}{l}\textsc{constr} = \{Y \ll X, Y \ll Z\}\\ \textsc{forward} = align(Z, \mathcal{E}_Z)\\ \textsc{front} = front(+Z)\end{array}\right]\\ \textsc{extr} = {}_{[5]}\left[\textsc{forward} = align(Z, \mathcal{E}_{\perp Y})\right]\end{array}\right]\\ \textsc{afford\_str} = \left[\begin{array}{l}\mathrm{A}_3 = H_{[4]} \rightarrow [grasp(x, [1])]\\ \mathrm{A}_3 = H_{[4]} \rightarrow [hold(x, [1])]lift(x, [1])\\ \mathrm{A}_4 = H_{[5]} \rightarrow [roll(x, [1])]\end{array}\right]\\ \textsc{embodiment} = \left[\begin{array}{l}\textsc{scale} = <\textbf{agent}\\ \textsc{movable} = \textbf{true}\end{array}\right]\end{array}\right]$$

(22)
$$\begin{bmatrix}
\textbf{paper sheet} \\
\text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{paper_sheet} \\ \text{TYPE} = \textbf{physobj, artifactj} \end{bmatrix} \\
\text{TYPE} = \begin{bmatrix} \text{HEAD} = \textbf{sheet[1]} \\ \text{COMPONENTS} = \textbf{nil} \\ \text{CONCAVITY} = \textbf{flat} \\ \text{ROTATSYM} = \{Y\} \\ \text{REFLECTSYM} = \{XY, YZ\} \end{bmatrix} \\
\text{HABITAT} = \begin{bmatrix} \text{INTR} = {}_{[2]} \begin{bmatrix} \text{UP} = align(Y, \mathcal{E}_Y) \\ \text{TOP} = top(+Y) \\ \text{CONSTR} = \{Y \ll X, Y \ll Z\} \end{bmatrix} \\ \text{EXTR} = \ldots \end{bmatrix} \\
\text{AFFORD_STR} = \begin{bmatrix} \text{A}_1 = H_{[2]} \rightarrow [grasp(x, [1])] \\ \text{A}_1 = H_{[2]} \rightarrow [hold(x, [1])] lift(x, [1]) \\ \text{A}_1 = H_{[2]} \rightarrow [slide(x, [1])] \end{bmatrix} \\
\text{EMBODIMENT} = \begin{bmatrix} \text{SCALE} = <\textbf{agent} \\ \text{MOVABLE} = \textbf{true} \end{bmatrix}
\end{bmatrix}$$

3.2 Programs

(23)
$$\begin{bmatrix}
\textbf{grasp} \\
\text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{grasp} \\ \text{TYPE} = \textbf{transition_event} \end{bmatrix} \\
\text{TYPE} = \begin{bmatrix} \text{HEAD} = \textbf{transition} \\ \text{ARGS} = \begin{bmatrix} \text{A}_1 = \textbf{x:agent} \\ \text{A}_2 = \textbf{y:physobj} \end{bmatrix} \\ \text{BODY} = \begin{bmatrix} \text{E}_1 = grasp(x, y) \end{bmatrix} \end{bmatrix}
\end{bmatrix}$$

(24)
$$\begin{bmatrix}
\textbf{hold} \\
\text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{hold} \\ \text{TYPE} = \textbf{state} \end{bmatrix} \\
\text{TYPE} = \begin{bmatrix} \text{HEAD} = \textbf{state} \\ \text{ARGS} = \begin{bmatrix} \text{A}_1 = \textbf{x:agent} \\ \text{A}_2 = \textbf{y:physobj} \end{bmatrix} \\ \text{BODY} = \begin{bmatrix} \text{E}_1 = grasp(x, y) \\ \text{E}_2 = maintain_rel(x, y) \end{bmatrix} \end{bmatrix}
\end{bmatrix}$$

(25)
$$\begin{bmatrix}
\textbf{touch} \\
\text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{touch} \\ \text{TYPE} = \textbf{transition_event} \end{bmatrix} \\
\text{TYPE} = \begin{bmatrix} \text{HEAD} = \textbf{transition} \\ \text{ARGS} = \begin{bmatrix} \text{A}_1 = \textbf{x:agent} \\ \text{A}_2 = \textbf{y:physobj} \end{bmatrix} \\ \text{BODY} = \begin{bmatrix} \text{E}_1 = \neg EC(x, y) \rightarrow move(x, toward(y)) \end{bmatrix} \end{bmatrix}
\end{bmatrix}$$

(26)
$$\begin{bmatrix}
\textbf{move} \\
\text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{move} \\ \text{TYPE} = \textbf{process} \end{bmatrix} \\
\text{TYPE} = \begin{bmatrix} \text{HEAD} = \textbf{process} \\ \text{ARGS} = \begin{bmatrix} \text{A}_1 = \textbf{x:agent} \\ \text{A}_2 = \textbf{y:physobj} \end{bmatrix} \\ \text{BODY} = \begin{bmatrix} \text{E}_1 = grasp(x, y) \\ \text{E}_2 = [while(hold(x, y), move(x, y)] \end{bmatrix} \end{bmatrix}
\end{bmatrix}$$

(27)
$$\left[\begin{array}{l}\textbf{turn}\\ \text{LEX} = \left[\begin{array}{l}\text{PRED} = \textbf{turn}\\ \text{TYPE} = \textbf{process}\end{array}\right]\\ \text{TYPE} = \left[\begin{array}{l}\text{HEAD} = \textbf{process}\\ \text{ARGS} = \left[\begin{array}{l}\text{A}_1 = \textbf{x:agent}\\ \text{A}_2 = \textbf{y:physobj}\end{array}\right]\\ \text{BODY} = \left[\begin{array}{l}\text{E}_1 = grasp(x,y)\\ \text{E}_2 = [while(hold(x,y), rotate(y)]\end{array}\right]\end{array}\right]\end{array}\right]$$

(28)
$$\left[\begin{array}{l}\textbf{roll}\\ \text{LEX} = \left[\begin{array}{l}\text{PRED} = \textbf{roll}\\ \text{TYPE} = \textbf{process}\end{array}\right]\\ \text{TYPE} = \left[\begin{array}{l}\text{HEAD} = \textbf{process}\\ \text{ARGS} = \left[\begin{array}{l}\text{A}_1 = \textbf{x:agent}\\ \text{A}_2 = \textbf{y:physobj}\\ \text{A}_3 = \textbf{z:physobj}\end{array}\right]\\ \text{BODY} = \left[\begin{array}{l}\text{E}_1 = grasp(x,y)\\ \text{E}_2 = [while(hold(x,y),\\ \quad while(EC(y,z), translocate(x,y), rotate(x,y)))]\end{array}\right]\end{array}\right]\end{array}\right]$$

(29)
$$\left[\begin{array}{l}\textbf{slide}\\ \text{LEX} = \left[\begin{array}{l}\text{PRED} = \textbf{slide}\\ \text{TYPE} = \textbf{process}\end{array}\right]\\ \text{TYPE} = \left[\begin{array}{l}\text{HEAD} = \textbf{process}\\ \text{ARGS} = \left[\begin{array}{l}\text{A}_1 = \textbf{x:agent}\\ \text{A}_2 = \textbf{y:physobj}\\ \text{A}_3 = \textbf{z:physobj}\end{array}\right]\\ \text{BODY} = \left[\begin{array}{l}\text{E}_1 = grasp(x,y)\\ \text{E}_2 = [while(hold(x,y),\\ \quad while(EC(y,z), move(x,y)))]\end{array}\right]\end{array}\right]\end{array}\right]$$

(30)
$$\left[\begin{array}{l}\textbf{spin}\\ \text{LEX} = \left[\begin{array}{l}\text{PRED} = \textbf{spin}\\ \text{TYPE} = \textbf{process}\end{array}\right]\\ \text{TYPE} = \left[\begin{array}{l}\text{HEAD} = \textbf{process}\\ \text{ARGS} = \left[\begin{array}{l}\text{A}_1 = \textbf{x:agent}\\ \text{A}_2 = \textbf{y:physobj}\end{array}\right]\\ \text{BODY} = \left[\begin{array}{l}\text{E}_1 = grasp(x,y)\\ \text{E}_2 = rotate(x,y)\\ \text{E}_3 = ungrasp(x,y)\end{array}\right]\end{array}\right]\end{array}\right]$$

(31)
$$\left[\begin{array}{l}\textbf{lift}\\ \text{LEX} = \left[\begin{array}{l}\text{PRED} = \textbf{lift}\\ \text{TYPE} = \textbf{process}\end{array}\right]\\ \text{TYPE} = \left[\begin{array}{l}\text{HEAD} = \textbf{process}\\ \text{ARGS} = \left[\begin{array}{l}\text{A}_1 = \textbf{x:agent}\\ \text{A}_2 = \textbf{y:physobj}\end{array}\right]\\ \text{BODY} = \left[\begin{array}{l}\text{E}_1 = grasp(x,y)\\ \text{E}_2 = [while(hold(x,y), move(x,y,vec(\mathcal{E}_Y)))]\end{array}\right]\end{array}\right]\end{array}\right]$$

(32)
$$\left[\begin{array}{l}\textbf{stack}\\ \text{LEX} = \left[\begin{array}{l}\text{PRED} = \textbf{stack}\\ \text{TYPE} = \textbf{transition\_event}\end{array}\right]\\ \text{TYPE} = \left[\begin{array}{l}\text{HEAD} = \textbf{transition}\\ \text{ARGS} = \left[\begin{array}{l}\text{A}_1 = \textbf{x:agent}\\ \text{A}_2 = \textbf{y[]:physobj}\end{array}\right]\\ \text{BODY} = \left[\begin{array}{l}\text{E}_1 = def(y[0], as(z)), for(o \in y[1..n])\\ \quad [put(o, on(z)), reify((z,o), as(z)]\end{array}\right]\end{array}\right]\end{array}\right]$$

(33)
$$\begin{bmatrix} \textbf{put} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{put} \\ \text{TYPE} = \textbf{transition\_event} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{HEAD} = \textbf{transition} \\ \text{ARGS} = \begin{bmatrix} \text{A}_1 = \textbf{x:agent} \\ \text{A}_2 = \textbf{y:physobj} \\ \text{A}_3 = \textbf{z:location} \end{bmatrix} \\ \text{BODY} = \begin{bmatrix} \text{E}_1 = grasp(x,y) \\ \text{E}_2 = [while(hold(x,y), move(x,y)] \\ \text{E}_3 = [at(y,z) \rightarrow ungrasp(x,y)] \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(34)
$$\begin{bmatrix} \textbf{lean} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{lean} \\ \text{TYPE} = \textbf{transition\_event} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{HEAD} = \textbf{transition} \\ \text{ARGS} = \begin{bmatrix} \text{A}_1 = \textbf{x:agent} \\ \text{A}_2 = \textbf{y:physobj} \\ \text{A}_3 = \textbf{z:location} \end{bmatrix} \\ \text{BODY} = \begin{bmatrix} \text{E}_1 = grasp(x,y) \\ \text{E}_2 = [while(hold(x,y), rotate(x,y)] \\ \text{E}_3 = [support(y,z) \rightarrow ungrasp(x,y)] \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(35)
$$\begin{bmatrix} \textbf{flip} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{flip} \\ \text{TYPE} = \textbf{transition\_event} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{HEAD} = \textbf{transition} \\ \text{ARGS} = \begin{bmatrix} \text{A}_1 = \textbf{x:agent} \\ \text{A}_2 = \textbf{y:physobj} \end{bmatrix} \\ \text{BODY} = \begin{bmatrix} \text{E}_1 = def(w, as(orient(y)))[grasp(x,y)] \\ \text{E}_2 = [while(hold(x,y), rotate(x,y)] \\ \text{E}_3 = [(orient(y) = opp(w)) \rightarrow ungrasp(x,y)] \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(36)
$$\begin{bmatrix} \textbf{close} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{close} \\ \text{TYPE} = \textbf{transition\_event} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{HEAD} = \textbf{transition} \\ \text{ARGS} = \begin{bmatrix} \text{A}_1 = \textbf{x:agent} \\ \text{A}_2 = \textbf{y:physobj} \end{bmatrix} \\ \text{BODY} = \begin{bmatrix} \text{E}_1 = grasp(x,y) \\ \text{E}_2 = [while(hold(x,y), move(x,y))] \\ \text{E}_3 = [EC(interior(y), \mathcal{E}) \rightarrow ungrasp(x,y)] \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(37)
$$\begin{bmatrix} \textbf{open} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{open} \\ \text{TYPE} = \textbf{transition\_event} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{HEAD} = \textbf{transition} \\ \text{ARGS} = \begin{bmatrix} \text{A}_1 = \textbf{x:agent} \\ \text{A}_2 = \textbf{y:physobj} \end{bmatrix} \\ \text{BODY} = \begin{bmatrix} \text{E}_1 = grasp(x,y) \\ \text{E}_2 = [while(hold(x,y), move(x,y))] \\ \text{E}_3 = [DC(interior(y), \mathcal{E}) \rightarrow ungrasp(x,y)] \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

3.3 Relations

(38)
$$\begin{bmatrix} \textbf{on} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{on} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{CLASS} = \textbf{config} \\ \text{VALUE} = \textbf{EC} \\ \text{ARGS} = \begin{bmatrix} \text{A}_1 = \textbf{x:3D} \\ \text{A}_2 = \textbf{y:3D} \end{bmatrix} \\ \text{CONSTR} = \textbf{y}\rightarrow\text{HABITAT}\rightarrow\text{INTR}[align] \end{bmatrix} \end{bmatrix}$$

(39)
$$\begin{bmatrix} \textbf{in} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{in} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{CLASS} = \textbf{config} \\ \text{VALUE} = \textbf{PO} \,\|\, \textbf{TPP} \,\|\, \textbf{NTPP} \\ \text{ARGS} = \begin{bmatrix} \text{A}_1 = \textbf{x:3D} \\ \text{A}_2 = \textbf{y:3D} \end{bmatrix} \\ \text{CONSTR} = \textbf{y}\rightarrow\text{HABITAT}\rightarrow\text{INTR}[align]\textbf{?} \end{bmatrix} \end{bmatrix}$$

(40)
$$\begin{bmatrix} \textbf{against} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{against} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{CLASS} = \textbf{force\_dynamic} \\ \text{VALUE} = \textbf{EC} \\ \text{ARGS} = \begin{bmatrix} \text{A}_1 = \textbf{x:3D} \\ \text{A}_2 = \textbf{y:3D} \end{bmatrix} \\ \text{CONSTR} = \textbf{nil} \end{bmatrix} \end{bmatrix}$$

(41)
$$\begin{bmatrix} \textbf{at} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{at} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{CLASS} = \textbf{config} \\ \text{VALUE} = \textbf{DC} \,\|\, \textbf{EC} \\ \text{ARGS} = \begin{bmatrix} \text{A}_1 = \textbf{x:3D} \\ \text{A}_2 = \textbf{y:3D} \end{bmatrix} \\ \text{CONSTR} = dist(x,y) < \epsilon \end{bmatrix} \end{bmatrix}$$

3.4 Functions

(42)
$$\begin{bmatrix} \textbf{edge} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{edge} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x}\rightarrow\text{HEAD} \\ \text{MAPPING} = \textbf{dimension(n):1} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{object} \\ \text{AXIS} = \textbf{ref:after} \\ \text{ARITY} = \textbf{x}\rightarrow\text{HABITAT}\rightarrow \\ \quad\text{INTR}[axis] \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(43)
$$\begin{bmatrix} \textbf{center} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{center} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x}\rightarrow\text{HEAD} \\ \text{MAPPING} = \textbf{dimension(n):0} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{object} \\ \text{AXIS} = \textbf{nil} \\ \text{ARITY} = intransitive \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

4 General Voxeme List

(44)
$$\begin{bmatrix} \textbf{top} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{top} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x}\rightarrow\text{HEAD} \\ \text{MAPPING} = \textbf{dimension(n):n-1} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{world} \\ \text{AXIS} = \textbf{+Y} \\ \text{ARITY} = \textbf{x}\rightarrow\text{HABITAT}\rightarrow \\ \quad\text{INTR}[top(axis)]: \\ \quad intransitive \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(45)
$$\begin{bmatrix} \textbf{bottom} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{bottom} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x}{\rightarrow}\text{HEAD} \\ \text{MAPPING} = \textbf{dimension(n):n-1} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{world} \\ \text{AXIS} = \textbf{-Y} \\ \text{ARITY} = \textbf{x}{\rightarrow}\text{HABITAT}{\rightarrow} \\ \quad \text{INTR}[bottom(axis)]: \\ \quad intransitive \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(46)
$$\begin{bmatrix} \textbf{front} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{front} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x}{\rightarrow}\text{HEAD} \\ \text{MAPPING} = \textbf{dimension(n):n-1} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{world} \\ \text{AXIS} = \textbf{+Z} \\ \text{ARITY} = \textbf{x}{\rightarrow}\text{HABITAT}{\rightarrow} \\ \quad \text{INTR}[front(axis)]: \\ \quad intransitive \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(47)
$$\begin{bmatrix} \textbf{back} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{back} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x}{\rightarrow}\text{HEAD} \\ \text{MAPPING} = \textbf{dimension(n):n-1} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{world} \\ \text{AXIS} = \textbf{-Z} \\ \text{ARITY} = \textbf{x}{\rightarrow}\text{HABITAT}{\rightarrow} \\ \quad \text{INTR}[back(axis)]: \\ \quad intransitive \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(48)
$$\begin{bmatrix} \textbf{right} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{right} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x}{\rightarrow}\text{HEAD} \\ \text{MAPPING} = \textbf{dimension(n):n-1} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{world} \\ \text{AXIS} = \textbf{+X} \\ \text{ARITY} = \textbf{x}{\rightarrow}\text{HABITAT}{\rightarrow} \\ \quad \text{INTR}[right(axis)]: \\ \quad intransitive \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(49)
$$\begin{bmatrix} \textbf{left} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{left} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x}{\rightarrow}\text{HEAD} \\ \text{MAPPING} = \textbf{dimension(n):n-1} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{world} \\ \text{AXIS} = \textbf{-X} \\ \text{ARITY} = \textbf{x}{\rightarrow}\text{HABITAT}{\rightarrow} \\ \quad \text{INTR}[left(axis)]: \\ \quad intransitive \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(50)
$$\begin{bmatrix} \textbf{center} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{center} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x}{\rightarrow}\text{HEAD} \\ \text{MAPPING} = \textbf{dimension(n):0} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{object} \\ \text{AXIS} = \textbf{nil} \\ \text{ARITY} = intransitive \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(51)
$$\begin{bmatrix} \textbf{edge} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{edge} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x}{\rightarrow}\text{HEAD} \\ \text{MAPPING} = \textbf{dimension(n):1} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{object} \\ \text{AXIS} = \textbf{(see linked attribute)} \\ \text{ARITY} = (seelinkedattribute) \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(52)
$$\begin{bmatrix} \textbf{corner} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{corner} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x}{\rightarrow}\text{HEAD} \\ \text{MAPPING} = \textbf{dimension(n):0} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{object} \\ \text{AXIS} = \textbf{(see linked attribute)} \\ \text{ARITY} = (seelinkedattribute) \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(53)
$$\begin{bmatrix} \textbf{diagonal} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{diagonal} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x}{\rightarrow}\text{HEAD} \\ \text{MAPPING} = \textbf{dimension(n):1} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{object} \\ \text{AXIS} = axes(\text{REFERENT}{\rightarrow}\text{HEAD}) \\ \text{ARITY} = (seelinkedattribute) \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(54)
$$\begin{bmatrix} \textbf{above} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{above} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x} \\ \text{MAPPING} = \textbf{dimension(n):n} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{world} \\ \text{AXIS} = \textbf{+Y} \\ \text{ARITY} = intransitive \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(55)
$$\begin{bmatrix} \textbf{below} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{below} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x} \\ \text{MAPPING} = \textbf{dimension(n):n} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{world} \\ \text{AXIS} = \textbf{-Y} \\ \text{ARITY} = intransitive \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(56)
$$\begin{bmatrix} \textbf{in\_front} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{in\_front} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x} \\ \text{MAPPING} = \textbf{dimension(n):n} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{pov} \\ \text{AXIS} = \textbf{+Z} \\ \text{ARITY} = intransitive \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(57)
$$\begin{bmatrix} \textbf{behind} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{behind} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x} \\ \text{MAPPING} = \textbf{dimension(n):n} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{pov} \\ \text{AXIS} = \textbf{-Z} \\ \text{ARITY} = intransitive \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(58)
$$\begin{bmatrix} \textbf{to\_the\_left} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{to\_the\_left} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x} \\ \text{MAPPING} = \textbf{dimension(n):n} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{pov} \\ \text{AXIS} = \textbf{-X} \\ \text{ARITY} = \textit{intransitive} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(59)
$$\begin{bmatrix} \textbf{to\_the\_right} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{to\_the\_right} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{ARG} = \textbf{x:physobj} \\ \text{REFERENT} = \textbf{x} \\ \text{MAPPING} = \textbf{dimension(n):n} \\ \text{ORIENTATION} = \begin{bmatrix} \text{SPACE} = \textbf{pov} \\ \text{AXIS} = \textbf{+X} \\ \text{ARITY} = \textit{intransitive} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(60)
$$\begin{bmatrix} \textbf{reach} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{reach} \\ \text{TYPE} = \textbf{process} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{HEAD} = \textbf{process} \\ \text{ARGS} = \begin{bmatrix} \text{A}_1 = \textbf{x:agent} \\ \text{A}_2 = \textbf{y:physobj} \end{bmatrix} \\ \text{BODY} = \begin{bmatrix} \text{E}_1 = [\textit{while}(!\textit{at}(x,y), \textit{extend}(x, \textit{align}(\textit{loc}(y) - \textit{loc}(x))))] \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(61)
$$\begin{bmatrix} \textbf{box} \\ \text{LEX} = \begin{bmatrix} \text{PRED} = \textbf{box} \\ \text{TYPE} = \textbf{physobj} \end{bmatrix} \\ \text{TYPE} = \begin{bmatrix} \text{HEAD} = \textbf{rectangular\_prism} \\ \text{COMPONENTS} = \textbf{nil} \\ \text{CONCAVITY} = \textbf{flat} \\ \text{ROTATSYM} = \{X, Y, Z\} \\ \text{REFLECTSYM} = \{XY, XZ, YZ\} \end{bmatrix} \\ \text{HABITAT} = \begin{bmatrix} \text{INTR} = \ldots \\ \text{EXTR} = \ldots \end{bmatrix} \\ \text{AFFORD\_STR} = \begin{bmatrix} \text{A}_1 = H_1 \rightarrow [E_1]R \\ \text{A}_2 = \textbf{...} \\ \text{A}_3 = \textbf{...} \end{bmatrix} \\ \text{EMBODIMENT} = \begin{bmatrix} \text{SCALE} = <\textbf{agent} \\ \text{MOVABLE} = \textbf{true} \end{bmatrix} \end{bmatrix}$$