Self-reconfiguring modular robots

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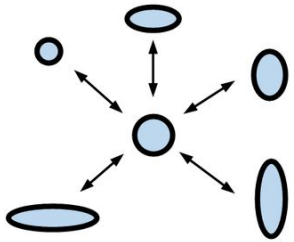
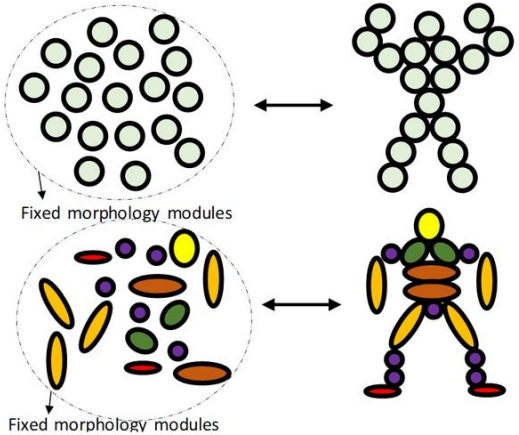
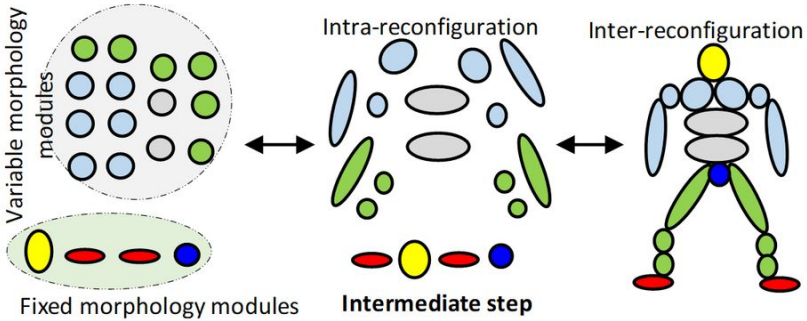


Intra-reconfigurability

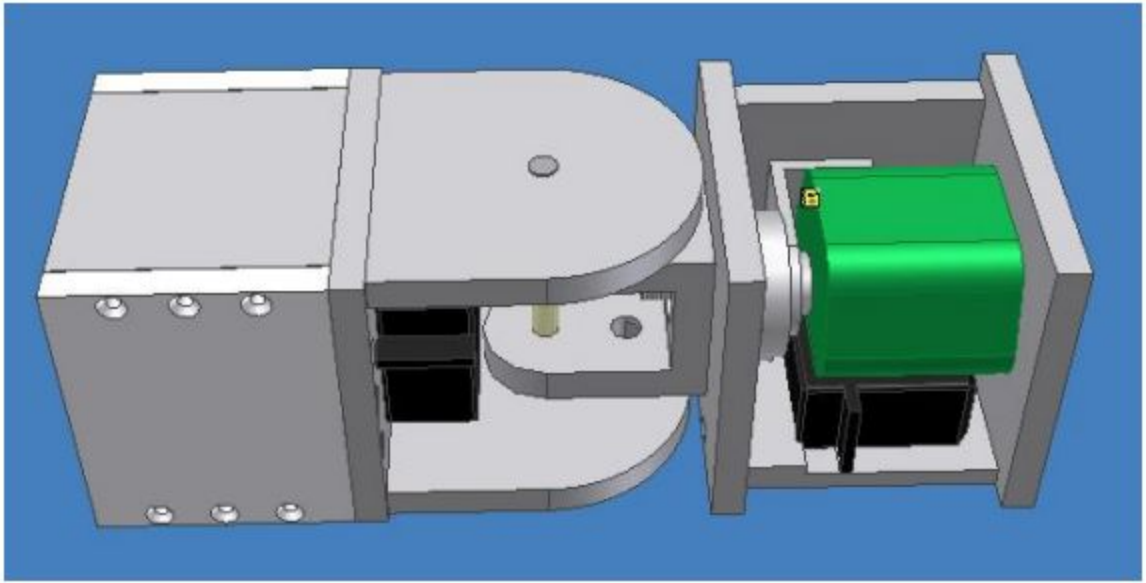


Inter-reconfigurability

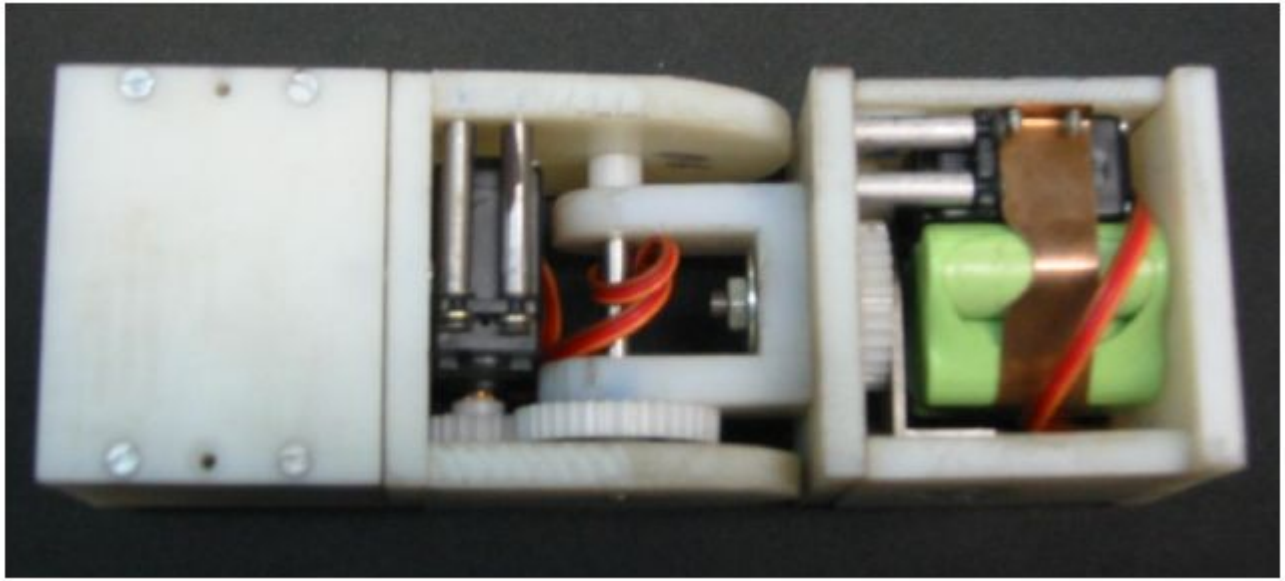


Nested-reconfigurability

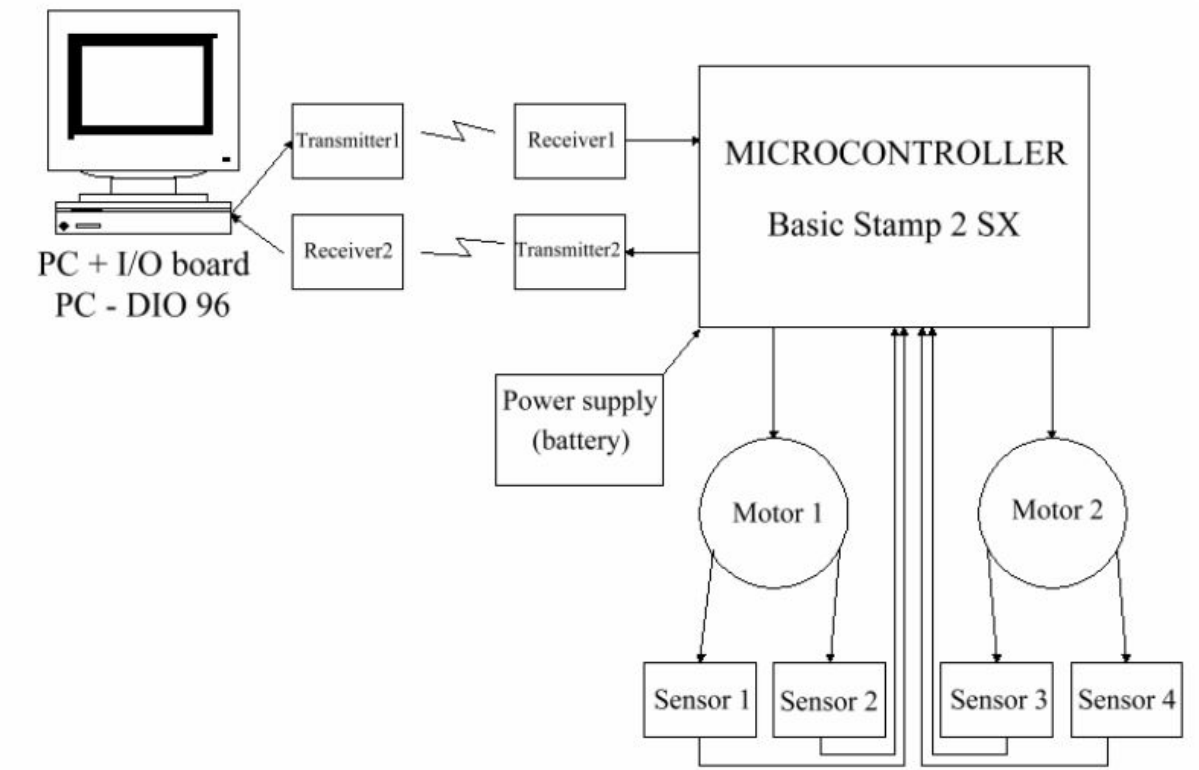
CAD image of the module



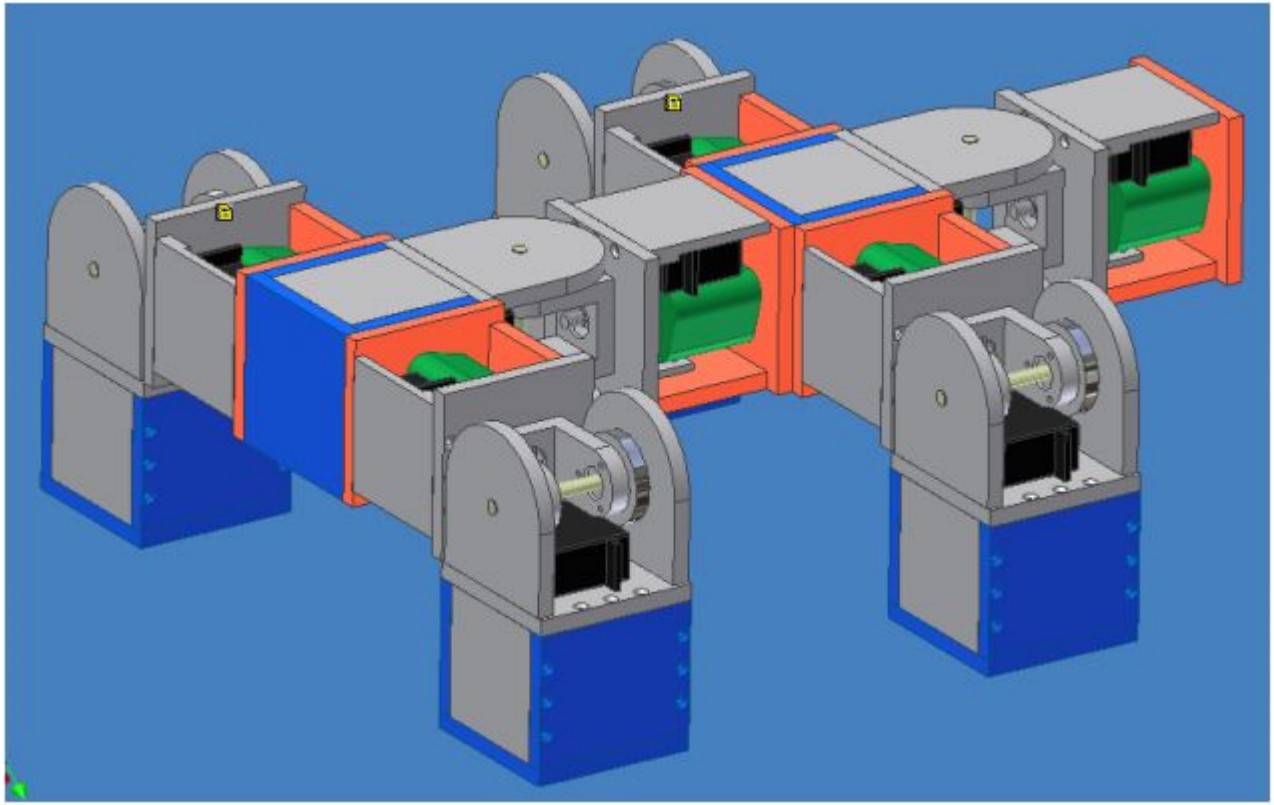
Actual module



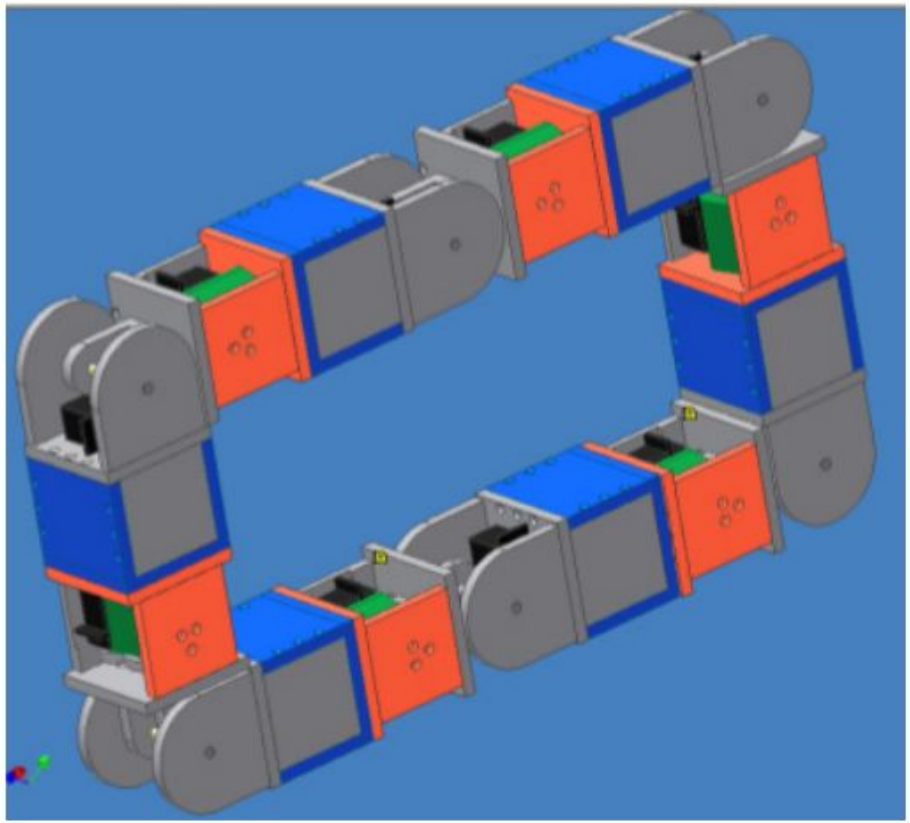
Robot control



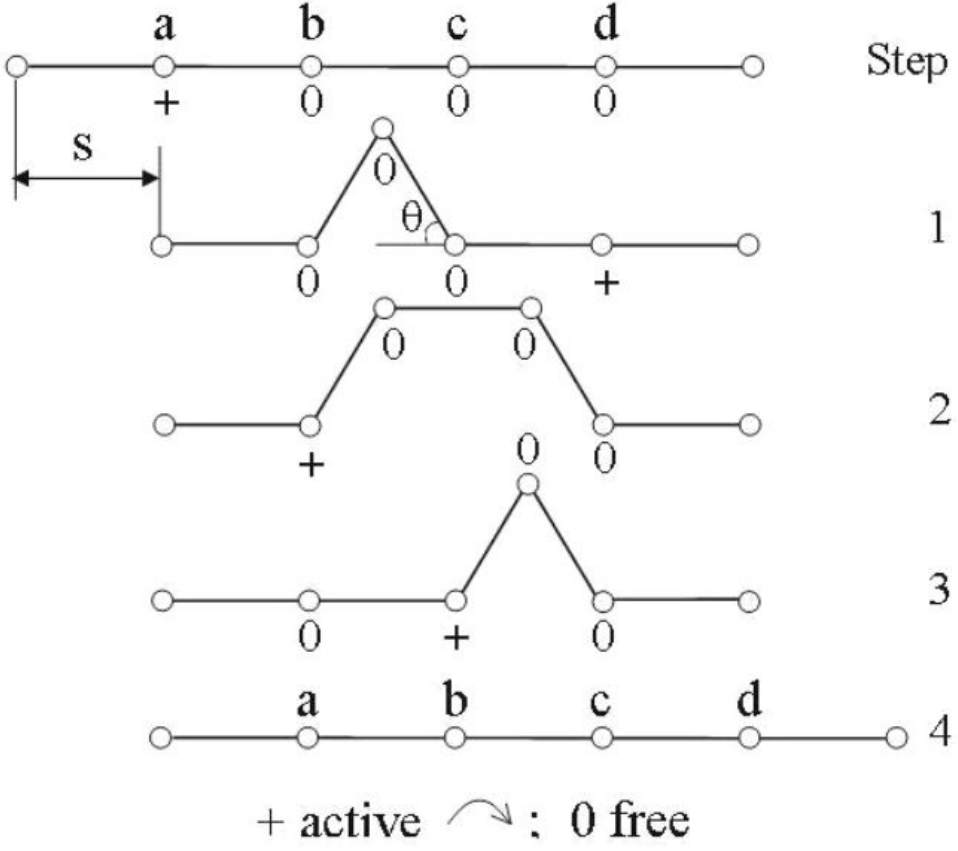
Example of the reconfigured system



Rolled-up snake



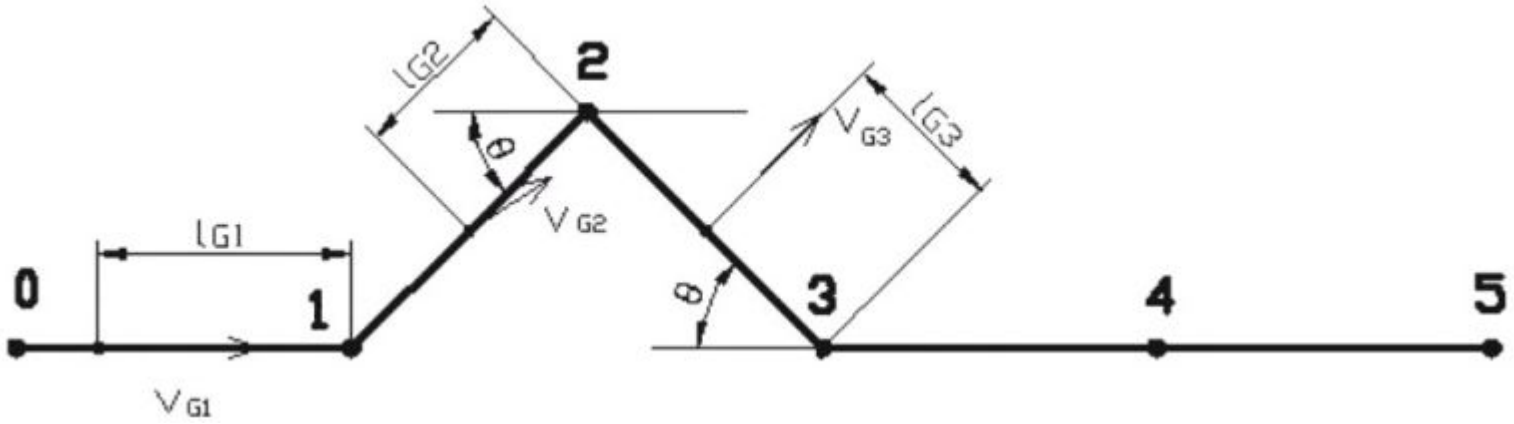
Crawl sequence



$$s = 2l(1-\cos\theta)\,.$$

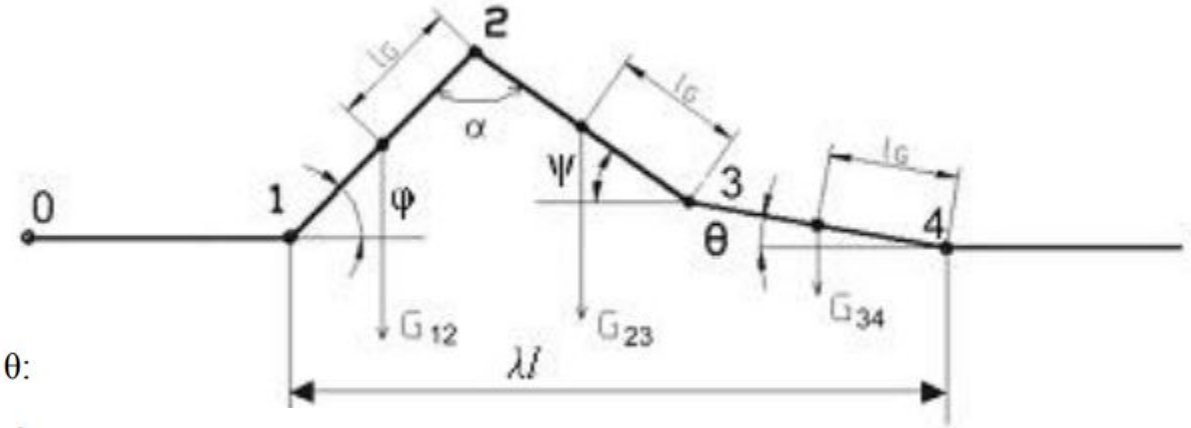
$$v = 2l\,\omega\frac{1-\cos\theta}{8\theta}$$

Dynamic model - step 1



$$J_r = 2J_G + ml_G^2 + 2m(l^2 + l_G^2) - 4mll_G \cos^2\theta + 4ml^2 \sin^2\theta$$

Step 2 and equations



depending on θ:

$$\varphi = \frac{1}{2}\arccos\frac{\lambda^2 - 1 - 2\lambda\cos\theta}{2} + \arcsin\frac{\sin\theta}{\sqrt{\lambda^2 + 1 - 2\lambda\cos\theta}}$$

where: $\lambda = 1 + \sin(\alpha/2)$

$$\psi = \frac{1}{2}\arccos\frac{\lambda^2 - 1 - 2\lambda\cos\theta}{2} - \arcsin\frac{\sin\theta}{\sqrt{\lambda^2 + 1 - 2\lambda\cos\theta}}$$

The equivalent moment of inertia about the 4-th axis is:

$$J_r = \left(J_G + ml_G^2 + ml^2\right)\frac{\dot{\varphi}^2}{\dot{\theta}^2} + \left[J_G + ml_G^2 + m(l - l_G)^2\right]\frac{\dot{\psi}^2}{\dot{\theta}^2} -$$

$$- ml(l - l_G)\left(\lambda^2 - 1 - 2\lambda\cos\theta\right)\frac{\dot{\psi}\dot{\varphi}}{\dot{\theta}^2} + J_G + ml_G^2$$

where: θ - angular speed of the segment 34; $\dot{\varphi}$ - angular speed of the segment 12; $\dot{\psi}$ - angular speed of the segment 23; J_G – moment of inertia for modules 12, 23 and 34 ; m – module mass; l_G – the distance between the gravity center of a module and its rotation axis.

Motion equation

$$u = L\frac{di}{dt} + R\,i + \gamma\, k_e\, \dot{\theta}$$

$$\gamma\, k_t\, i = J_r(\theta)\,\ddot{\theta} + c\,\dot{\theta} + M_r(\theta)$$

where: L, R – motor winding inductance and resistance; u, i – control voltage and current; k_e, k_t – electromechanical coupling coefficients; c – damping coefficient; θ, $\dot{\theta}$ - position and angular speed respectively, of the active joint; γ – additional gear ratio.

Thank you for watching!

Bibliography

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