<Lightening Talk>

Robot Motion Programming

한재영
로봇자동화연구실
서울대학교

Formal Language

Alphabet Σ

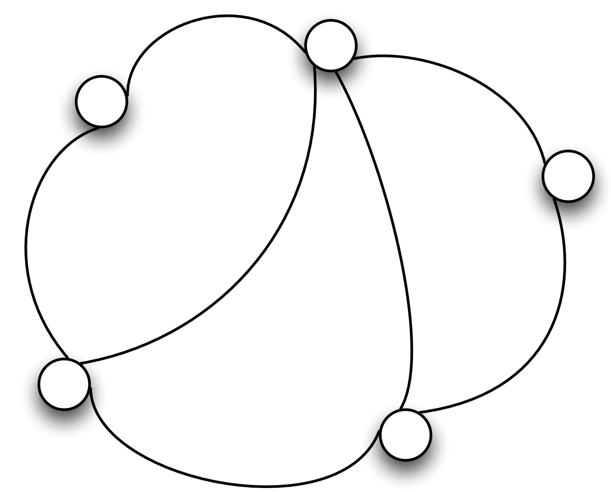
Language $L \subseteq \Sigma^*$

FSM $(\Sigma, X, Y, \delta, \gamma)$

Σ, X, Y: finite sets

$$\delta : X \times \Sigma \to X$$

$$\gamma : X \to Y$$



$$x_{i+1} = \delta(x_i, u_i)$$

Motion Description Language

Brockett [88,90]

Alphabet U

Language $L \subseteq U^*$

Kinematic Machine (U, X, Y, G, h)

U : control input space

X : joint space

Y : output space

$h : X \to Y$

$$\dot{x} = G(x)u$$

Atom of Language

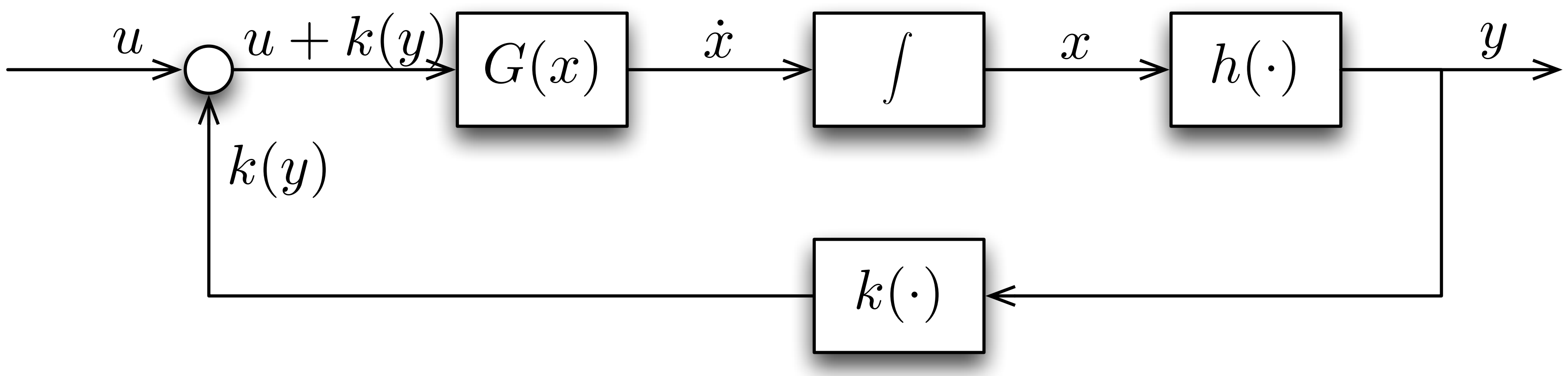
- (u, k, T)

  $\dot{x} = G(x)u$

Atom of Language

- $(u,\ k,\ T)$

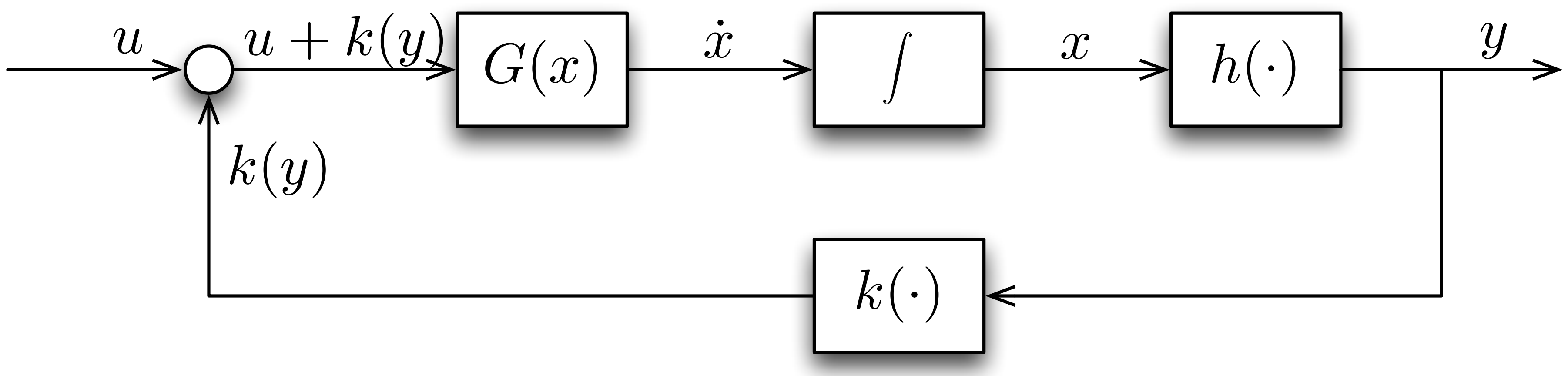
  $$\dot{x} = G(x)(u + k(y)); \quad y = h(x); \quad 0 \leq t < T$$



Atom of Language

- $(u,\ k,\ T)$

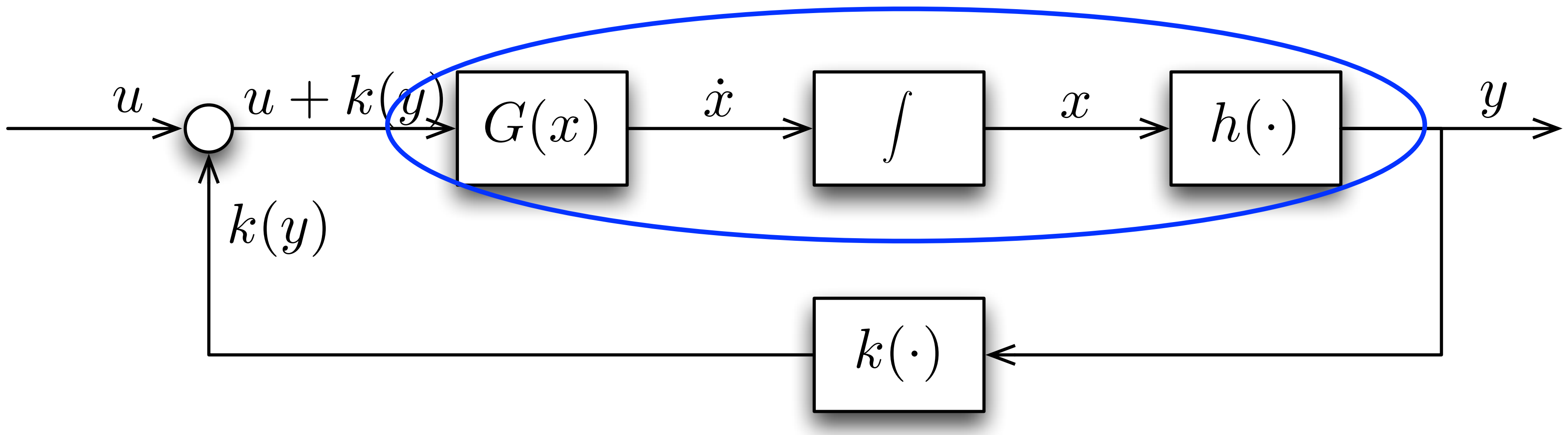
$$\dot{x} = G(x)(u + k(y)); \quad y = h(x); \quad 0 \le t < T$$



Atom of Language

- $(u,\ k,\ T)$

$$\dot{x} = G(x)(u + k(y)); \quad y = h(x); \quad 0 \le t < T$$



Atom of Language

- $(u,\, k,\, T)$

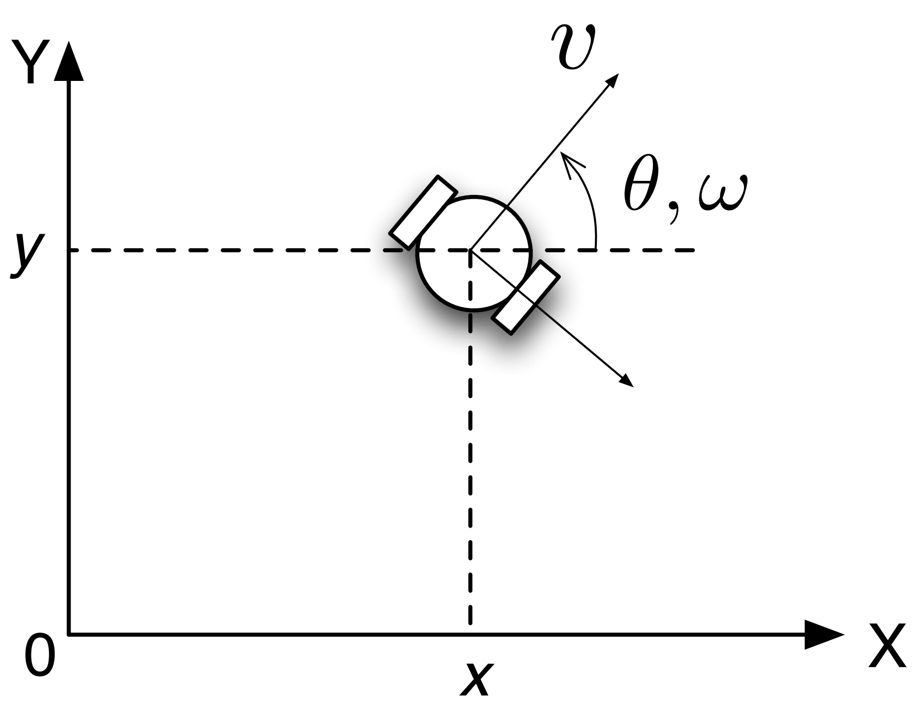
$$\dot{x} = G(x)(u + k(y)); \quad y = h(x); \quad 0 \le t < T$$

- **input string** $(u_1,\, k_1,\, T_1) \cdots (u_n,\, k_n,\, T_n)$

$$\begin{aligned} \dot{x} &= G(x)(u_1 + k_1(y)); & t_0 \le t < t_0 + T_1 \\ &\vdots & \vdots \\ \dot{x} &= G(x)(u_n + k_n(y)); & t_0 + T_1 + \cdots + T_{n-1} \le t < t_0 + T_1 + \cdots + T_n \end{aligned}$$

Mobile Robot

- Governing Equation



v: driving velocity

ω: steering velocity

$$\begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{pmatrix} = \begin{pmatrix} \cos\theta & 0 \\ \sin\theta & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} v \\ \omega \end{pmatrix}$$

$$\Downarrow$$

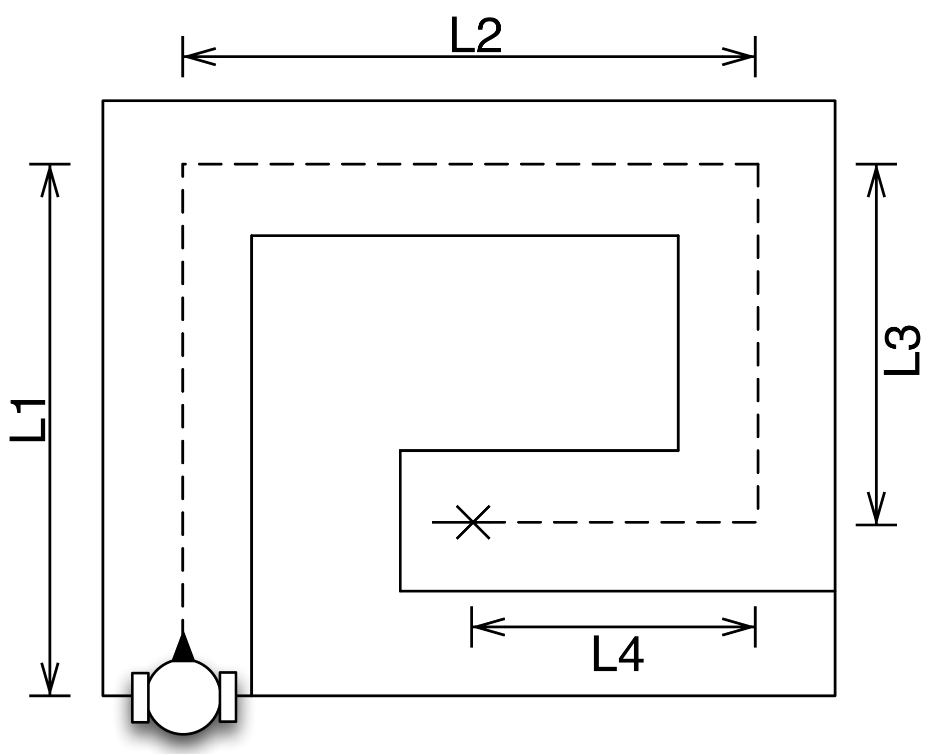
$$\dot{\mathbf{x}}(t) = f(\mathbf{x}(t))\mathbf{u}(t)$$

Motion Description

$$\dot{\mathbf{x}}(t) = f(\mathbf{x}(t))\mathbf{u}(t) \text{ for } t_0 \leq t < t_0 + T$$

$(\mathbf{u},\ T)$	Description	Command
$((1,\ 0), d)$	move forward for ***d*** meters with 1 *m/s*	$mf(d)$
$((-1,\ 0), d)$	move backward for ***d*** meters with 1 *m/s*	$mb(d)$
$((0,\ 1), a)$	turn left for ***a*** radians with 1 *rad/s*	$tl(a)$
$((0,\ -1), a)$	turn right for ***a*** radians with 1 *rad/s*	$tr(a)$
$((0,\ 0), t)$	stop for ***t*** *sec*	$stop(t)$

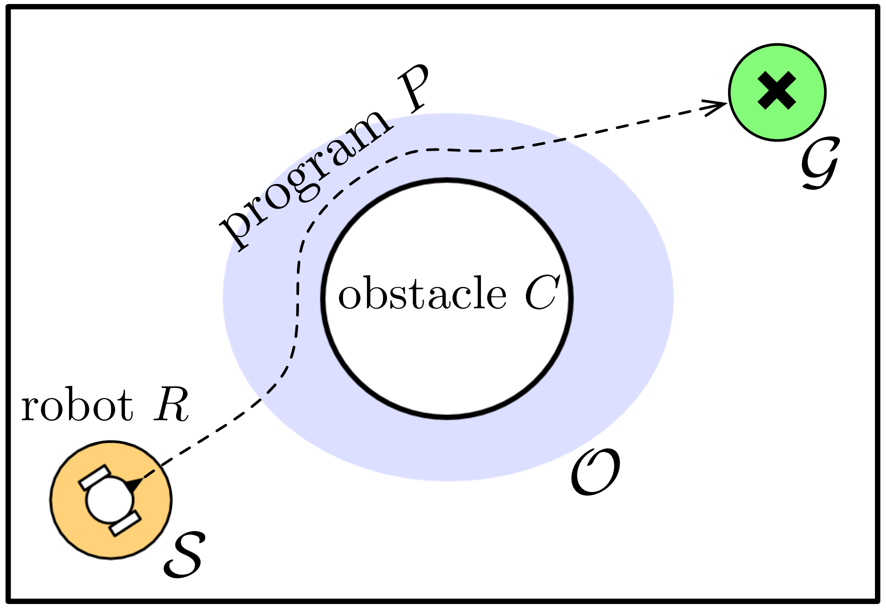
Maze



- Motion Programming

$$mf(L1)$$
$$tr(\frac{\pi}{2})$$
$$mf(L2)$$
$$tr(\frac{\pi}{2})$$
$$mf(L3)$$
$$tr(\frac{\pi}{2})$$
$$mf(L4)$$
$$stop()$$

Static Analysis I



- Verifying path plan:

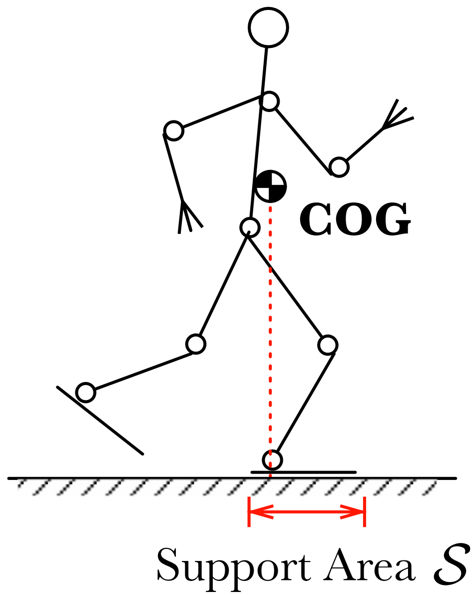
Given $R_{initial} \in \mathcal{S}$ and $C \in \mathcal{O}$,

does motion program P

guarantee $R_{final} \in \mathcal{G}$?

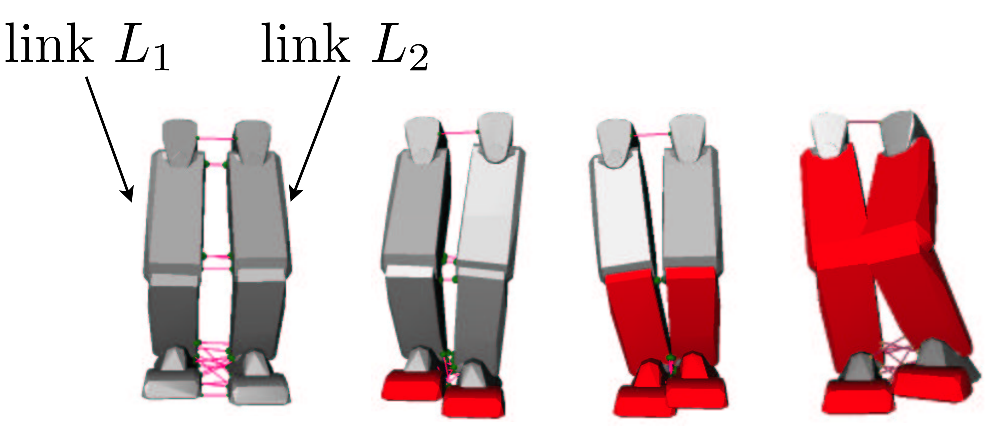
Static Analysis II

- Balance



Does program P guarantee COG in S?

- Self-collision Avoidance



Does program P guarantee that $\forall p \in L_1$ and $\forall q \in L_2$ are not coincided?