Shirley Ryan AbilityLab

Modeling Expected Reaching Error and Behaviors for Motor Adaptation

Eric J. Earley | PhD Candidate, Northwestern University

Motivation

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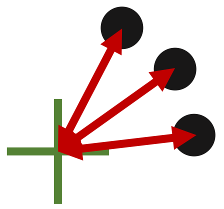
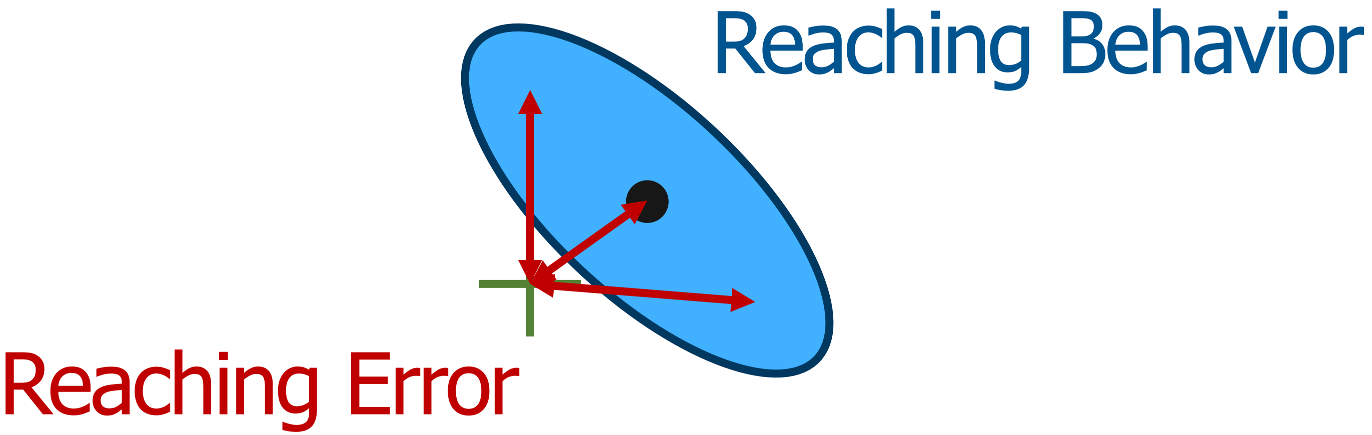


Adaptation calculated based on Euclidean distance

Euclidean distance is not unique metric

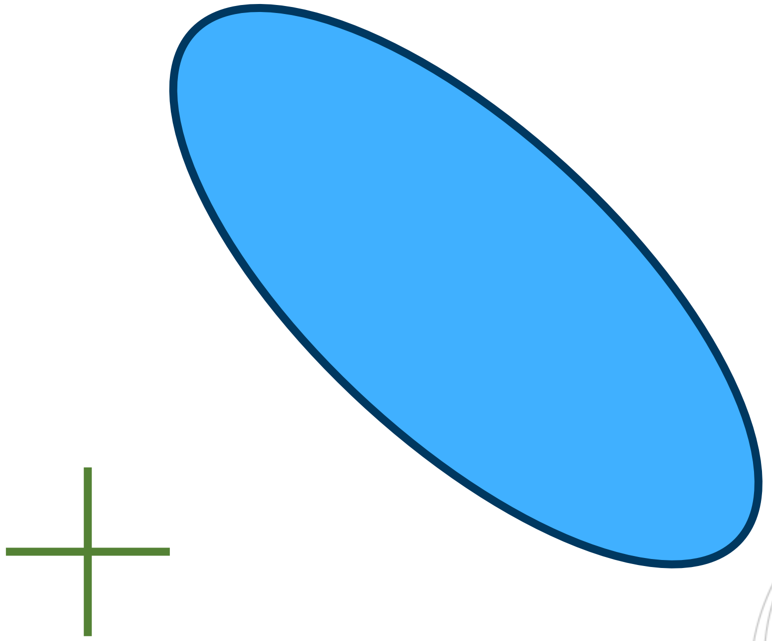
Motivation



Error adaptation has indeterminate behavior solutions

Motivation

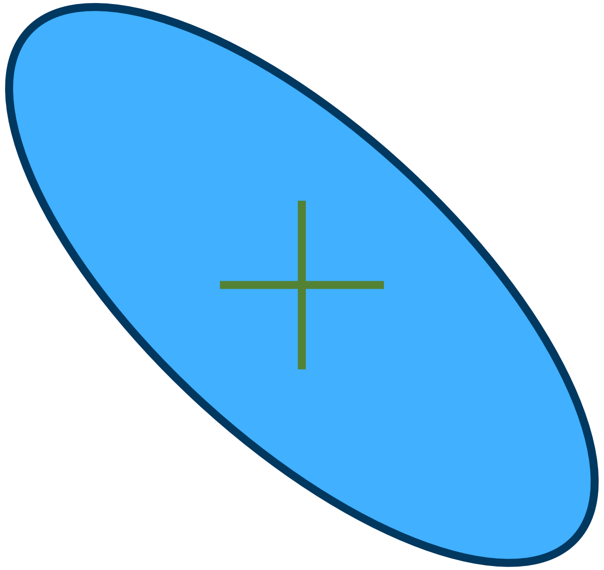
Error adaptation has indeterminate behavior solutions



Motivation

Error adaptation has indeterminate behavior solutions

1) Shift distribution

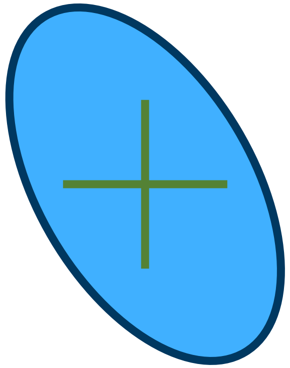


Motivation

Error adaptation has indeterminate behavior solutions

1) Shift distribution

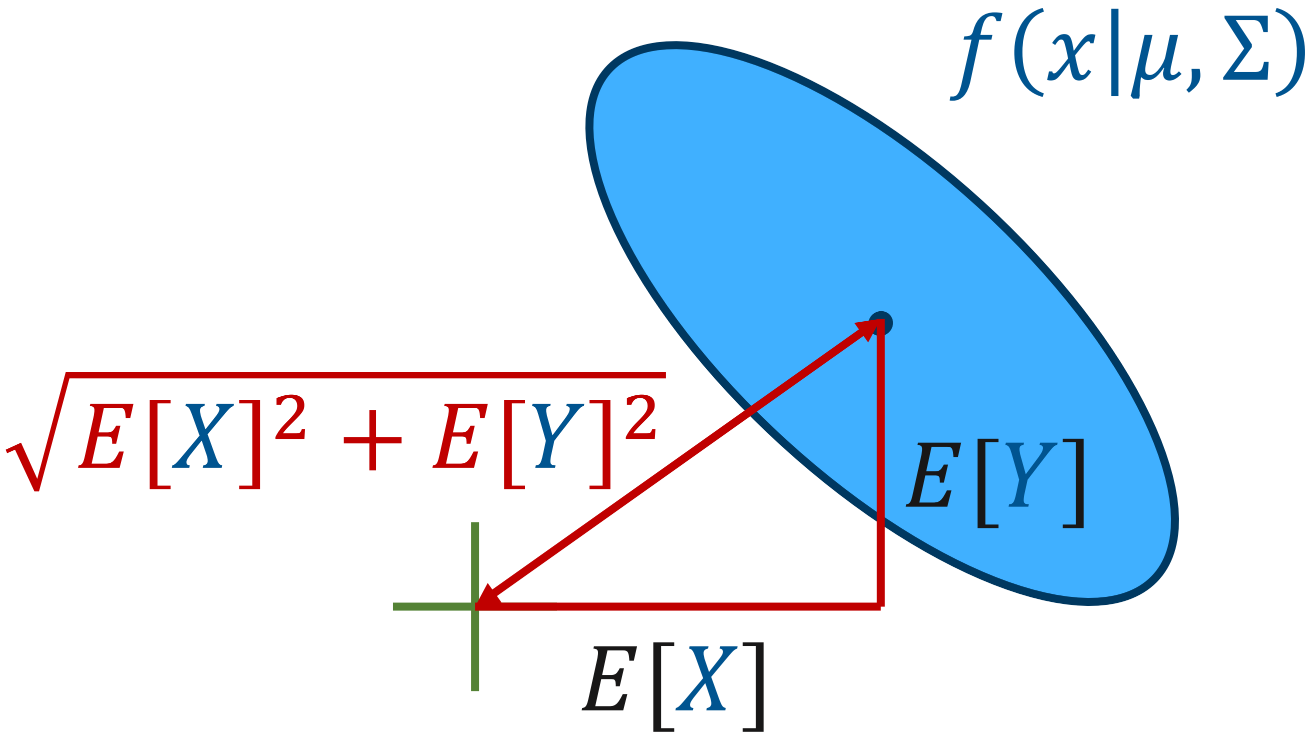
2) Reduce variability



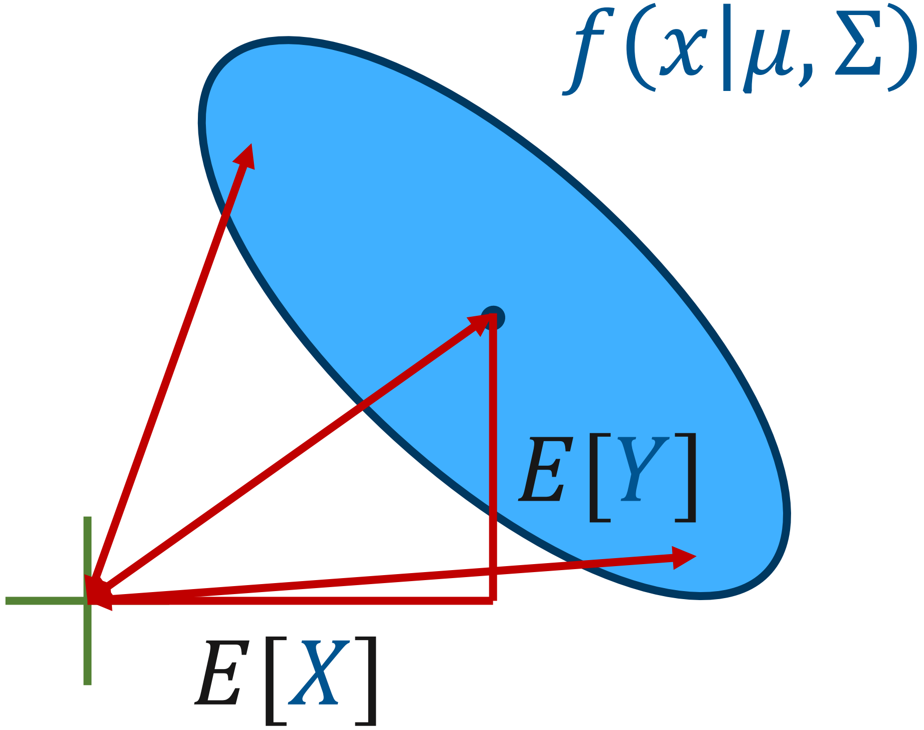
Error paints an incomplete picture of adaptation

Understanding the relationship between
behavior and error
opens avenues for deeper modeling of
motor adaptation

Behavior → Error



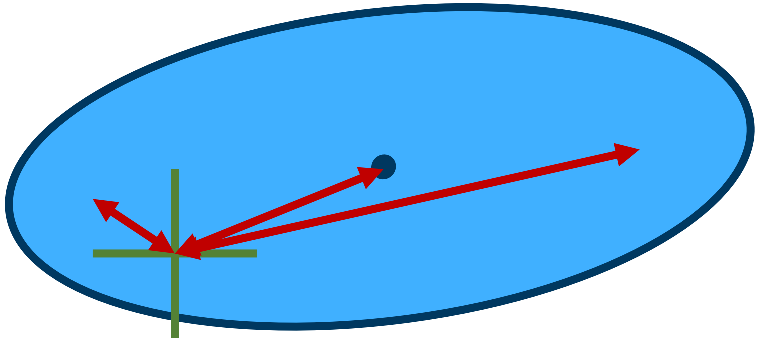
Behavior → Error



$$\sqrt{E[X]^2 + E[Y]^2} \leq E\left[\sqrt{X^2 + Y^2}\right]$$

Behavior → Error

$f(x|\mu, \Sigma)$



$$\sqrt{E[X]^2 + E[Y]^2} \leq E\left[\sqrt{X^2 + Y^2}\right]$$

Behavior → Error

$$E\left[\sqrt{X^2+Y^2}\right] = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \sqrt{x^2+y^2} f(x|\mu,\Sigma)\, dydx$$

$$E[X^2+Y^2] = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} (x^2+y^2) f(x|\mu,\Sigma)\, dydx$$

Reaching error can be calculated directly from reaching behavior

Error → Behavior

$$E\left[\sqrt{X^2+Y^2}\right] = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\sqrt{x^2+y^2}\,f(x|\mu,\Sigma)\,dydx$$

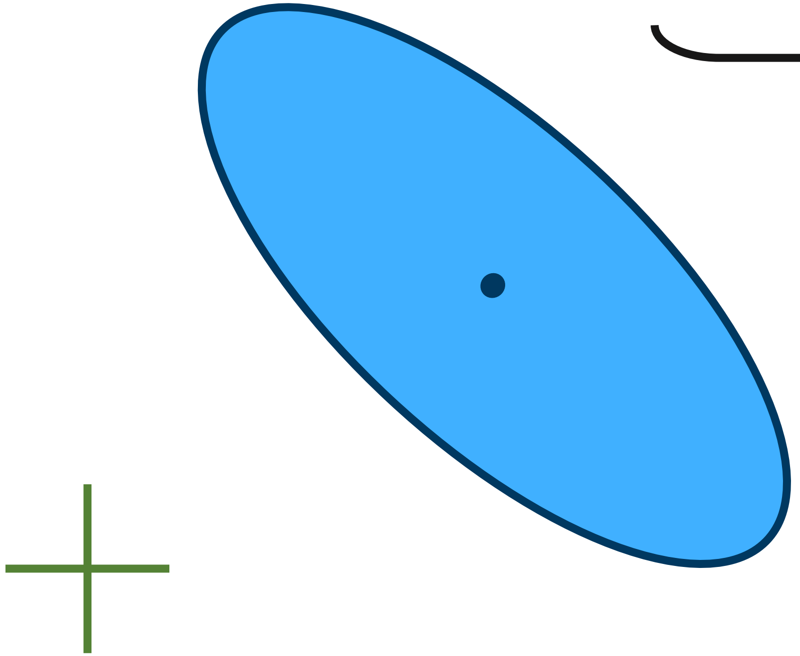
$$E[X^2+Y^2] = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}(x^2+y^2)f(x|\mu,\Sigma)\,dydx$$

Reaching behavior can not be calculated directly from reaching error

Error → Behavior

$$\mu = \begin{bmatrix} \mu_x \\ \mu_y \end{bmatrix} \quad \Sigma = \begin{bmatrix} {\sigma_{xx}}^2 & {\sigma_{xy}}^2 \\ {\sigma_{yx}}^2 & {\sigma_{yy}}^2 \end{bmatrix}$$

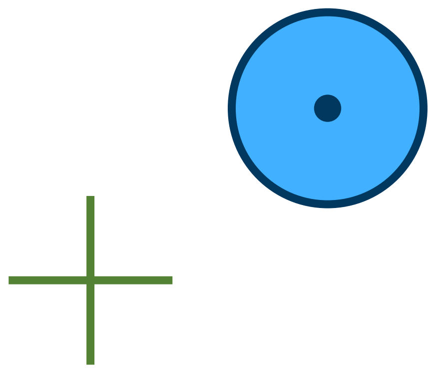
$$E\left[\sqrt{X^2 + Y^2}\right]$$



Describing behavior from error requires: 1) Numerical methods

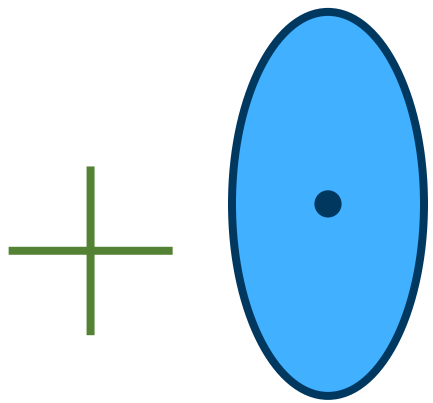
2) Assumptions about μ and Σ

Error → Behavior



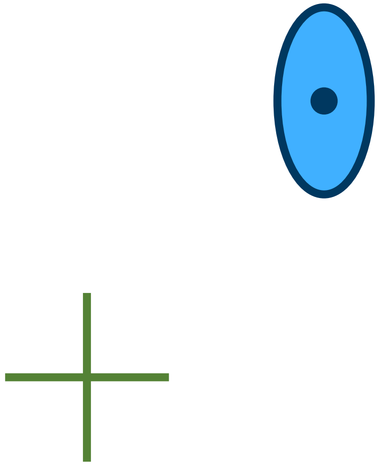
For given error, varying assumptions yields different valid behaviors

Error → Behavior



For given error, varying assumptions yields different valid behaviors

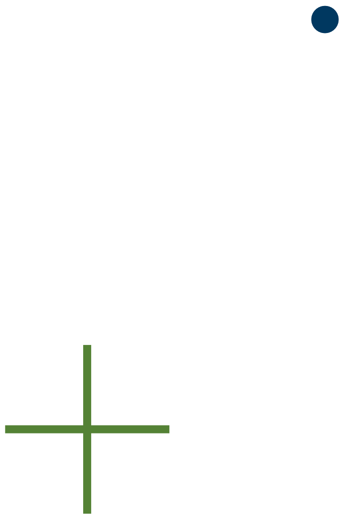
Error → Behavior



For given error, varying assumptions yields different valid behaviors

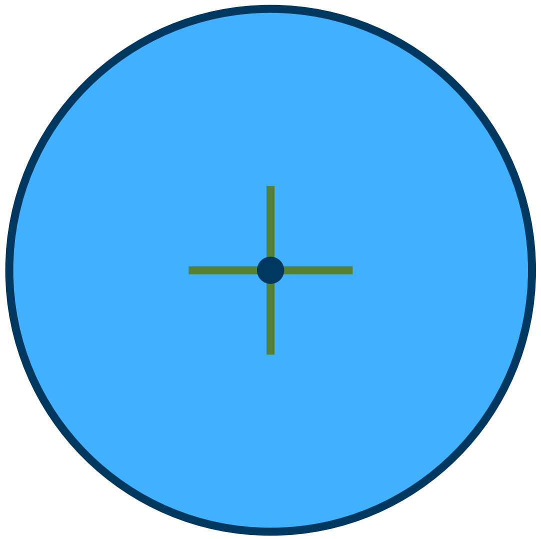
Error → Behavior

Maximum distance: $\sigma = 0$



For given error, varying assumptions yields different valid behaviors

Error → Behavior



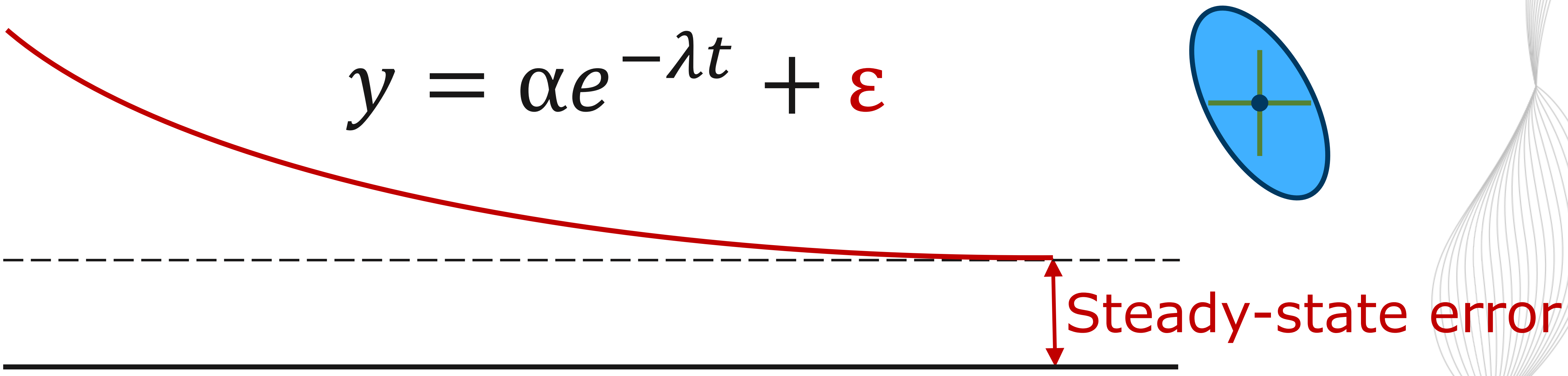
Maximum variance: $\mu = 0$

For given error, varying assumptions yields different valid behaviors

Potential Applications

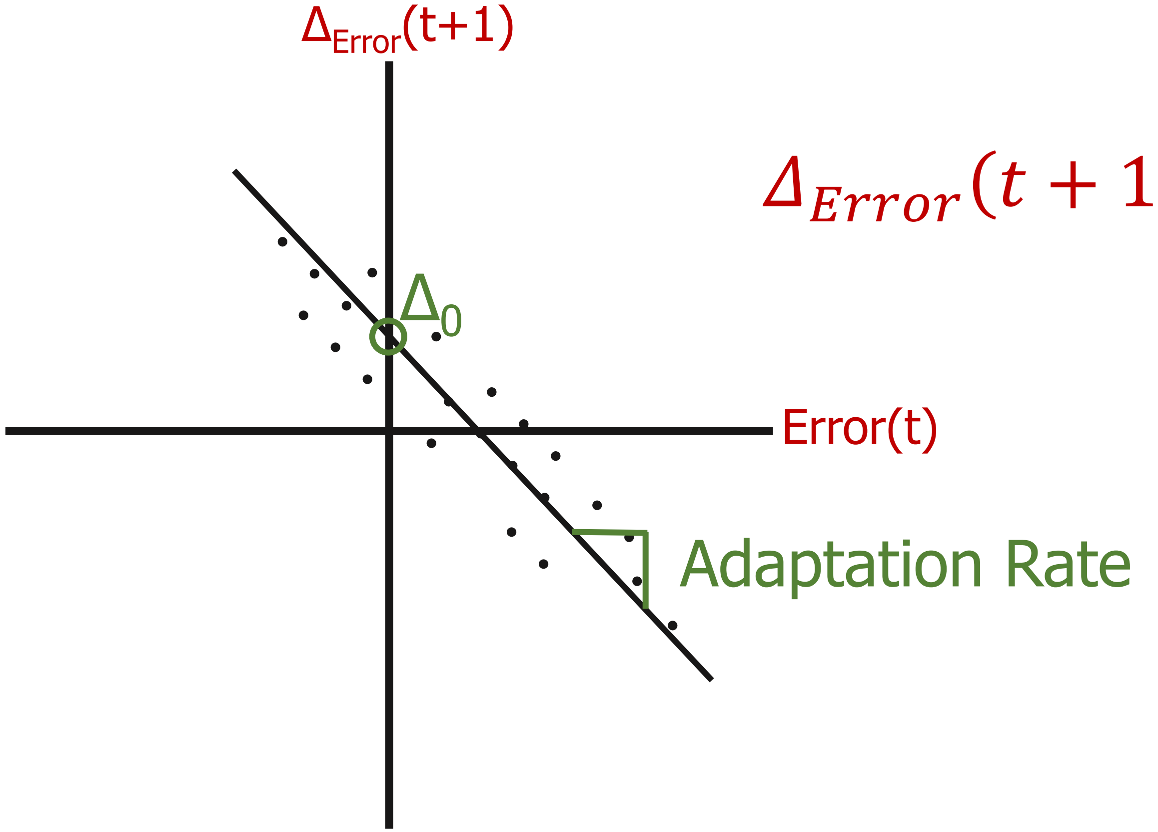
Determine minimum possible steady-state error

$$y = \alpha e^{-\lambda t} + \varepsilon$$

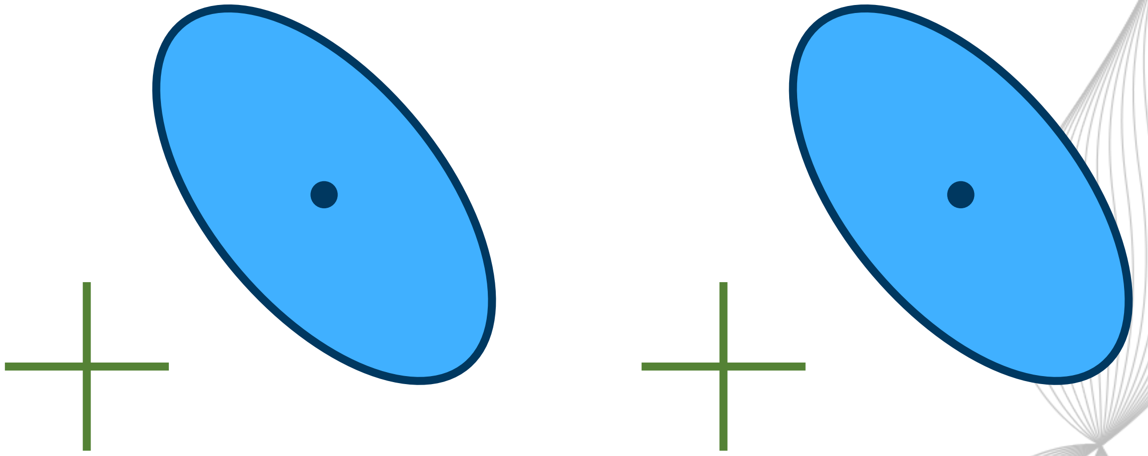


Potential Applications

Model behavior during adaptation simulations



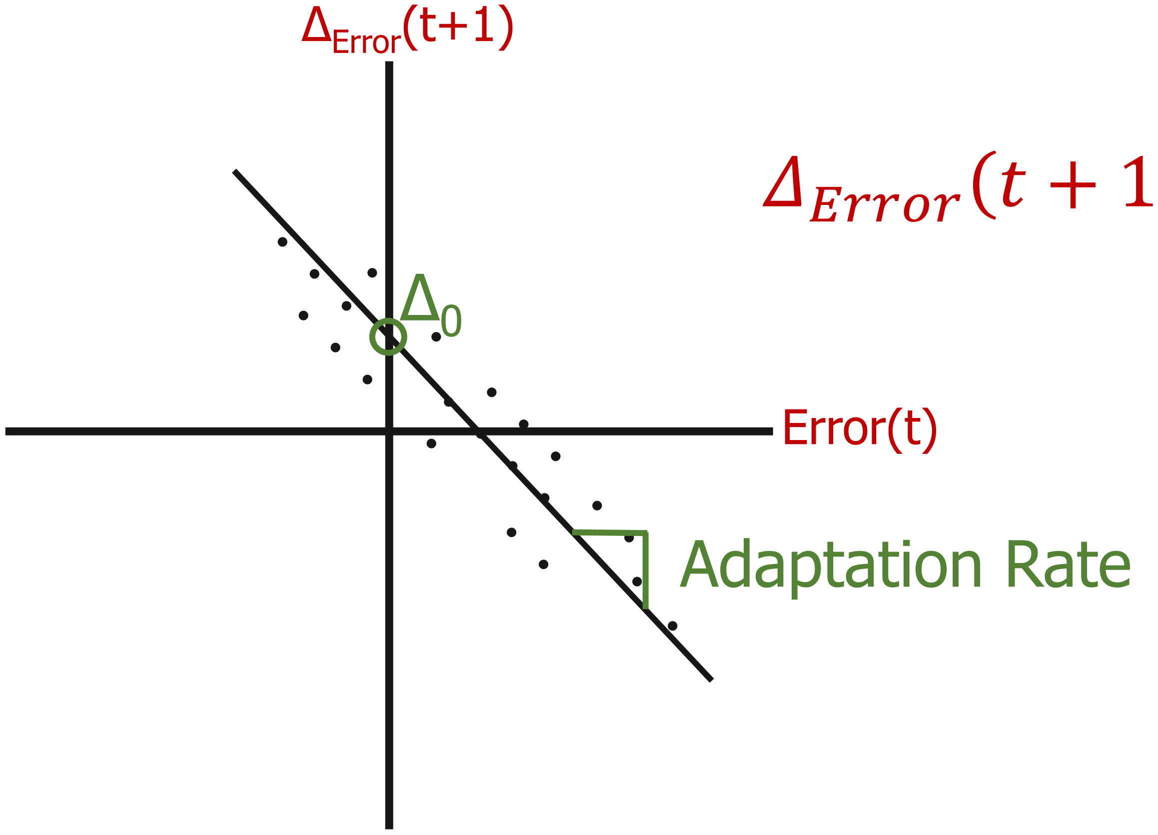
$$\Delta_{Error}(t+1) = a * Error(t) + \Delta_0$$

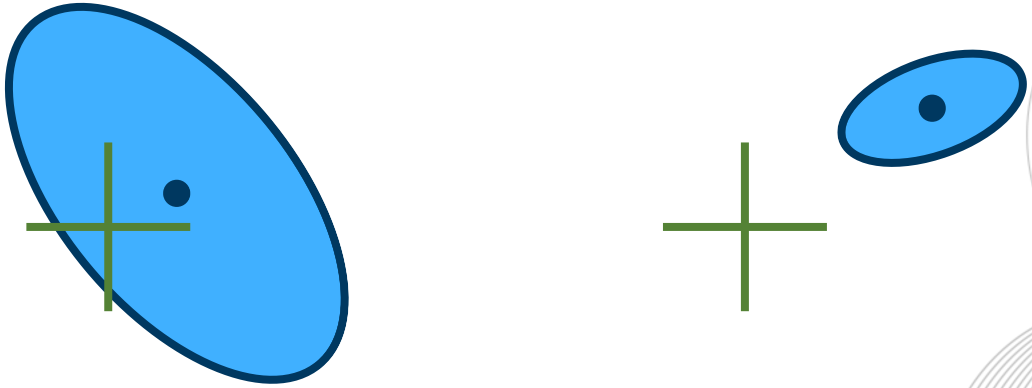


Potential Applications

Model behavior during adaptation simulations

$$\Delta_{Error}(t+1) = a * Error(t) + \Delta_0$$





Summary

Error adaptation has indeterminate behavior solutions

Reach behavior can be used to calculate reach error

Reach error can provide insights into reach behavior

May allow for deeper modeling of adaptation behavior

MATLAB Code Repository
Open Science Framework

https://osf.io/nskhq/

Levi Hargrove
Northwestern University

NIH T32
HD07418

NSF-NRI
1317379

Thank You

@EricJEarley
www.ericjearley.com