Terrain-Aware Morphology Searching Algorithm for Self-reconfigurable Modular Robot in Dynamic Environment Supplemental Material

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A Module joint rules

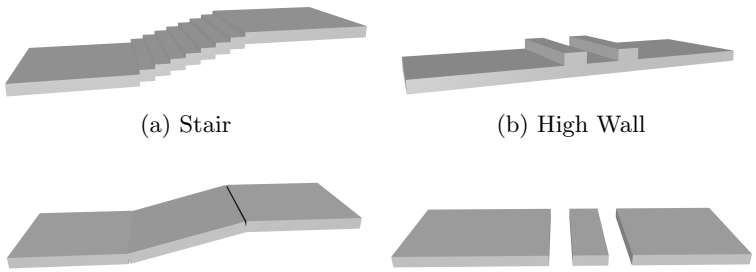
The module joint rules consist of 40 sub-rules, as shown in Table 1. The sub-rules $(r_1 - r_2)$ determine the extension direction of the trunk in the morphology. The footer Y of T stands for horizontal direction, and Z for vertical direction. The sub-rules $(r_3 - r_{34})$ are the rules available to the trunk (or limb), where the footer of J_T (or J_L) is the rotation direction of a joint (Stationary, X-axis, Y-axis, and Z-axis). The sub-rule r_{35} is the only rule available to the trunk joint. The sub-rules $(r_{36} - r_{40})$ are the rules available to the limb, where the footer of L is the initial direction of a limb. Furthermore, Y is forward or backward, and Z is upward or downward. In particular, $+X$ is the direction of outward the trunk. The initial direction of a limb cannot be toward the trunk, so there is no rule $J_L \to T_{-X}J_Le$.

Table 1: Module joint rules

Index	Rule	Index	Rule	Index	Rule	Index	Rule
1	$R \to T_Y Re$	11	$T \to eTJ_{L+Z}$	21	$T \to J_{TY}TJ_{LS}$	31	$L \to J_{LX}Le$
2	$R \to T_Z Re$	12	$T \to eTJ_{L-Z}$	22	$T \to J_{TY}TJ_{LX}$	32	$L \to J_{LY}Le$
3	$T \to J_{TS}Te$	13	$T \to J_{TS}TJ_{LS}$	23	$T \to J_{TY}TJ_{LY}$	33	$L \to J_{LZ}Le$
4	$T \to J_{TX}Te$	14	$T \to J_{TS}TJ_{LX}$	24	$T \to J_{TY}TJ_{LZ}$	34	$L \to eLe$
5	$T \to J_{TY}Te$	15	$T \to J_{TS}TJ_{LY}$	25	$T \to J_{TZ}TJ_{LS}$	35	$J_T \to T_JLe$
6	$T \to J_{TZ}Te$	16	$T \to J_{TS}TJ_{LZ}$	26	$T \to J_{TZ}TJ_{LX}$	36	$J_L \to L_{+X}J_Le$
7	$T \to eTJ_{LS}$	17	$T \to J_{TX}TJ_{LS}$	27	$T \to J_{TZ}TJ_{LY}$	37	$J_L \to L_{+Y}J_Le$
8	$T \to eTJ_{LX}$	18	$T \to J_{TX}TJ_{LX}$	28	$T \to J_{TZ}TJ_{LZ}$	38	$J_L \to L_{-Y}J_Le\ J_L$
9	$T \to eTJ_{L+Y}$	19	$T \to J_{TX}TJ_{LY}$	29	$T \to eTe$	39	$J_L \to L_{+Z}J_Le$
10	$T \to eTJ_{L-Y}$	20	$T \to J_{TX}TJ_{LZ}$	30	$L \to J_{LS}Le$	40	$J_L \to L_{-Z}J_Le$

B Dynamic environment setting

Our study designs a dynamic environment composed of five distinct terrains. These terrains are plane, stair, high wall, incline, and gap with different difficulties and with/without noise. The stair, high wall, incline, and gap terrains are shown in Fig.1.



(a) Stair (b) High Wall

(c) Incline (d) Gap

Fig. 1: Diagram of the four terrains.

Besides basic terrains, we also design simpler terrains than basic terrains. The difference lies in the parameters of the terrains, including the height of the stair and high wall, the slope of the incline, and the width of the gap, detailed in Table 2.

Table 2: The parameters of all terrains

Name	Parameters	Add noise
plane	-	False
plane-noisy	-	True
stair	0.15	False
stair-simple	0.075	False
stair-noisy	0.15	True
high wall	1.5	False
high wall-simple	0.75	False
high wall-noisy	1.5	True
incline	15	False
incline-simple	7	False
incline-noisy	15	True
gap	0.6	False
gap-simple	0.3	False
gap-noisy	0.6	True

For plane terrain, it does not have any parameters. Hence there is no plane-simple either.