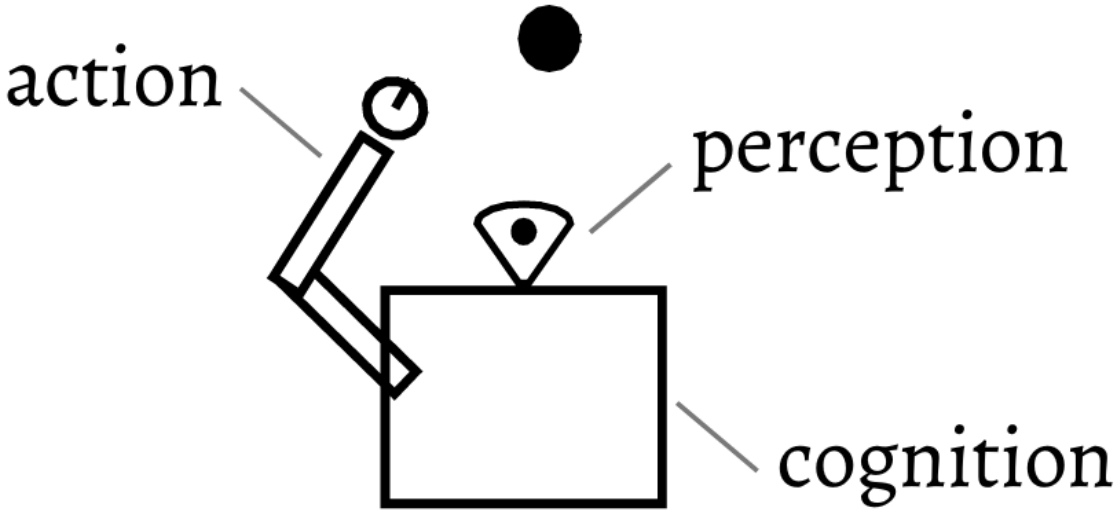
A neural dynamic architecture to generate arm movements directed at objects

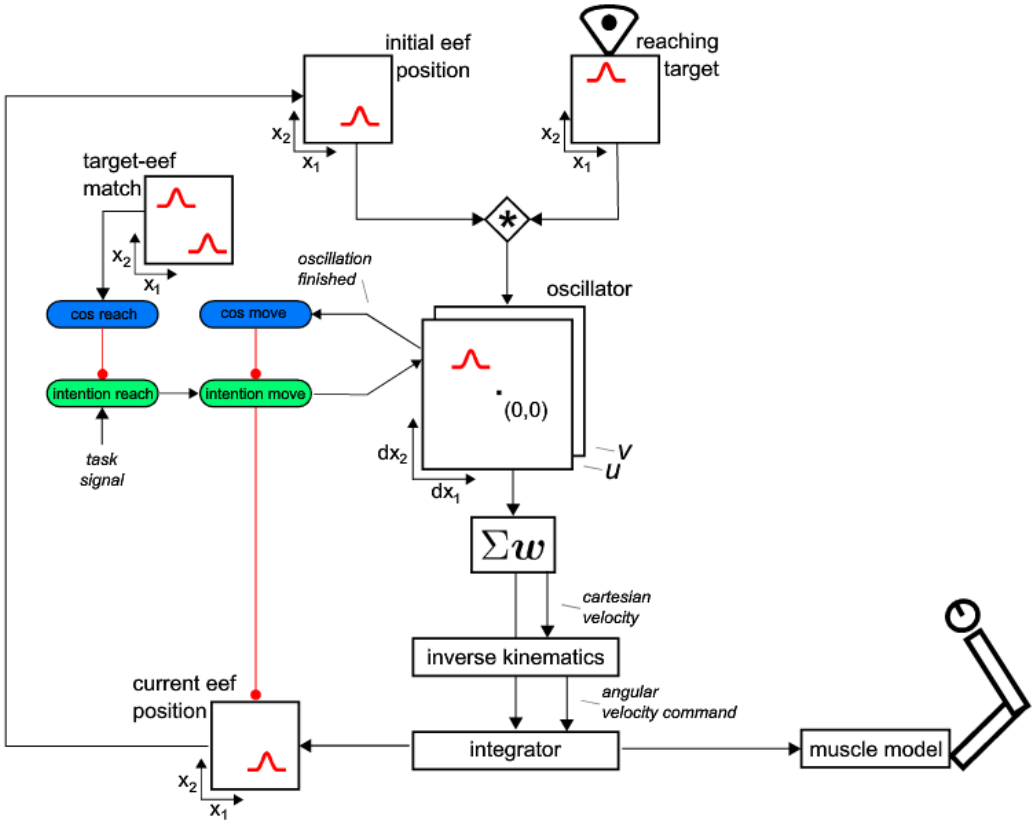
13.07.2017

Jan Tekülve

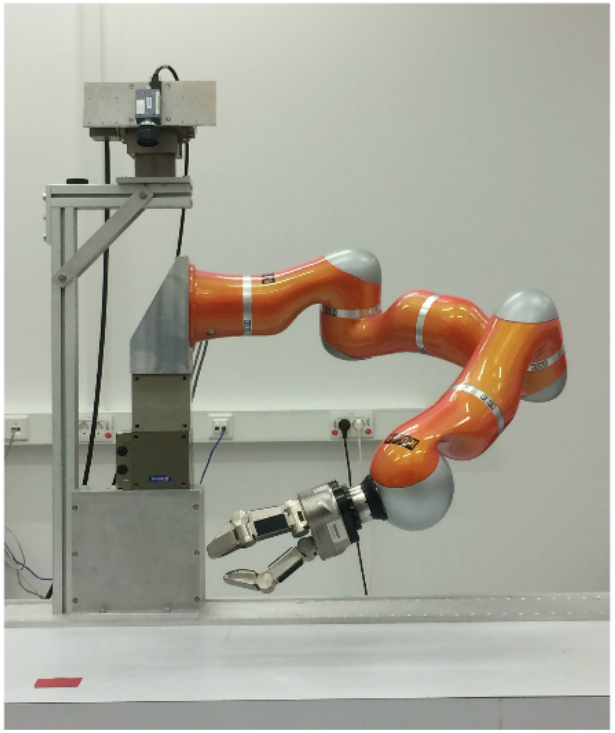
A Neural Process Account to Generate Goal Directed Arm Movements

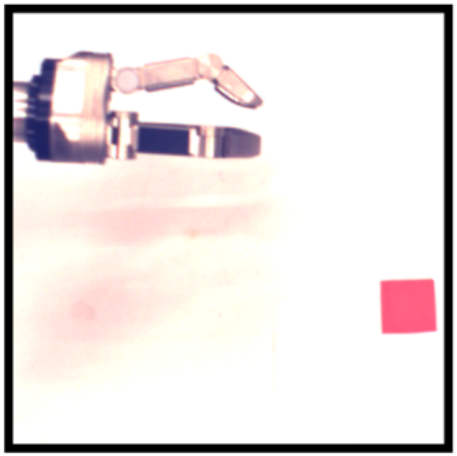


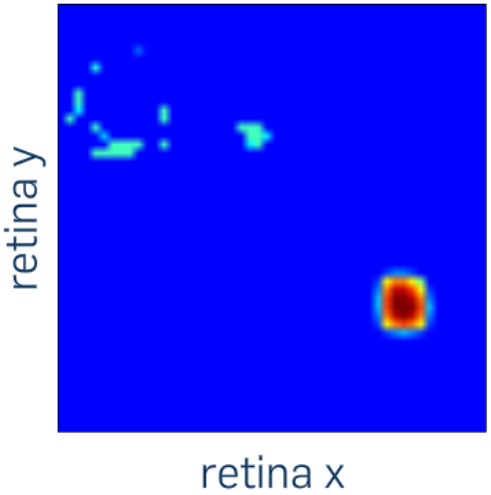
A Dynamic Field Architecture



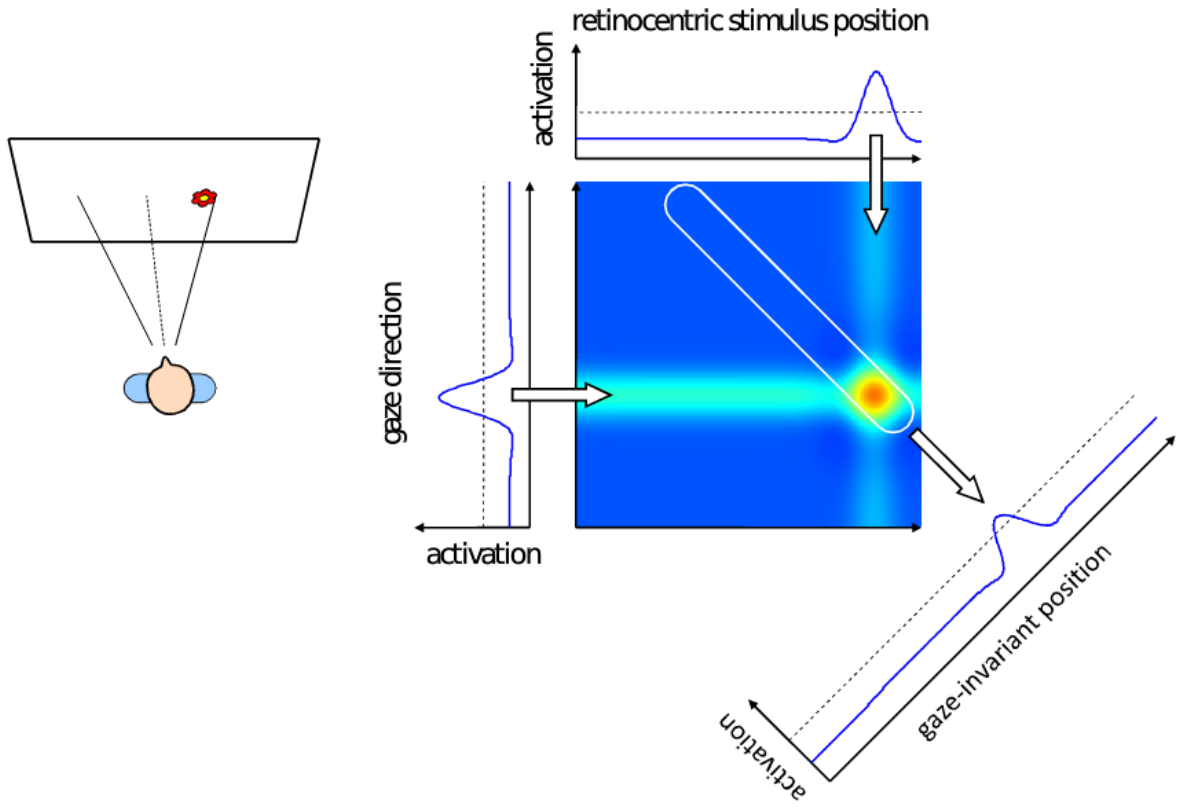
Target Representation





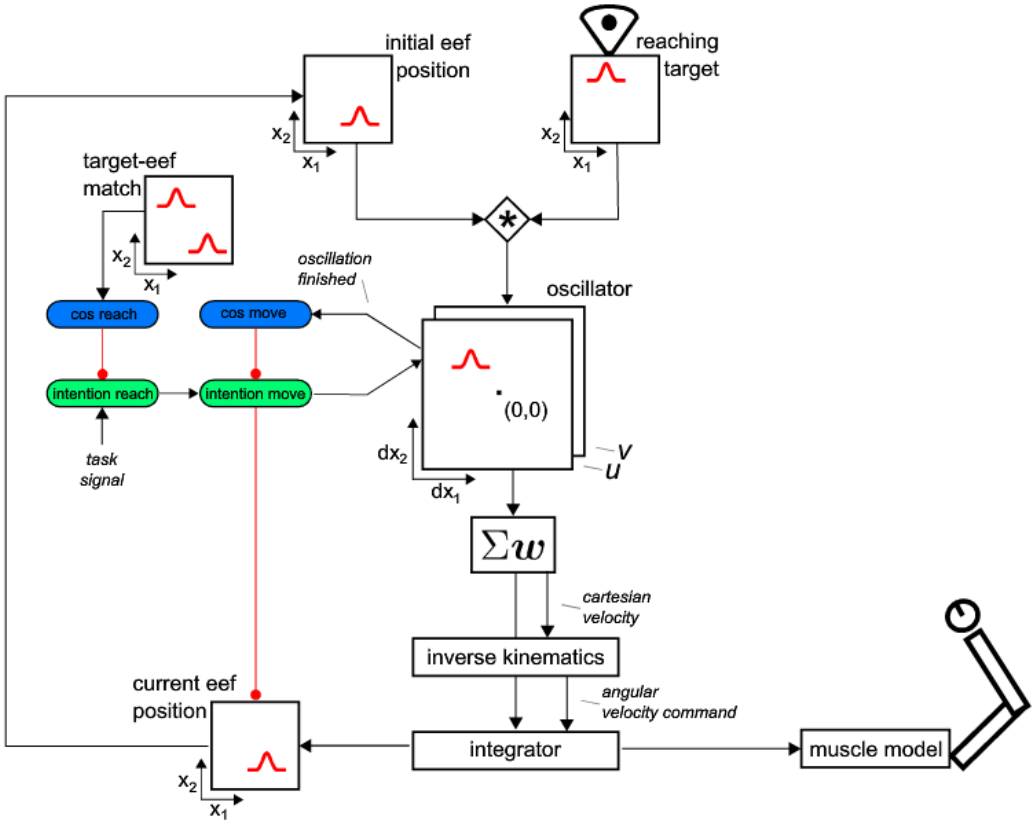


Excursion: Coordinate Transformations

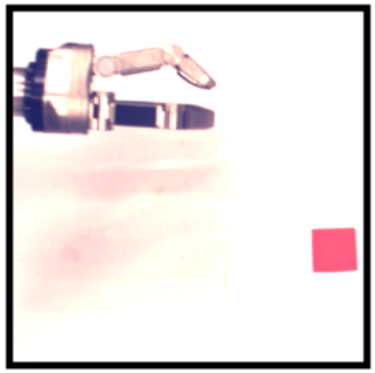


[Schneegans 2012]

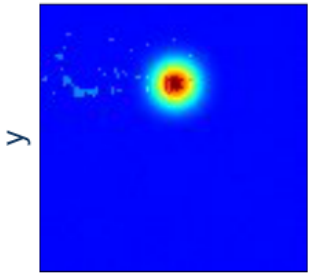
A Dynamic Field Architecture



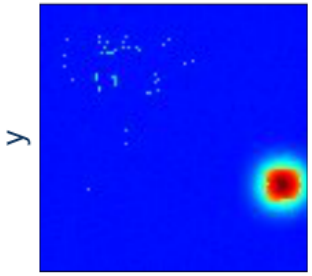
Extracting a Movement Plan



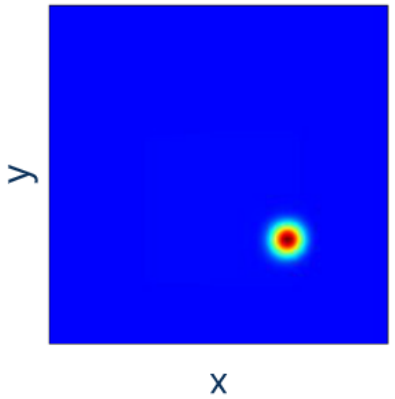
Hand



Target

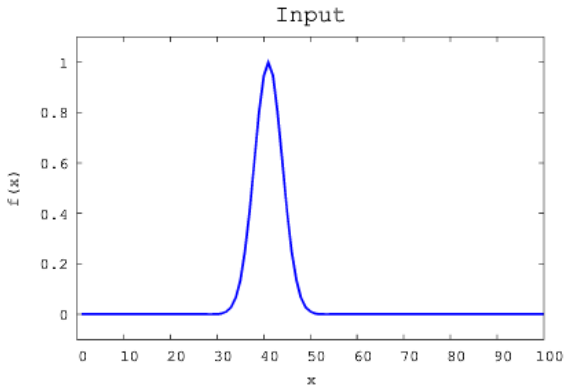


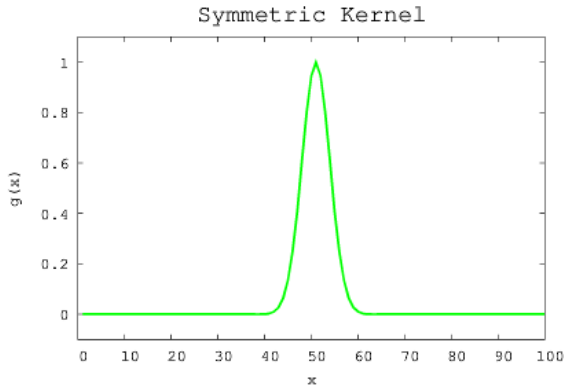
Hand-Centered Frame

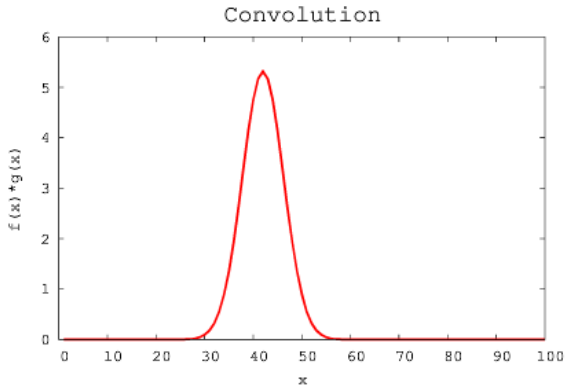


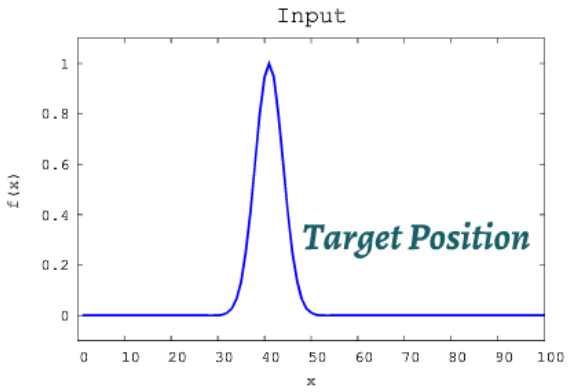
Excursion: Convolution

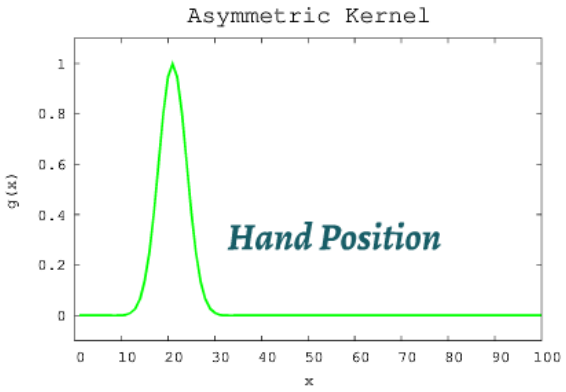
$$f(x) * g(x) = \int f(x')g(x - x')dx'$$

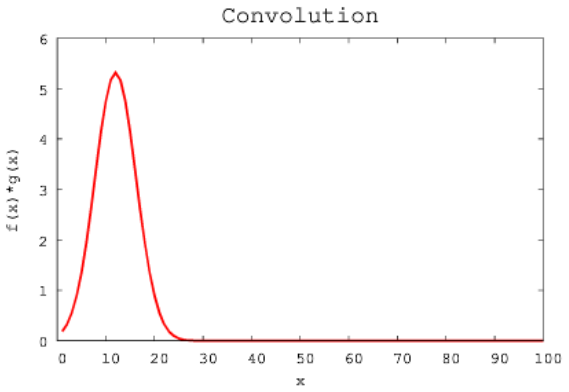


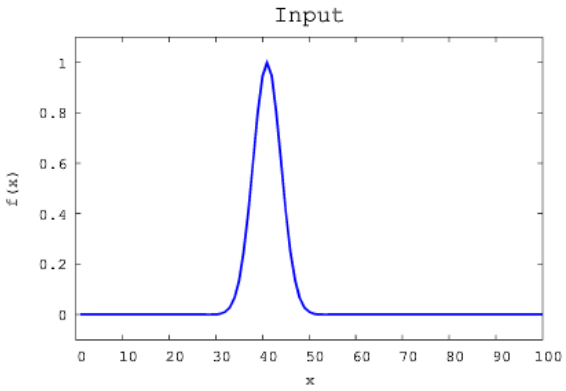


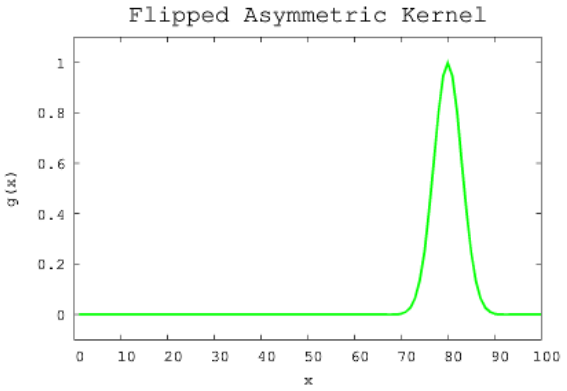


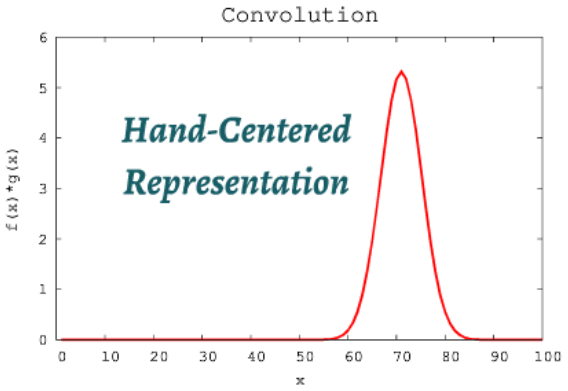

Input
f(x)
x
Target Position


Asymmetric Kernel
g(x)
x
Hand Position

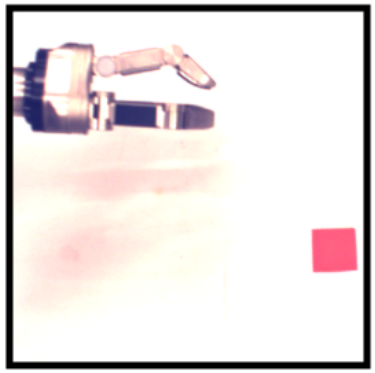

Convolution
f(x)*g(x)
x


Input
f(x)
x

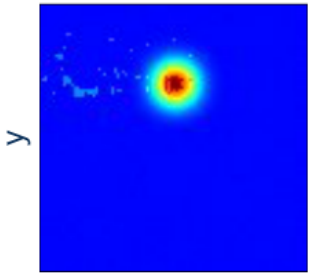

Flipped Asymmetric Kernel
g(x)
x


Convolution
f(x)*g(x)
x
Hand-Centered
Representation

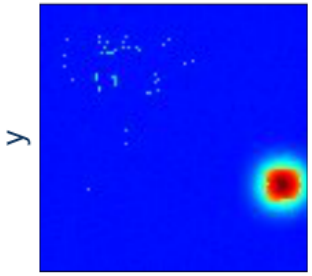
Extracting a Movement Plan



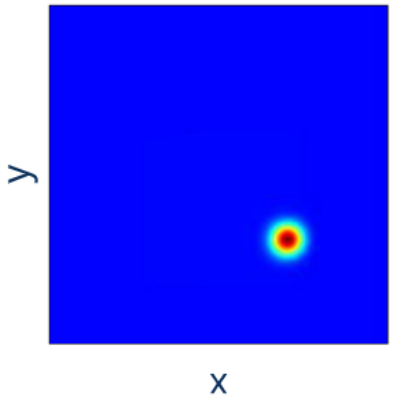
Hand



Target

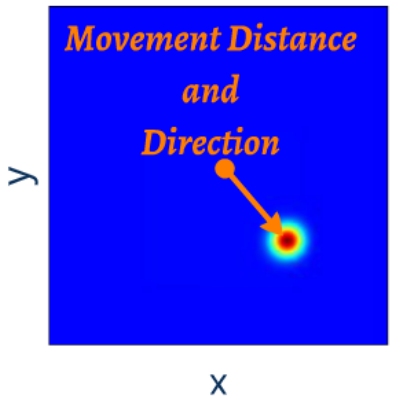


Hand-Centered Frame



Extract Movement Parameters From Relative Frame

Hand-Centered Frame



Weight Matrix

w

-3	-2	-1	0	1	2	3
-3	-2	-1	0	1	2	3
-3	-2	-1	0	1	2	3
-3	-2	-1	0	1	2	3
-3	-2	-1	0	1	2	3
-3	-2	-1	0	1	2	3
-3	-2	-1	0	1	2	3

x-direction

-3	-3	-3	-3	-3	-3	-3
-2	-2	-2	-2	-2	-2	-2
-1	-1	-1	-1	-1	-1	-1
0	0	0	0	0	0	0
1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3

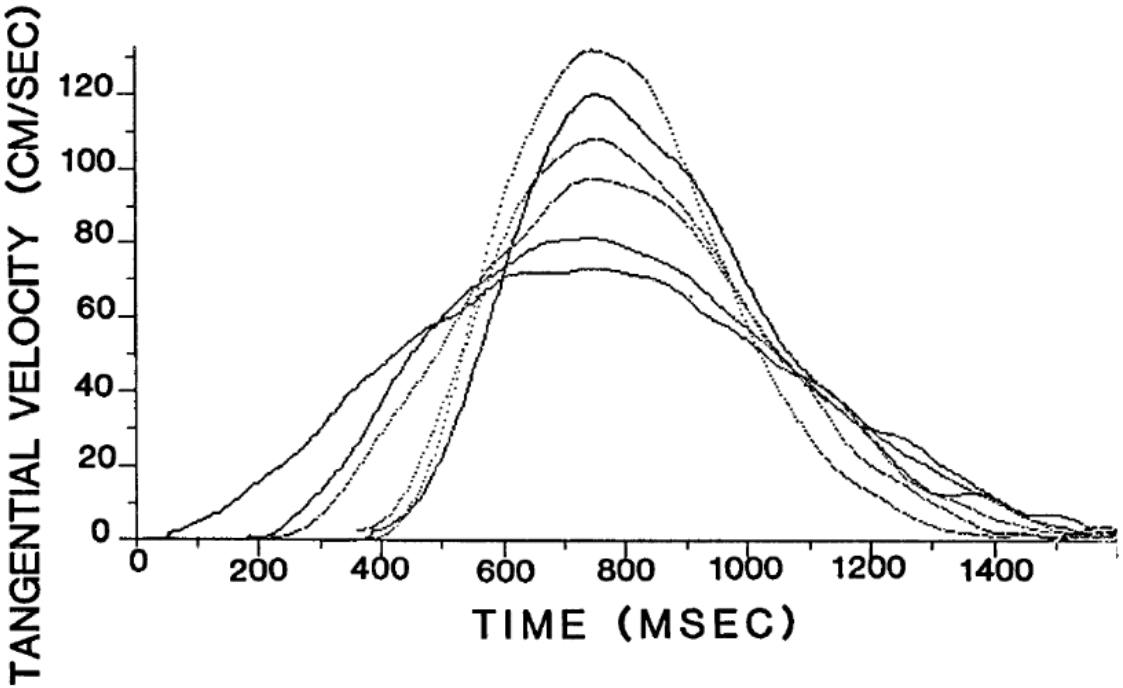
y-direction

Velocity

v

$$\mathbf{v} = \iint \mathbf{w}(x,y)\sigma(u(x,y))\,dxdy$$

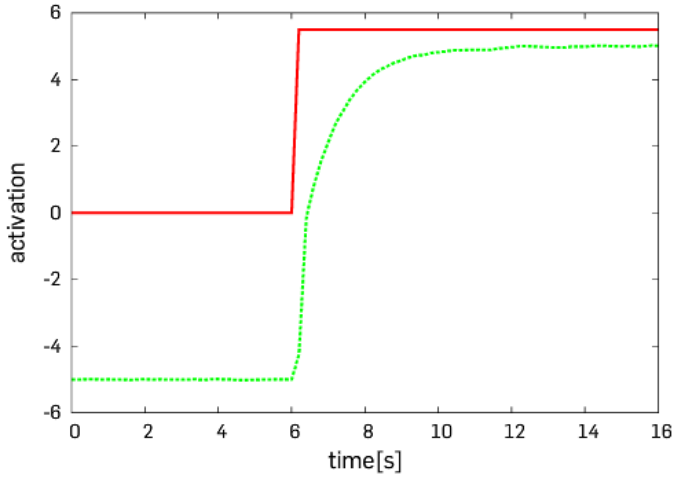
Velocity Profile of Human Arm Movements



[Atkeson, Hollerbach 1985]

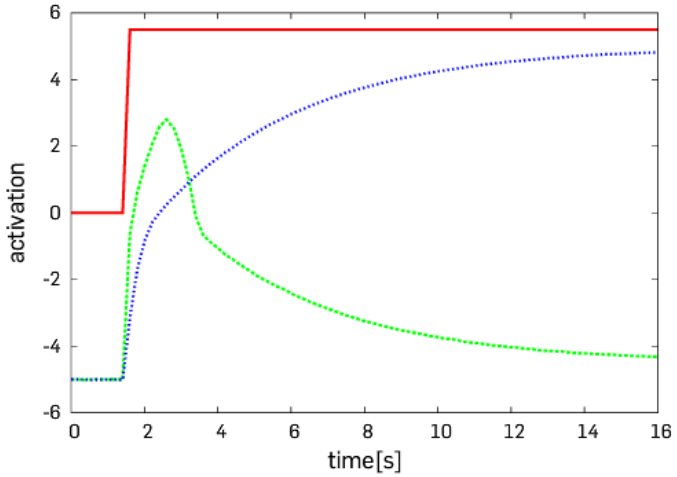
Generating a Bell Shaped Timing Profile

Single Node



$$\tau_u \dot{u}(t) = -u(t) + S(t) + h$$

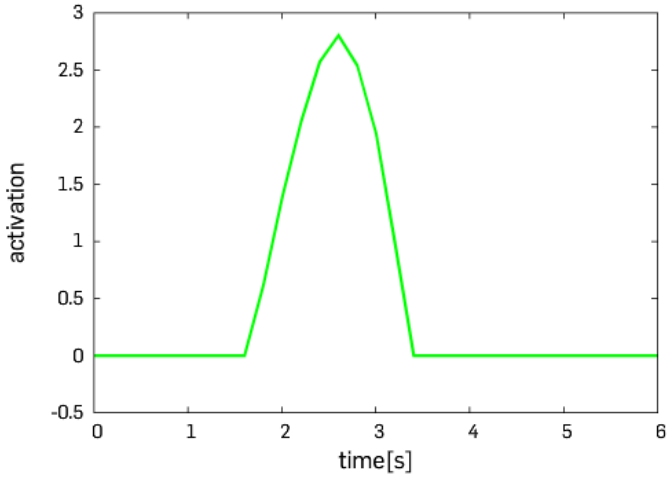
Two Nodes different Time-Scales



$$\tau_u \dot{u}(t) = -u(t) + S(t) + h - v(t)$$
$$\tau_v \dot{v}(t) = -v(t) + S(t) + h$$

$$\tau_u < \tau_v$$

Sigmoided Activation



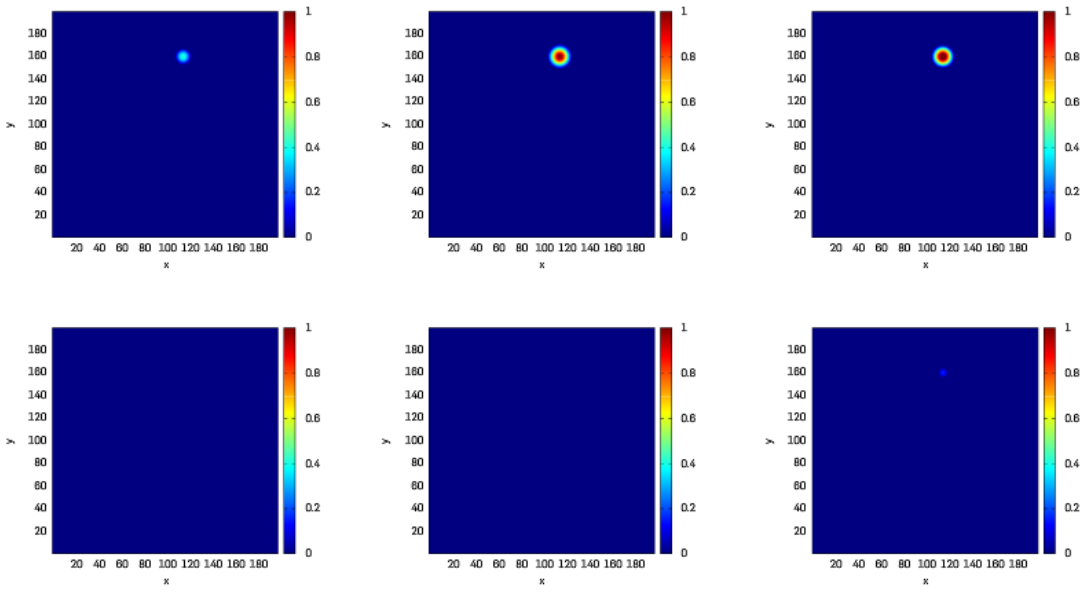
$$\Theta(u(t))$$

$$\Theta(x) = \begin{cases} x, & \text{if } x > 0 \\ 0, & \text{otherwise} \end{cases}$$

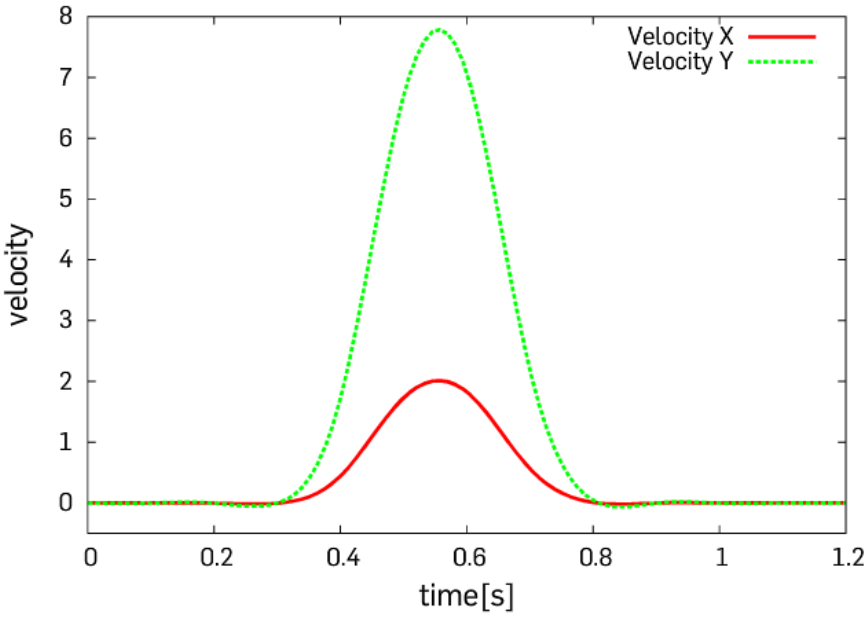
Combine this Oscillator with the Relative 2D-Field

u

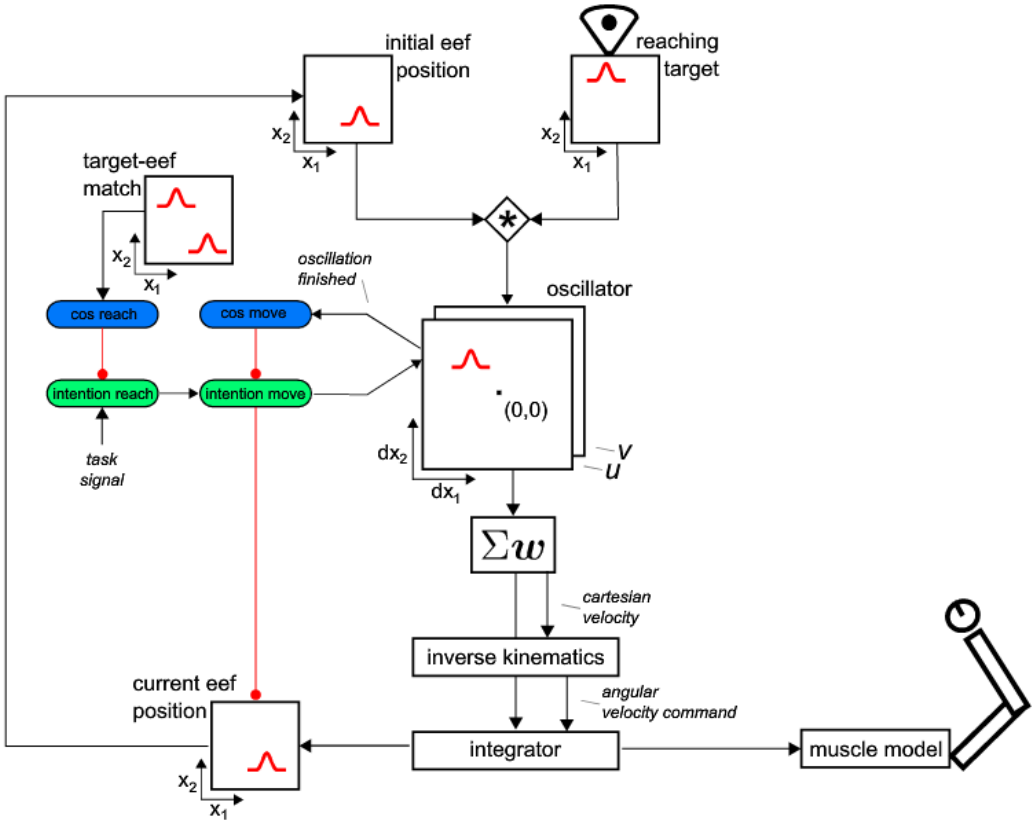
v



time



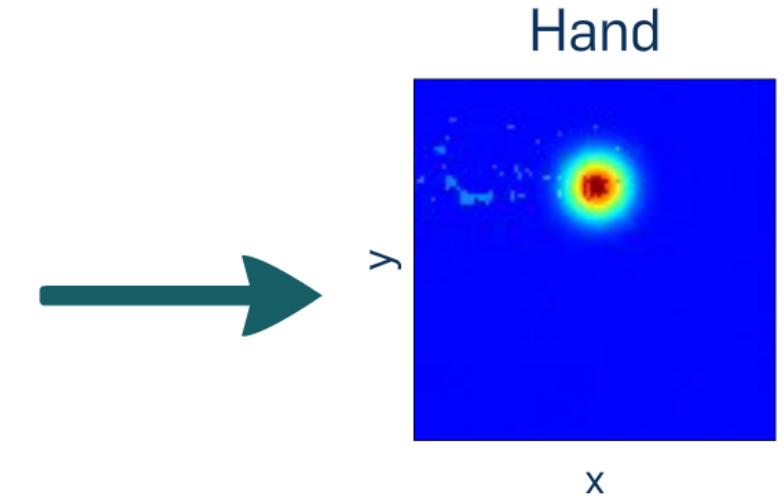
A Dynamic Field Architecture



Updating the Arm Position: Rate to Space Code

$$\dot{\boldsymbol{p}} = \boldsymbol{v}$$

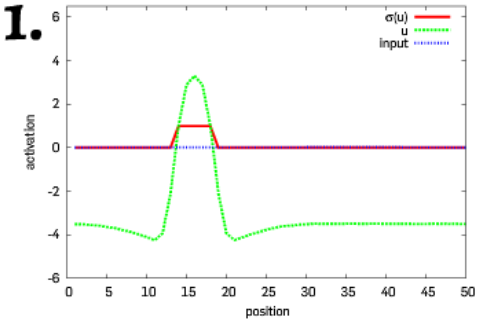
$$\boldsymbol{p} = \begin{pmatrix} p_x \\ p_y \end{pmatrix}$$



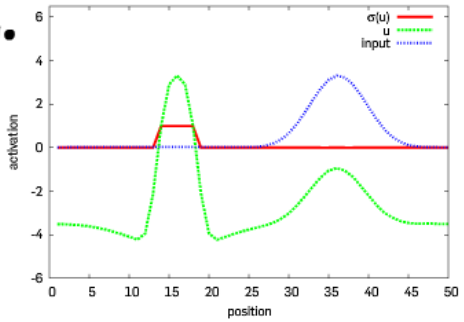
$$s_p(x, y, t) = c \, \exp\left(-\left(\frac{(x-p_x)^2}{2\sigma_x^2} + \frac{(y-p_y)^2}{2\sigma_y^2}\right)\right)$$

Updating the Arm Position: Selective Memory Field

1.



2.



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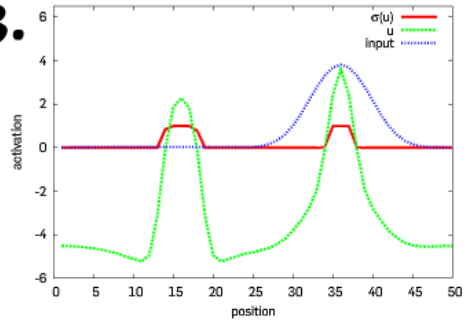

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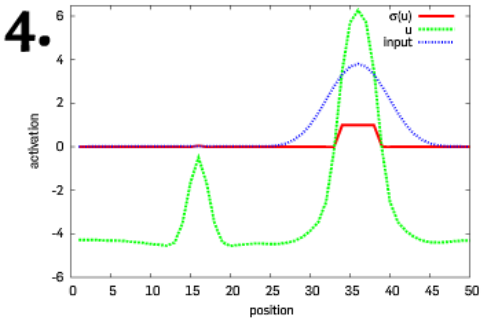

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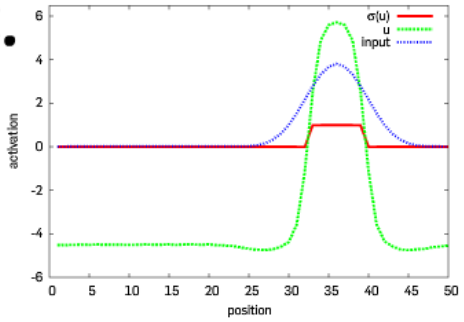

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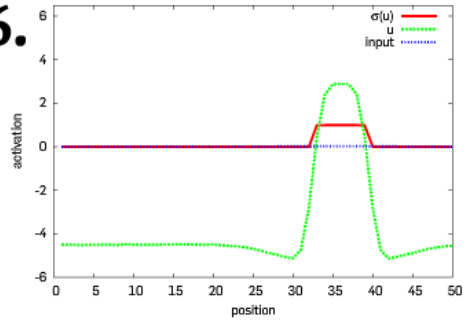
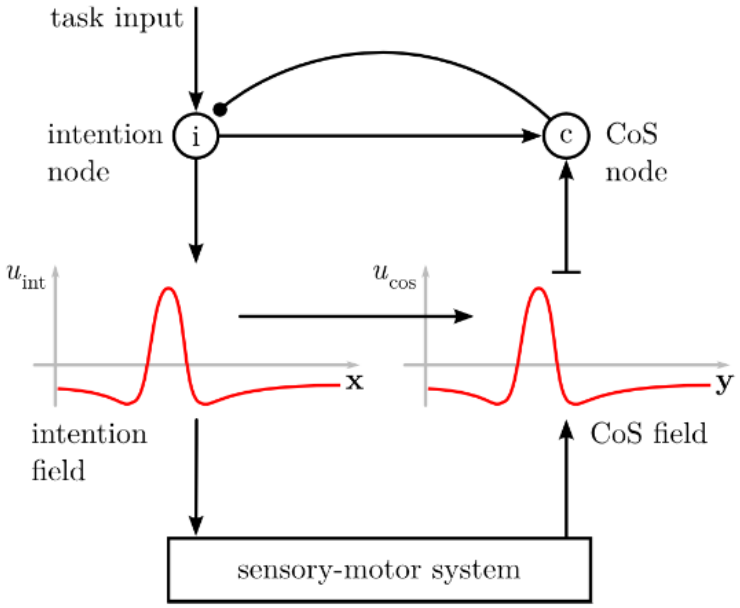
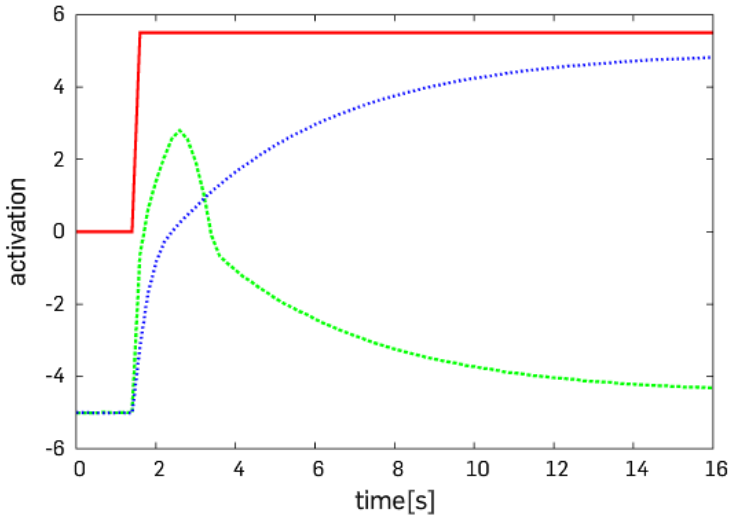


Organizing a Single Movement

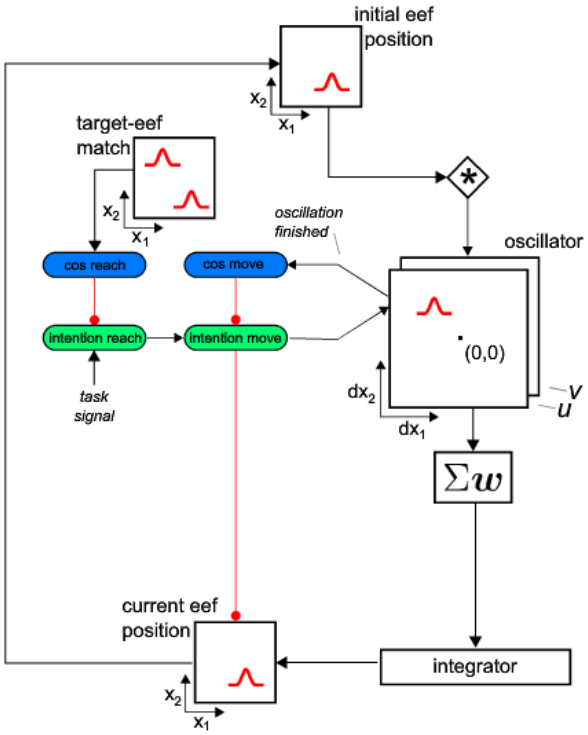
Elementary BEHAVIOR

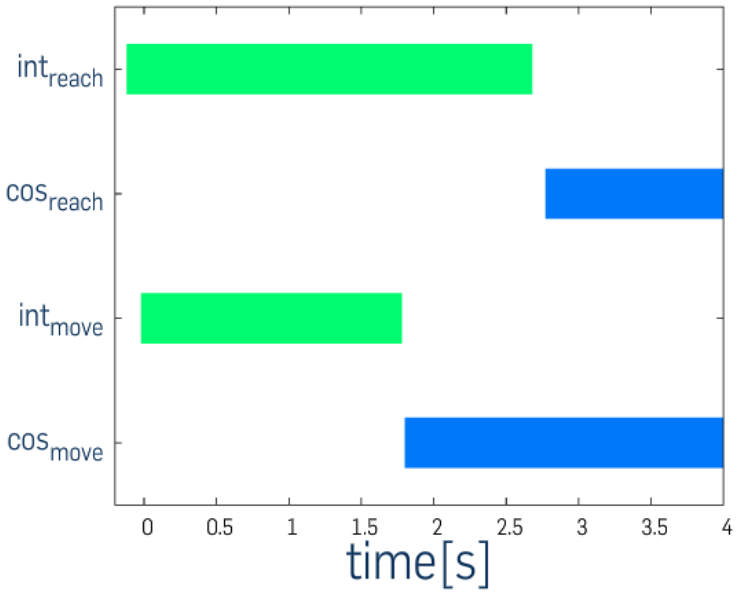




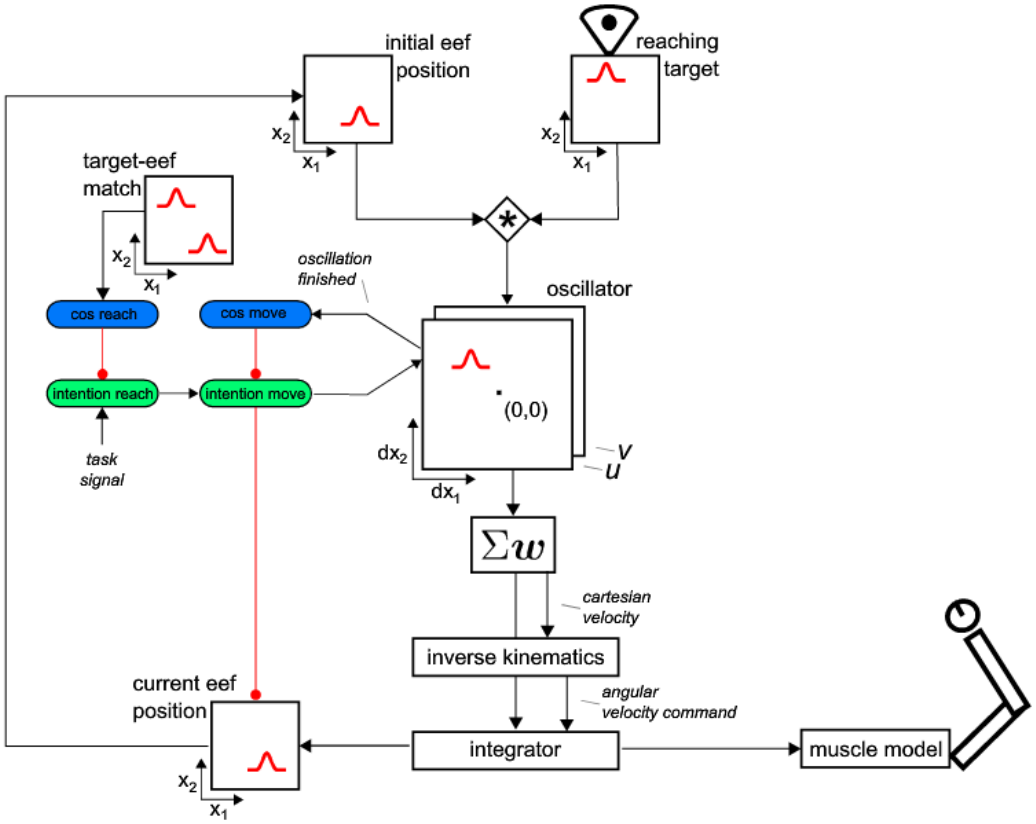
$$\tau_u \dot{u}(t) = -u(t) + S(t) + h - v(t)$$
$$\tau_v \dot{v}(t) = -v(t) + S(t) + h$$

Organizing a Single Movement





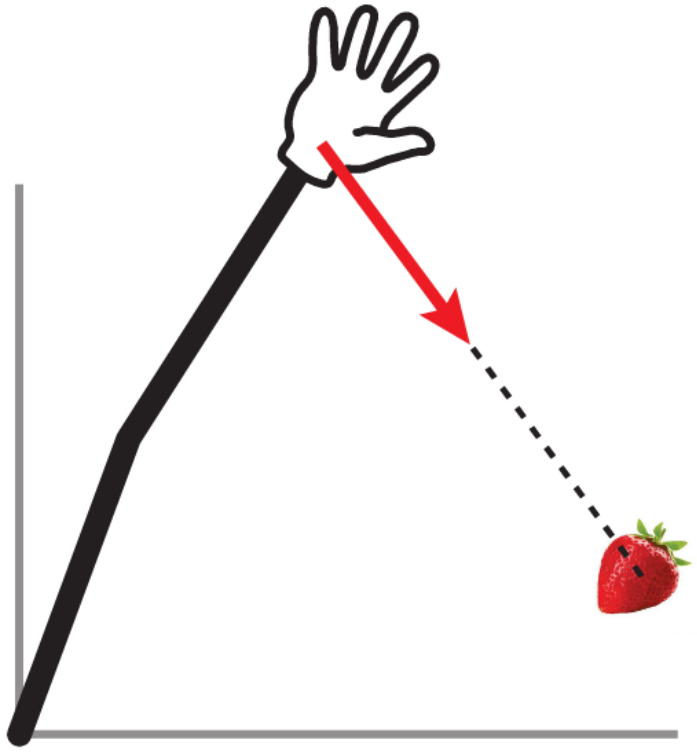
A Dynamic Field Architecture



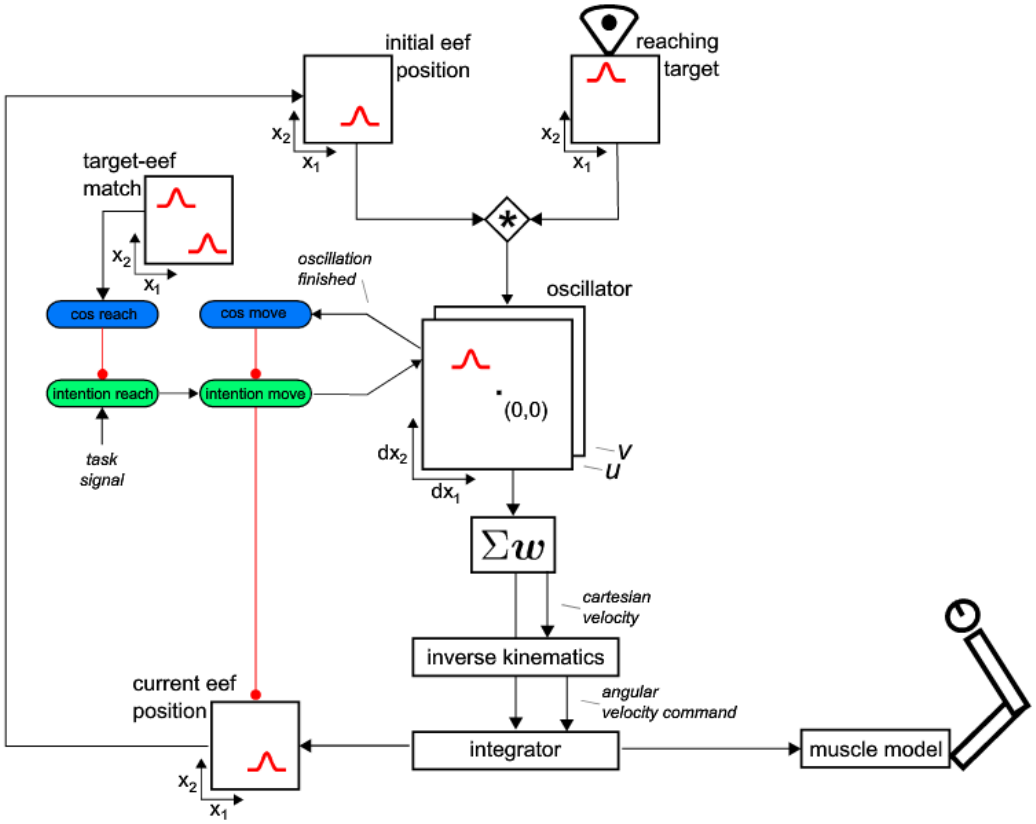
From Cartesian to Angle Space

$$\dot{\theta} = J^{+}\dot{p}$$

Integrating yields: θ

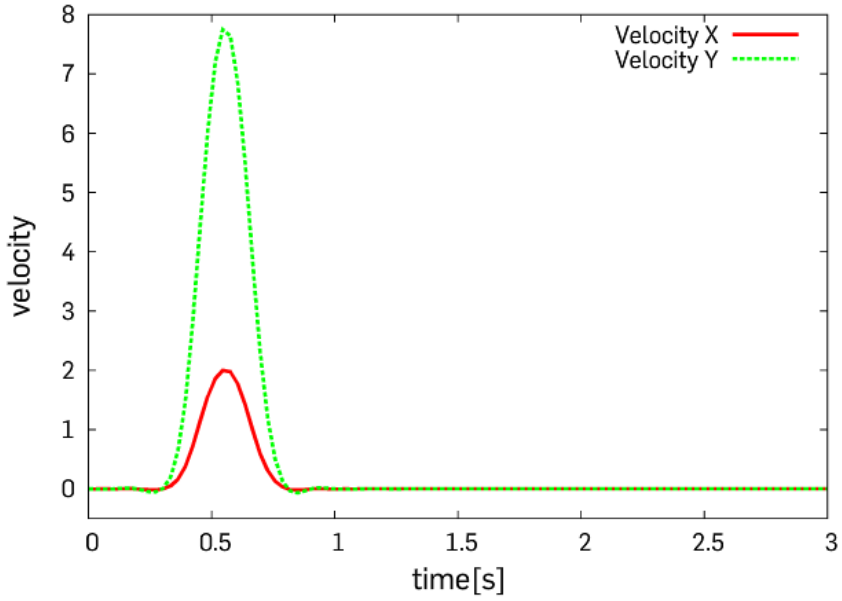


A Dynamic Field Architecture



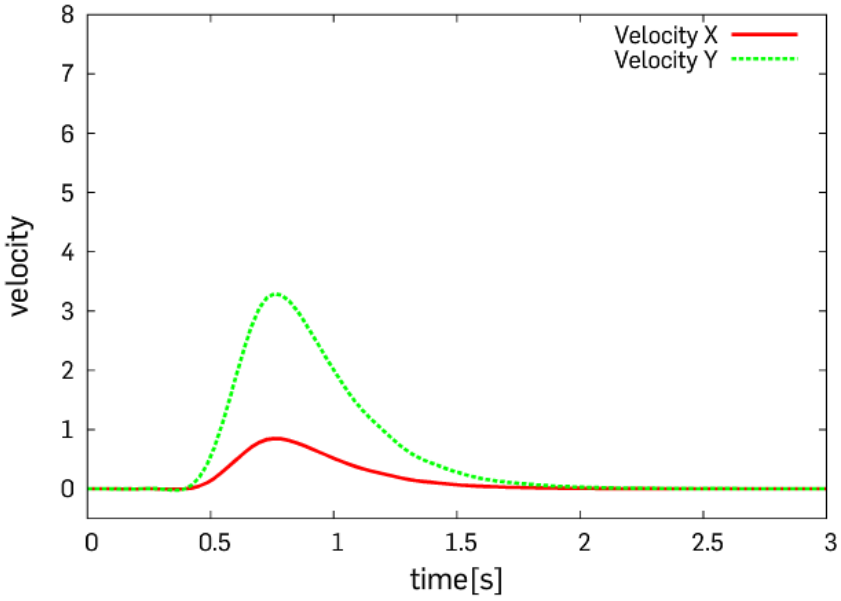
Muscle Model

Velocity Signal



v

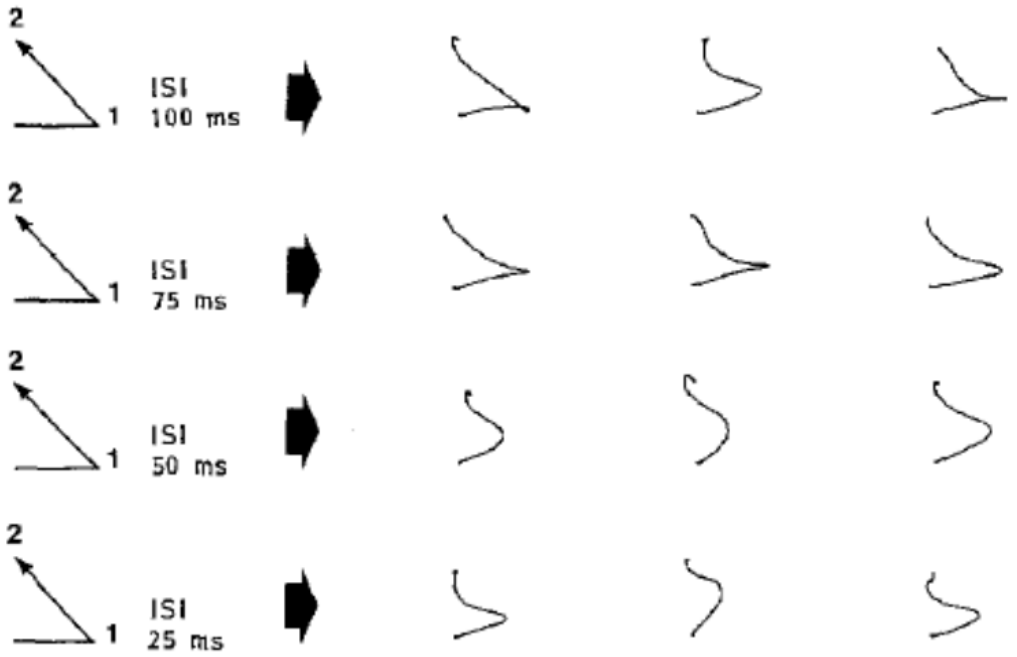
Delayed Velocity Signal



$$\ddot{\phi} = -K(\phi - \theta) - B\dot{\phi}$$

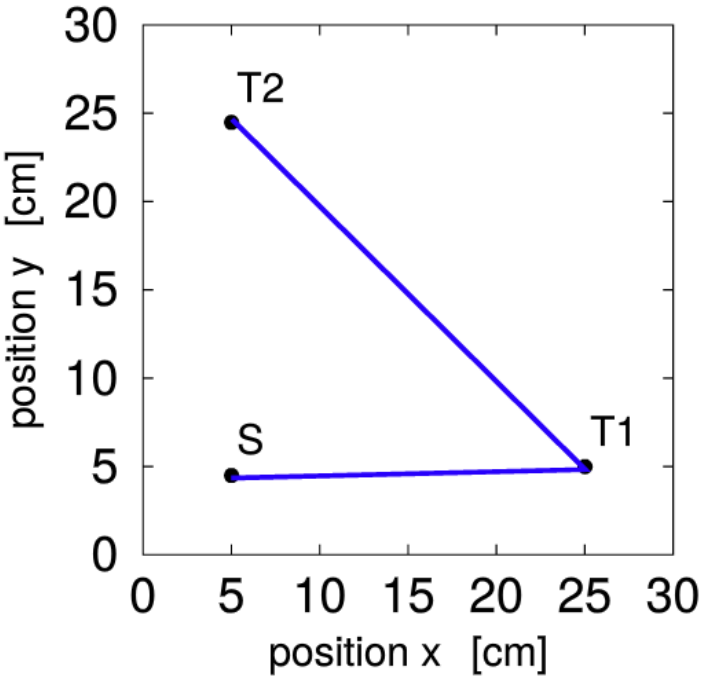
harmonic oscillator

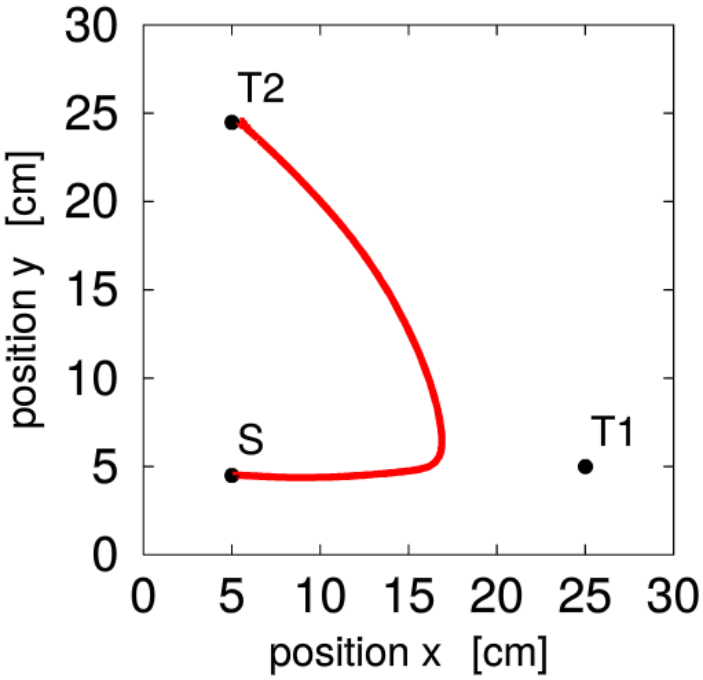
Online Updating of Human Arm Movements



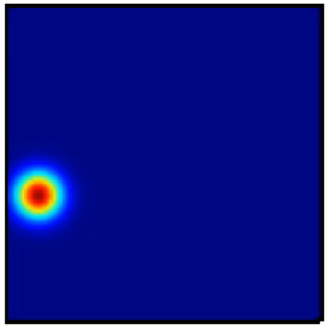
[van Sonderen, van der Gon, Gielen 1988]

Delay enables smooth updating

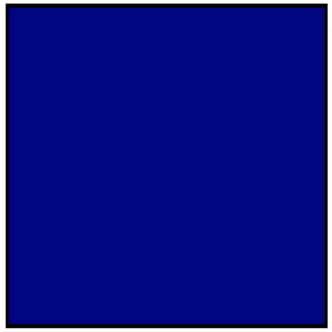




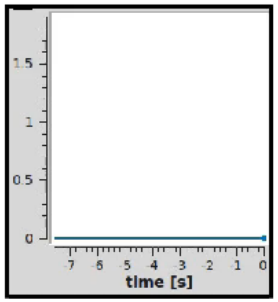
Target



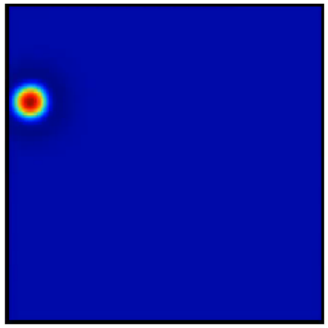
Oscillator-U



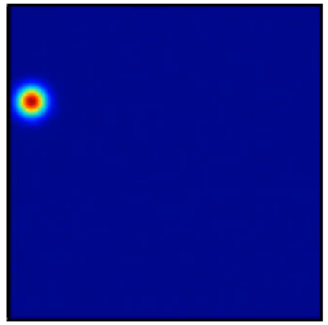
Velocity



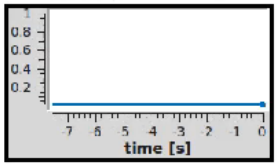
Init Eef

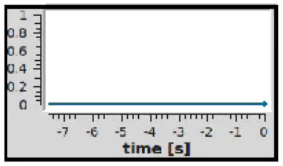


Cur Eef

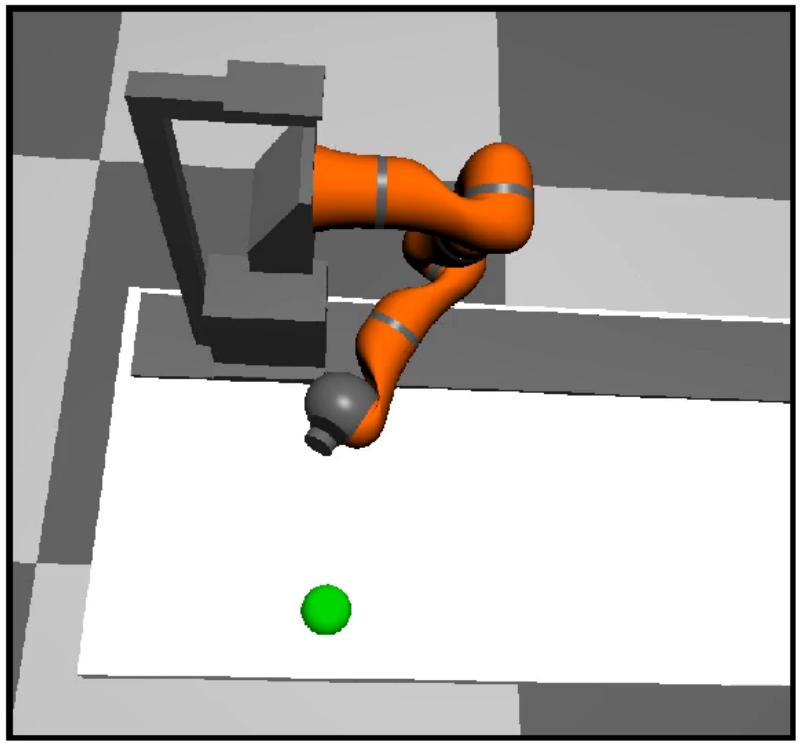


Int Move

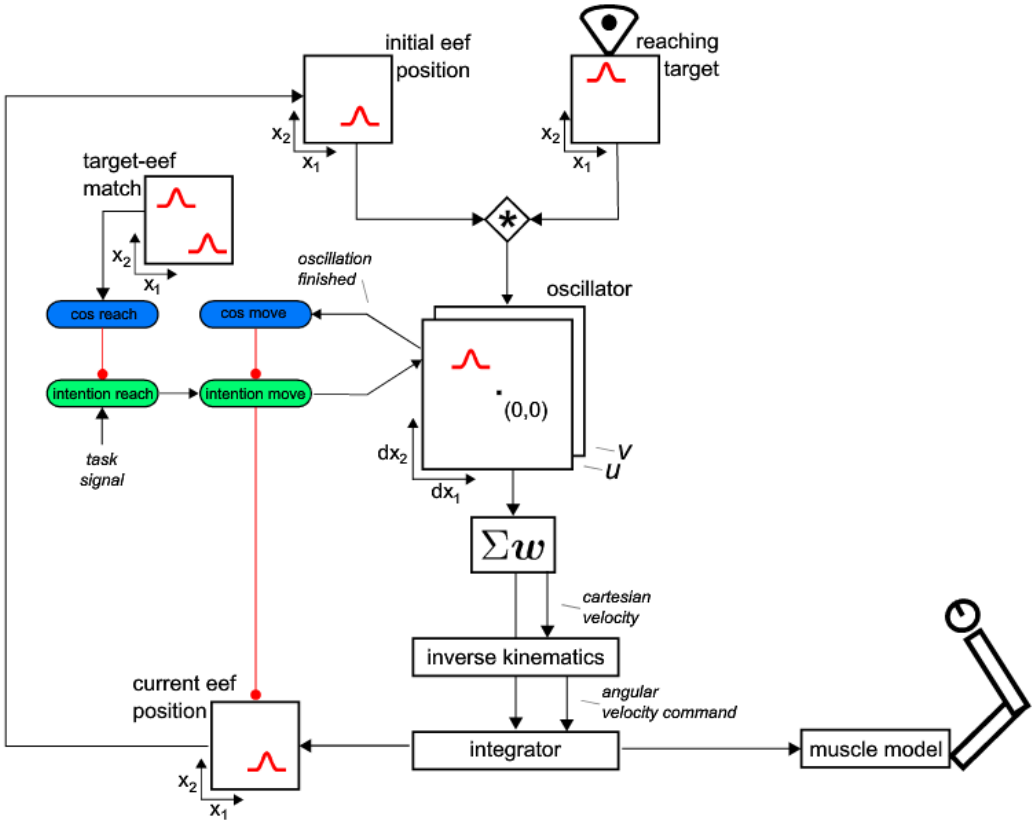




CoS Move



A Dynamic Field Architecture



Conclusion

- Pathway from Perception to Motor
- Neural Oscillator generates Timing
- Elementary Behaviors enable Autonomy

Next Time

- Advanced Muscle Models