Fusing sensory and motor information
in a model of the *hippocampal formation*

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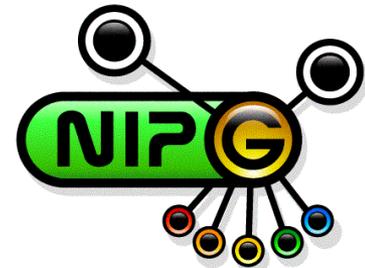
Cognition

More than reflex

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Mental processes (thoughts) and states of intelligent entities

Cognition

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➢ Representation

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➤ Representation

  ➤ Homunculus fallacy

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Resolution of fallacy

  – Generative network – loop structure

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  – **Plus prediction**

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➢ Representation

    ➢ Homunculus fallacy

Resolution of fallacy

    – Generative network – loop structure

    – **Plus prediction ➡ predictive loop**

Cognition

More than reflex

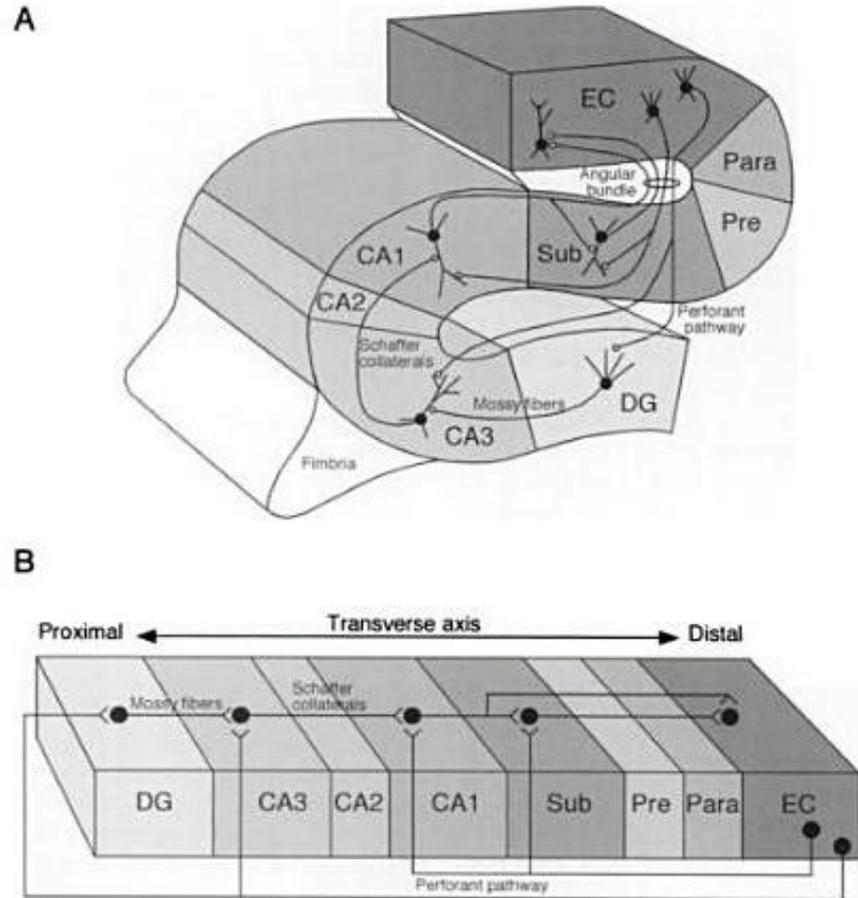Mental processes (thoughts) and states of intelligent entities

➢ Representation

　　➢ Homunculus fallacy

Resolution of fallacy

　– Generative network – loop structure

　– **Plus prediction ➜ predictive loop**

　　　➜ ARMA modell
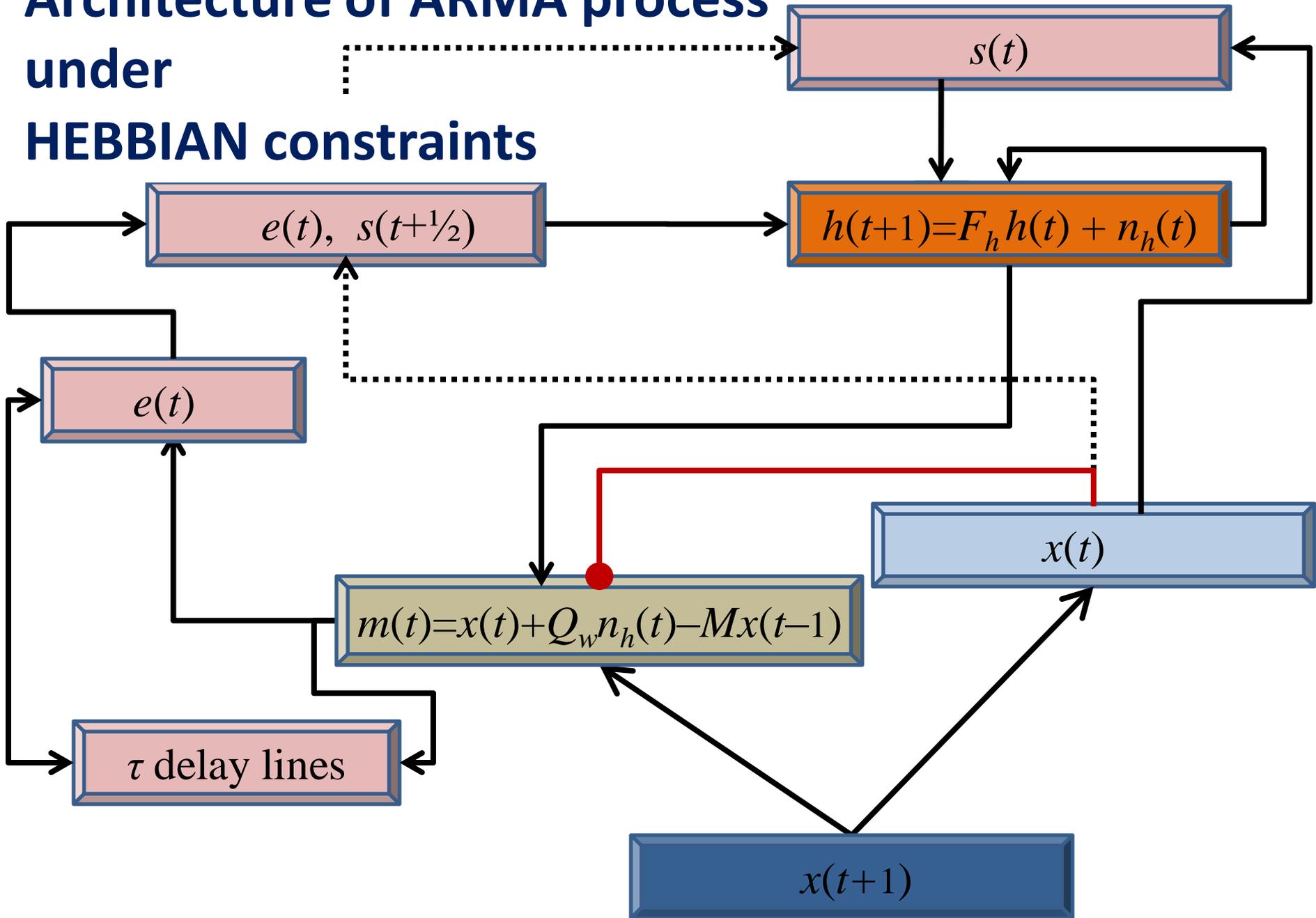
Hippocampal formation Simplified diagram

More details

Architecture of ARMA process

$$s(t)$$

$$e(t), \ s(t+\tfrac{1}{2})$$

$$h(t+1) = F_h h(t) + n_h(t)$$

$$e(t)$$

$$x(t)$$

$$m(t) = x(t) + Q_w n_h(t) - M x(t-1)$$

$$\tau \text{ delay lines}$$

$$x(t+1)$$

Architecture of ARMA process under HEBBIAN constraints

$s(t)$

$e(t),\ s(t+\tfrac{1}{2})$

$h(t+1) = F_h\,h(t) + n_h(t)$

$e(t)$

$m(t) = x(t) + Q_w\,n_h(t) - M\,x(t-1)$

$x(t)$

τ delay lines

$x(t+1)$

Bonuses

- Integration of information from different sources

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- Completion of missing information

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  - in space and time

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Demostrations in progress

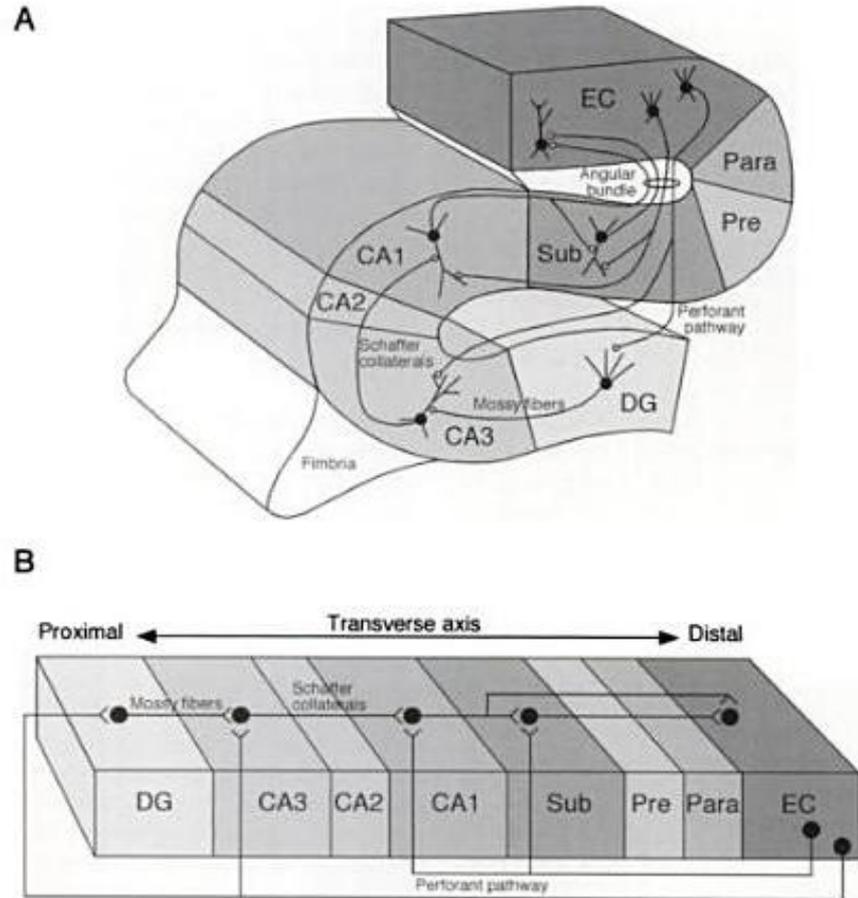# References

A. Lőrincz and Gy. Buzsáki

New York Academy of Sciences, 2000

A. Lőrincz and G. Szirtes

Neural Networks, 2009

Thank you for your attention

Hippocampal formation

Contributions

Model

- core function of the hippocampal region in forming episodic memory and supporting spatial navigation

Theory

- combinatorial gains without combinatorial efforts – we can learn hidden ARMAX models (talk on Wednesday)

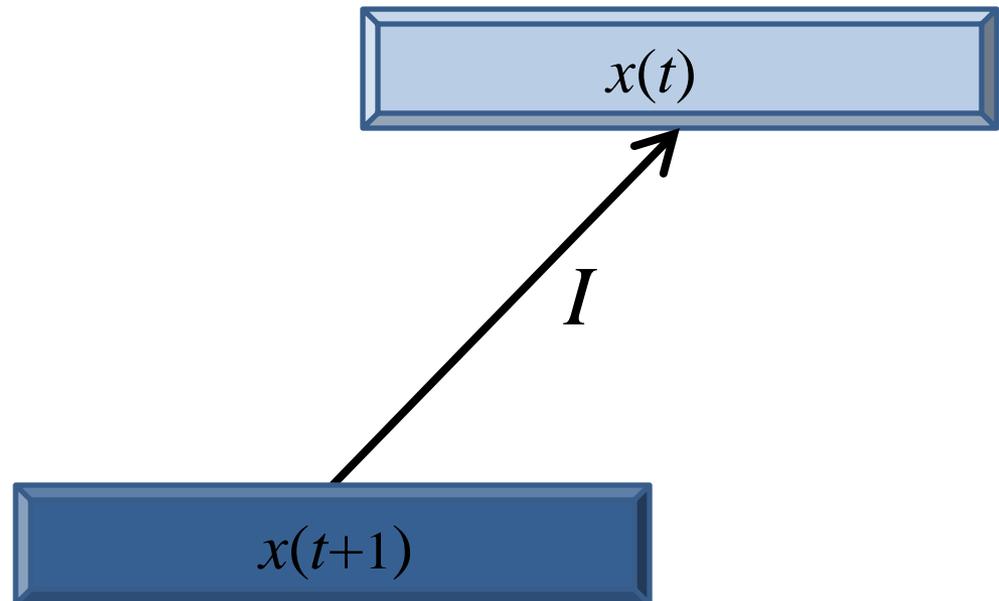# Autoregressive process and Hebbian constraints

Notations
Rectangles are neural layers
Black arrows are excitatory,
red lines with dots are inhibitory
   connections

Assumption (w.l.o.g.):
$x(t)$ **is a first order autoregressive process**

Step 1: Novelty detection
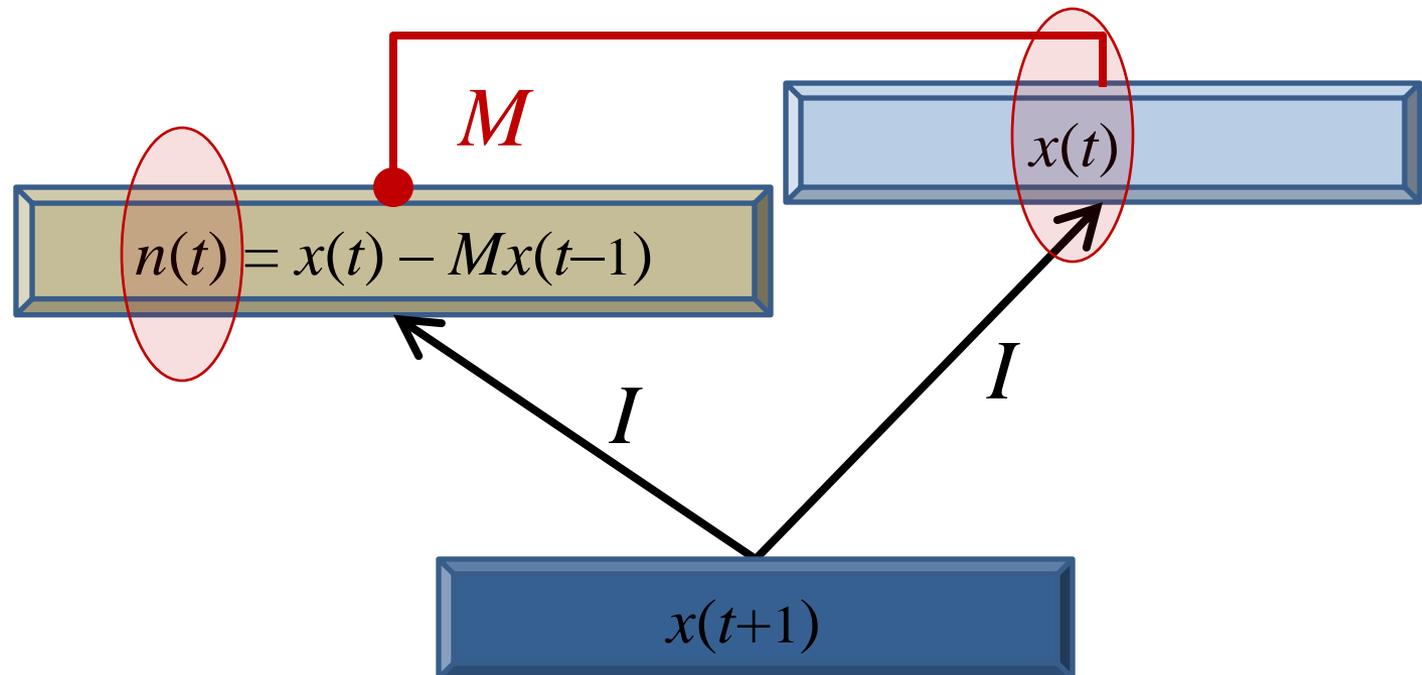
Notations
Rectangles are neural layers
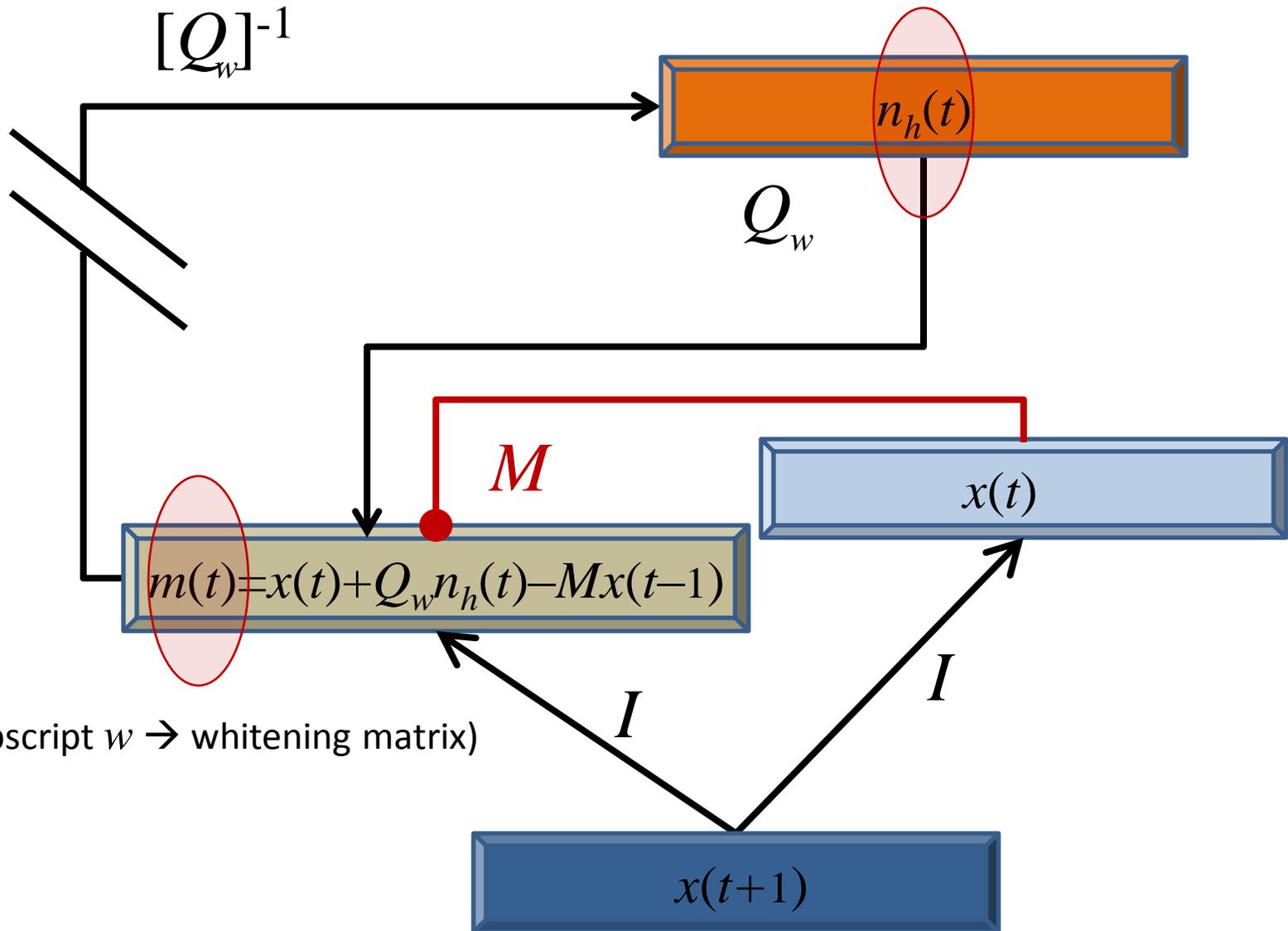Black arrows are excitatory,
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Assumption (w.l.o.g.):
$x(t)$ **is a first order autoregressive process**

$$M$$

$$n(t) = x(t) - Mx(t-1)$$

$$x(t)$$

$$I$$

$$I$$

$$x(t+1)$$

Step 2: Whitening – preprocessing

$[Q_w]^{-1}$

$n_h(t)$

Q_w

M

$x(t)$

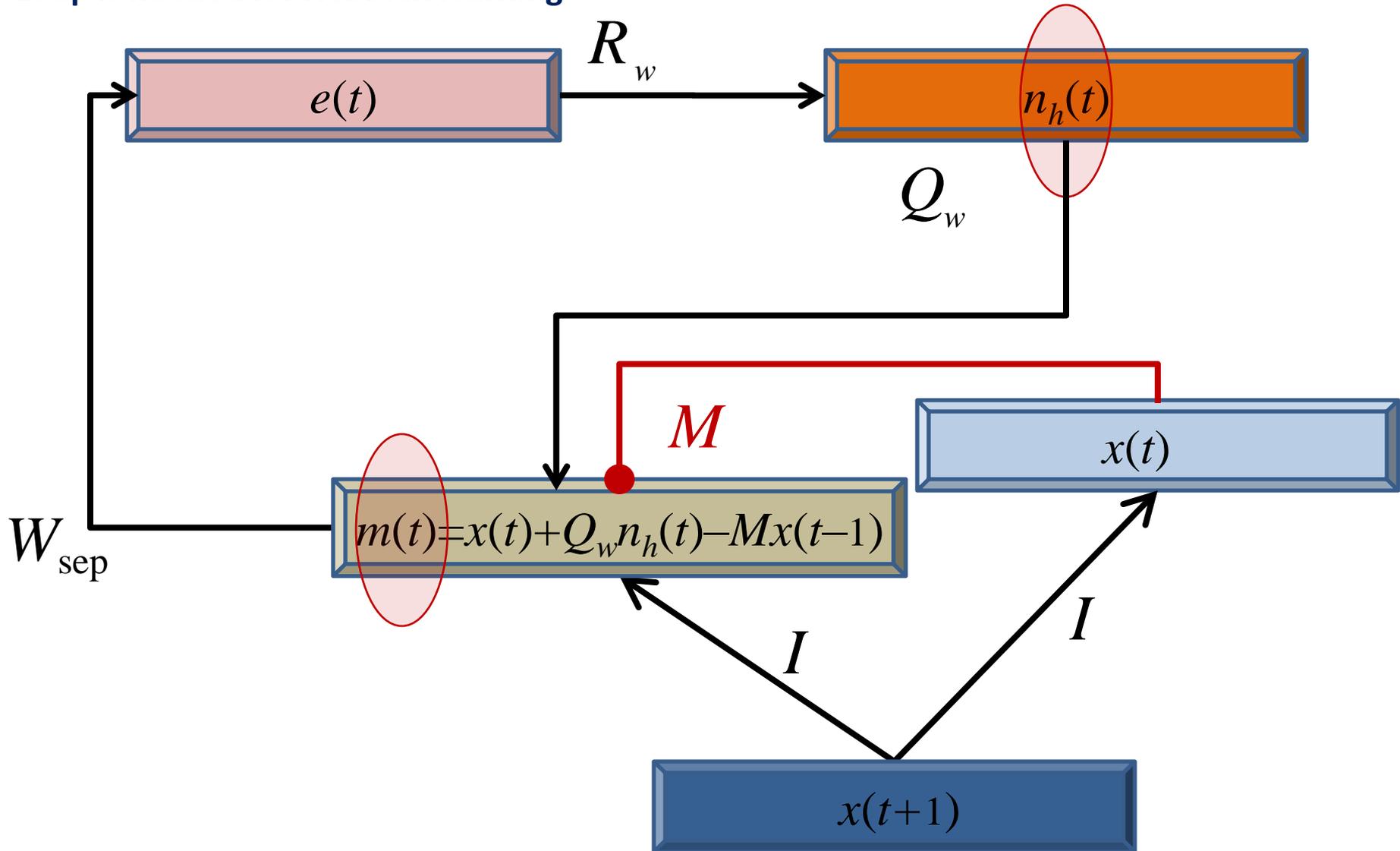$m(t)=x(t)+Q_w n_h(t)-Mx(t-1)$
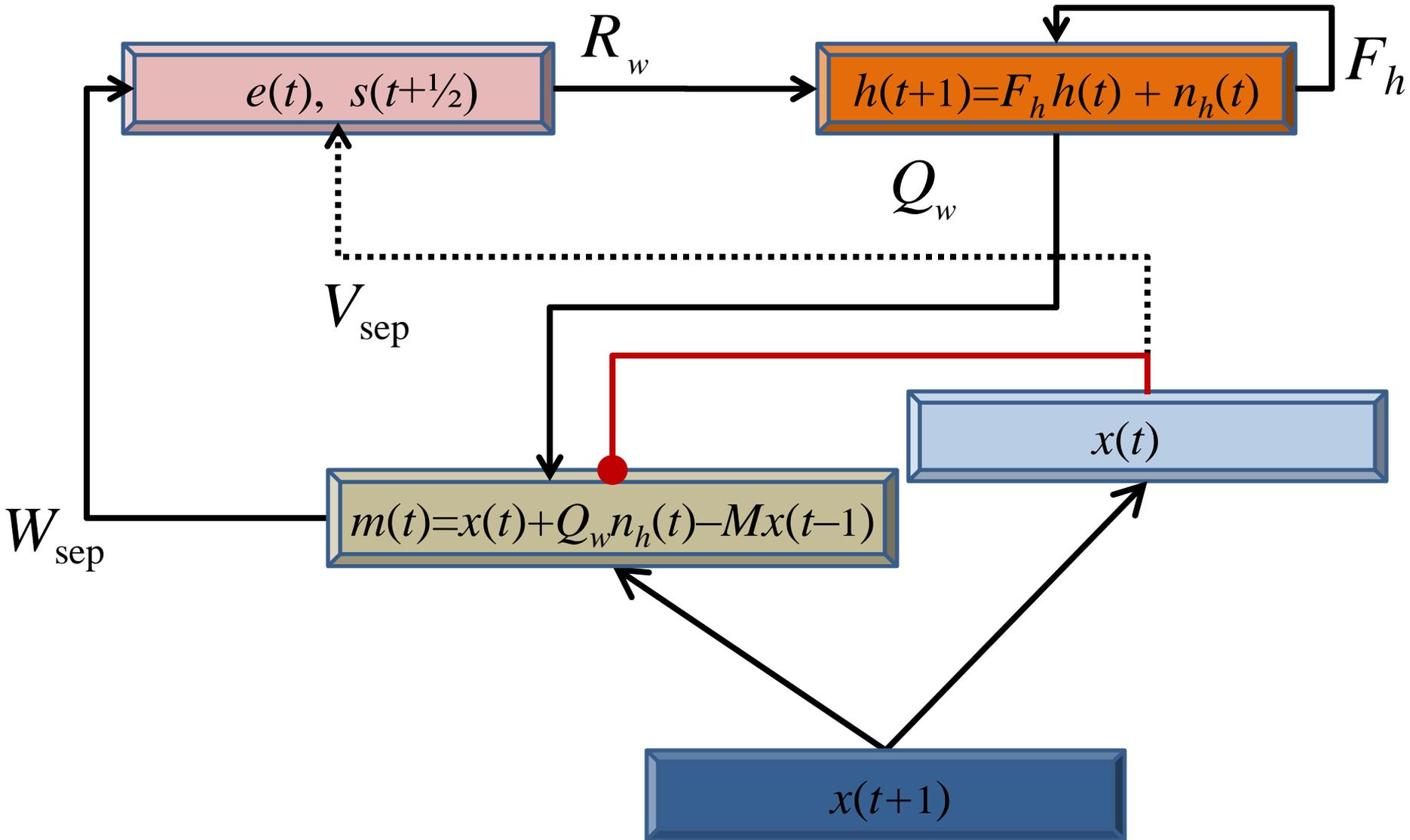
I

I

$x(t+1)$

(notation: subscript w → whitening matrix)

Step 3: Learn independent novelty sources

Loop is needed for Hebbian learning

Step 4: Learn the hidden autoregressive model

R_w

$e(t), \ s(t+\frac{1}{2})$

$h(t+1)=F_h\,h(t) + n_h(t)$

F_h

Q_w

V_{sep}

$x(t)$

W_{sep}

$m(t)=x(t)+Q_w n_h(t)-Mx(t-1)$

$x(t+1)$

Separation of processes
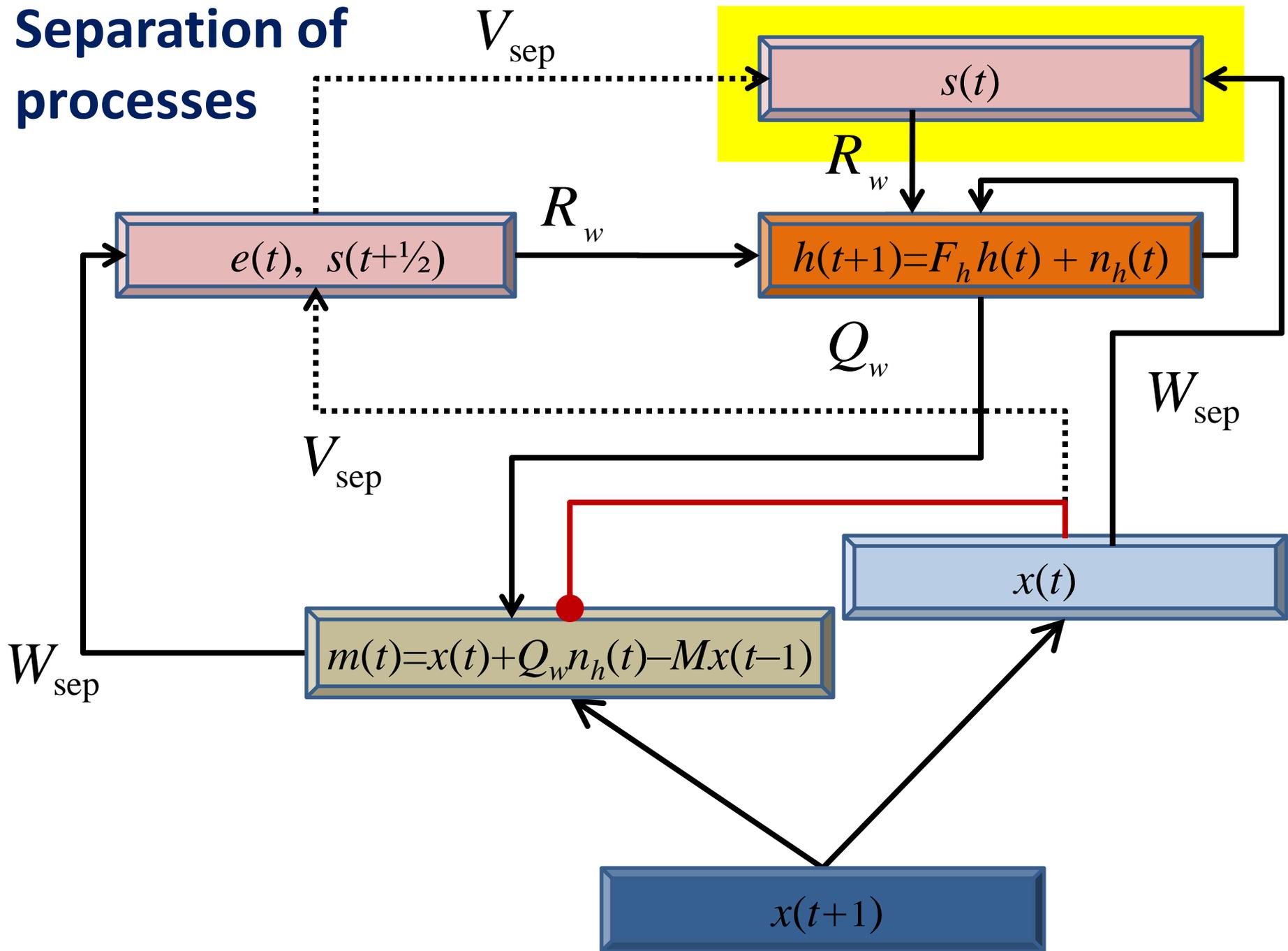
Generalization to ARMA processes

$s(t)$

$e(t),\ s(t+\frac{1}{2})$

$h(t+1)=F_h\,h(t)+n_h(t)$

$e(t)$

add delay loops to eliminate echoes

$m(t)=x(t)+Q_w n_h(t)-Mx(t-1)$

$x(t)$

τ delay lines

$x(t+1)$

With more details

$V_{\mathrm{sep}}^{\text{CA1-to-SUB}}$

subiculum

$R_w^{\text{SUB-to-EC deep}}$

$R_w^{\text{CA1-to-EC deep}}$

CA1

entorhinal deep layers

$Q_w^{\text{EC deep-to-EC sup}}$

$W_{\mathrm{sep}}^{\text{ECIII-to-SUB}}$

CA3

$V_{\mathrm{sep}}^{\text{ECIII-to-CA1}}$

$W_{\mathrm{sep}}^{\text{ECII-to-CA3}}$

entorhinal layer III

entorhinal layer II

dentate gyrus

postrhinal ctx