Modeling ERPs and Word Reaction Times with Artificial Neural Networks

Shinichi Asakawa

Waseda University, 20251008

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Event-related potentials (ERPs) and word reaction times (RTs) are central measures in cognitive neuroscience, yet they have rarely been modeled within a unified computational framework. Laszlo & Armstrong and their colleagues demonstrated that neural networks can relate ERPs and RTs using α-function approximations. Extending this work, we directly compare two state-of-the-art architectures—long short-term memory (LSTM) networks and Transformer models—for their ability to jointly predict RTs and generate internal representations aligned with ERP components, including the N400 and P600. Unlike approaches that assume predefined response functions, both architectures learn temporal

and contextual dynamics directly from data. Our results reveal complementary strengths: LSTMs capture fine-grained sequential dependencies, while Transformers better model long-range contextual effects. To our knowledge, no prior study has systematically compared these architectures in the joint modeling of ERPs and RTs. This comparative approach highlights the potential of modern ANN models to advance data-driven theories of semantic and syntactic processing in the brain.

I would like to show a great thank to Hino sensei for give a chance for me to talk today.

Introduction

Who am I?

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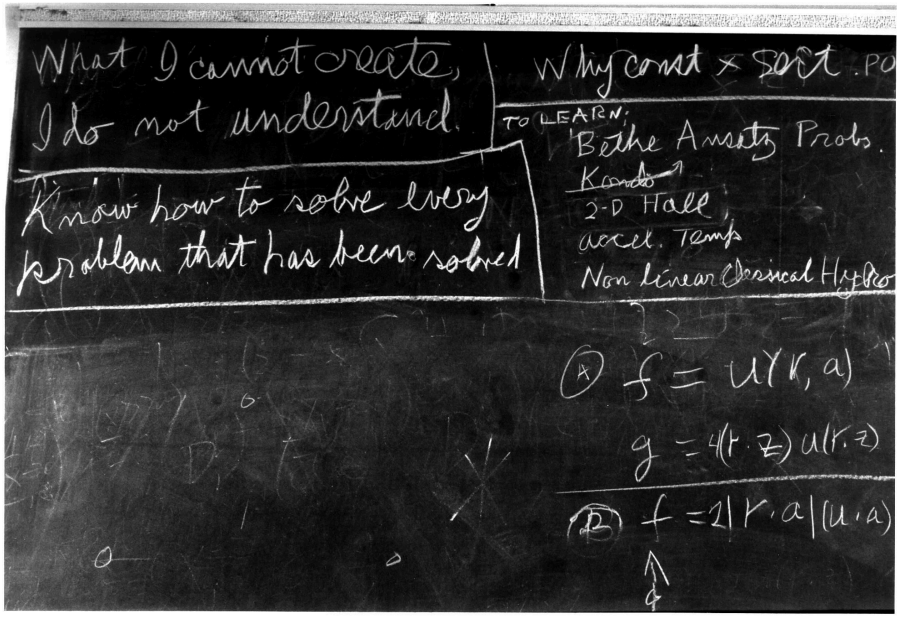
In colaboration with CCAP (Computational Clinical Aphasia Project) research group: Ayane Tateba (JCHO Kumamoto General Hospital), Shinji Uema (Musashino University), Kosei Hashimoto (Mejiro University), Masahiro Yoshihara (Hokkaido University), Shotaro Daimon (Hokkaido Neurosurgical Memorial Hospital), Yasushi Terao (University of Shizuoka), Yuna Uesugi (University of Tsukuba)

I would also show grateful thanks to Dr. Hiroshige Takeichi (RIKEN, Kyushu University) and Dr. Wataru Suzuki (RIKEN) for useful suggestions in order to improve an important idea, especially Gaussian Processes, showen later in this talk.

With Jeff Elman at UCSD campus

Takeaways, and key points

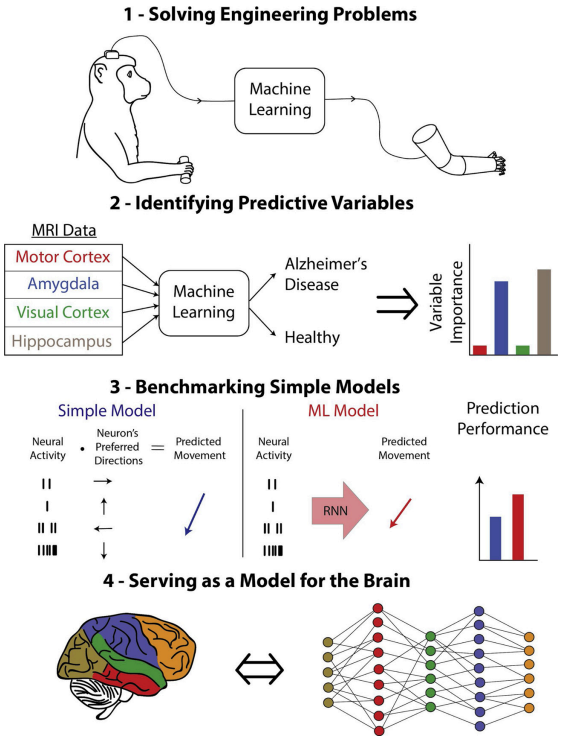


Richard Feynmann's blackboard

One of the important messages in this talk, is that, I suppose, models should be implemented at an adequate level of abstraction.

After Feynmann, if we understand a phenomenon, we should be able to provide a model of it that can itself be further evaluated by assessing the importance of model parameters linked to neural parameters (Cichy&Kaiser2019)

Background (1) How to use machine learning models



Examples of the four roles of supervised machine learning in neuroscience.

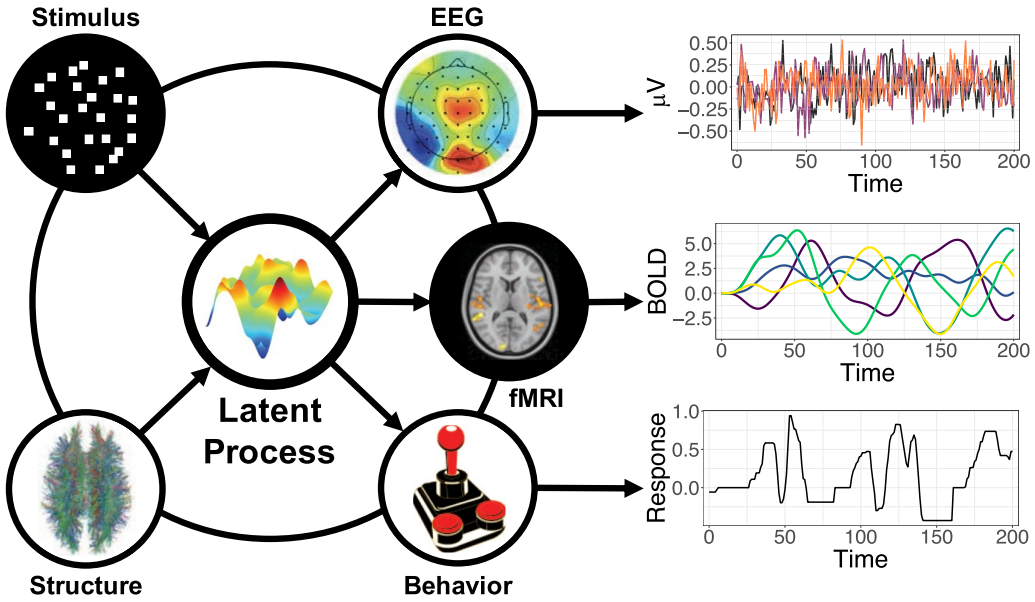
1. **ML can solve engineering problems.**

2. ML can identify predictive variables.

3. ML can benchmark simple models.

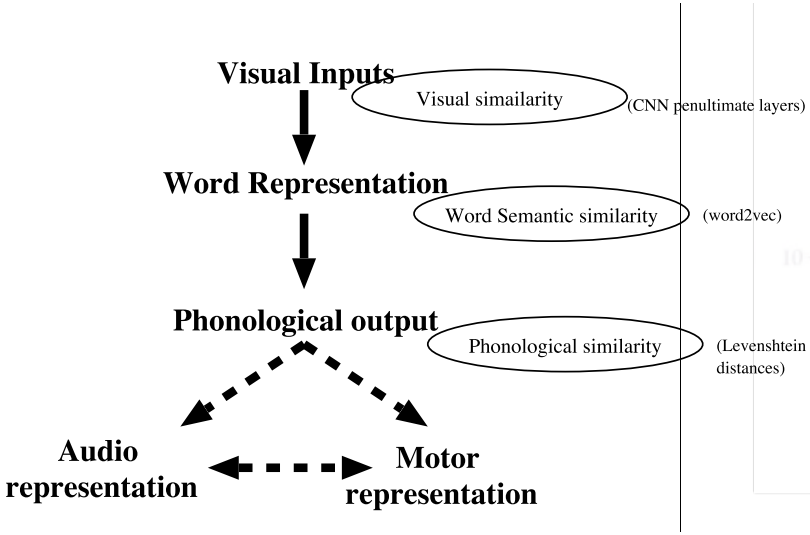
4. ML can serve as a model of the brain. From Glaser+(2019)

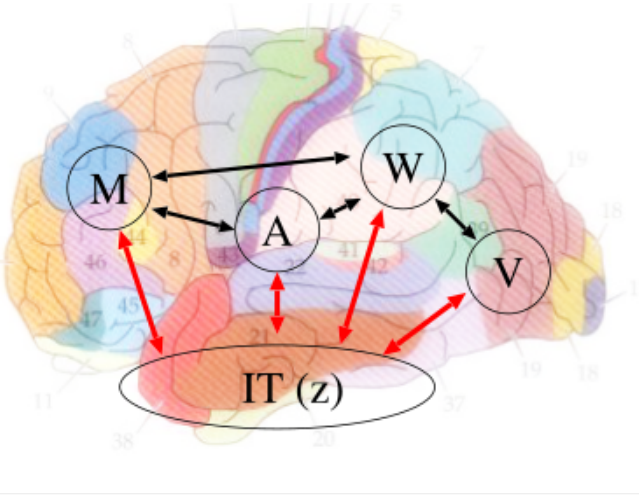
Background (2) Latent variables connecting mind, brain, and behavior.



A schematic of the joint modeling framework, where experimental information and structural information specify the structure of a generative model of brain function. The generative model is used to jointly explain all available manifest variables such as response times, blood oxygenated level-dependent response, or electroencephalogram activity. In the present article, a latent Gaussian process is used to link the manifest variables, enabling the most plausible linking function to emerge from fitting the model to data. From Bahg+ (2020) Fig. 1

Comparison between the Conventional and Proposed Models (without semantics)





Transfer Learning of Picture Naming Task

189 Miss[37 108 187 307 314] foot n

正解:toe, 出力:foot,nose,toe

correct：toe　output：Foot,nose,toe

190 Miss[13 188 274 286 244] pen as

正解:asparagus, 出力:pen,asparagus,chisel

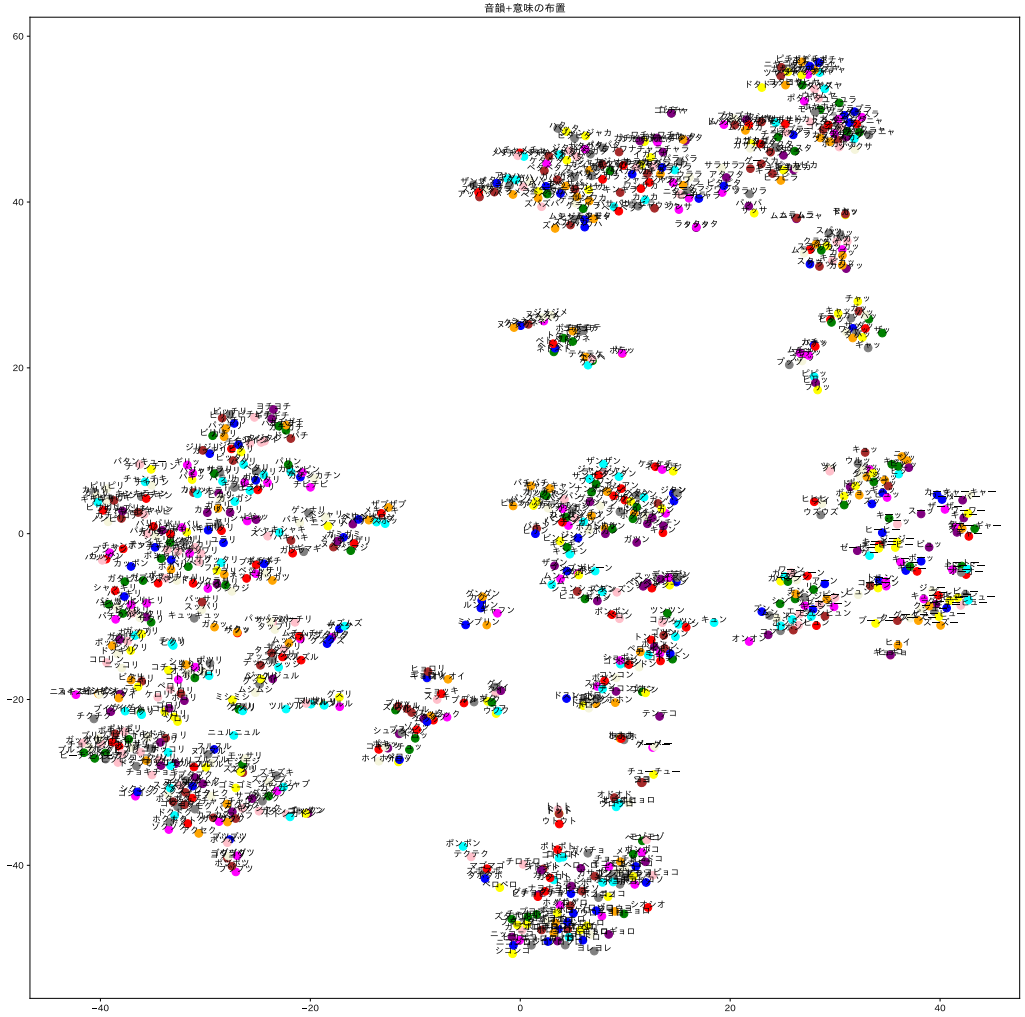
correct：asparagus　output：pen,asparagus,chisel

191 Miss[305 233 48 183 94] footba

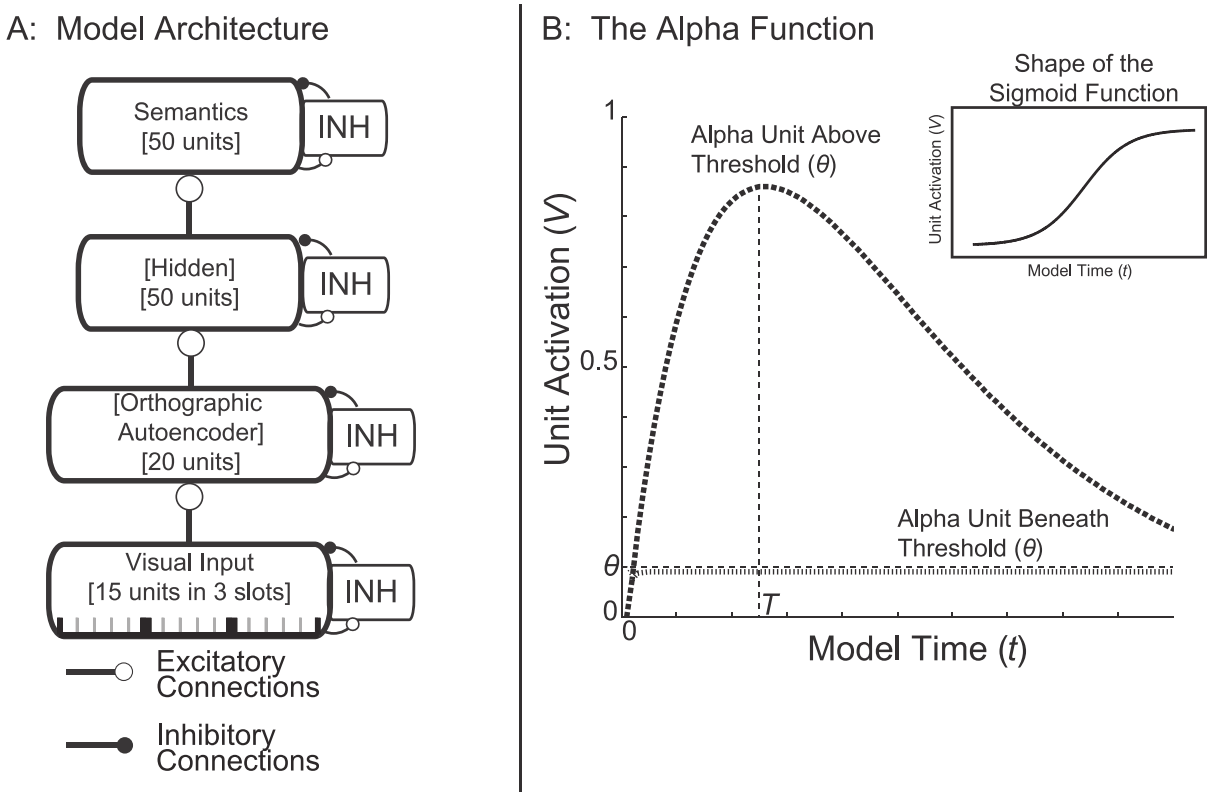
正解:duck, 出力:football helmet,pocketbook,duck

correct：duck　output：football,helmet,pocketbook,duck

tSNE plot of representation of Semantics and Phonetics combined

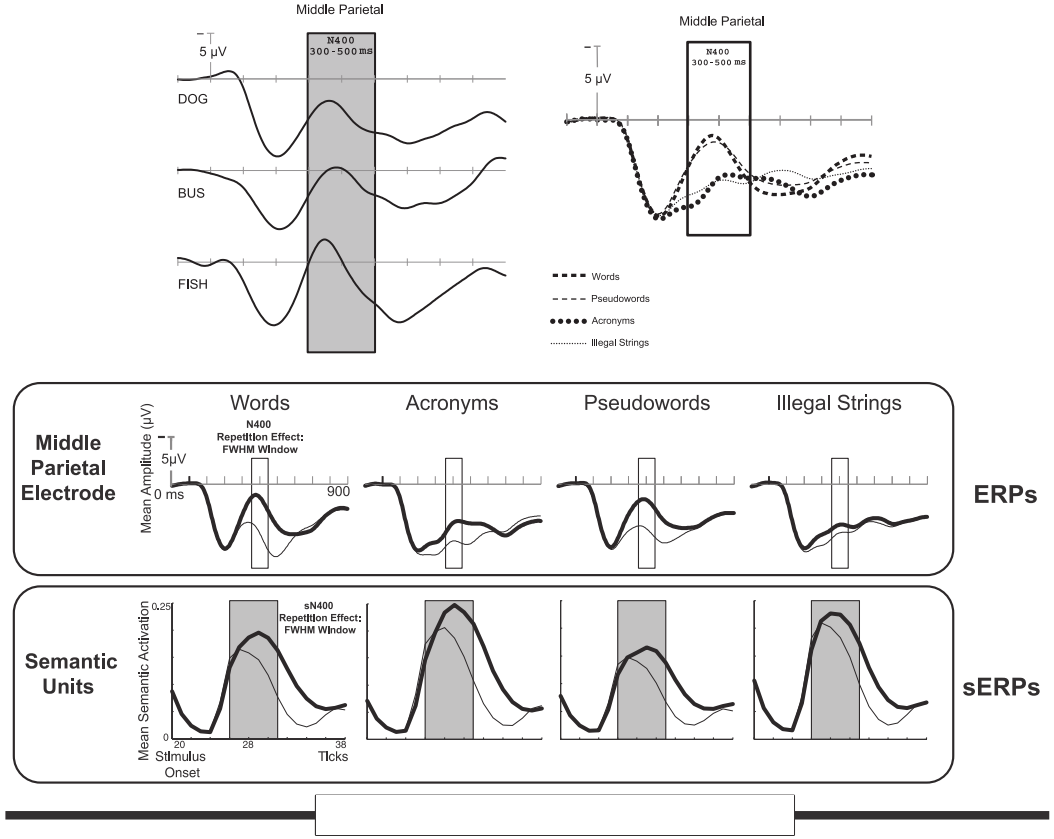


Related works (1)



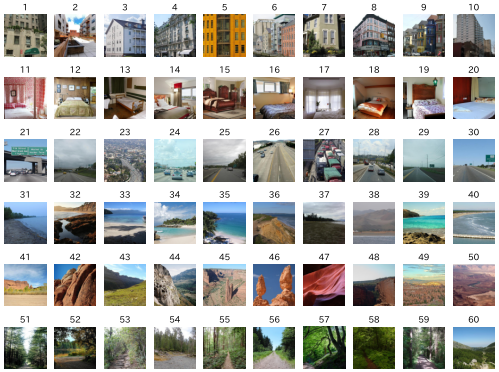
Laszlo&Armstrgn(2014) Fig. 1. (A) Architecture of the ERP model. INH stands for ‘‘inhibitory’’.
(B) The shape of the sigmoid function (inset), and of the alpha function above and below threshold. Note that for alpha units, as $t \to \infty$, $V \to \Theta$.

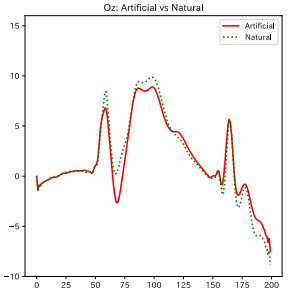
Related works (2)

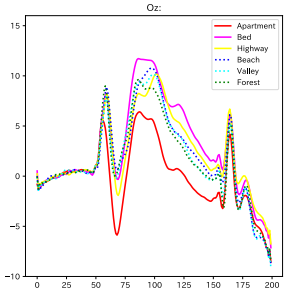


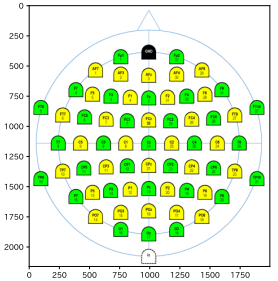
From Laszlo&Plaut(2012) Fig. 1 and Laszlo&Armstrong(2014) Fig. 2

Karapetian+(2022)

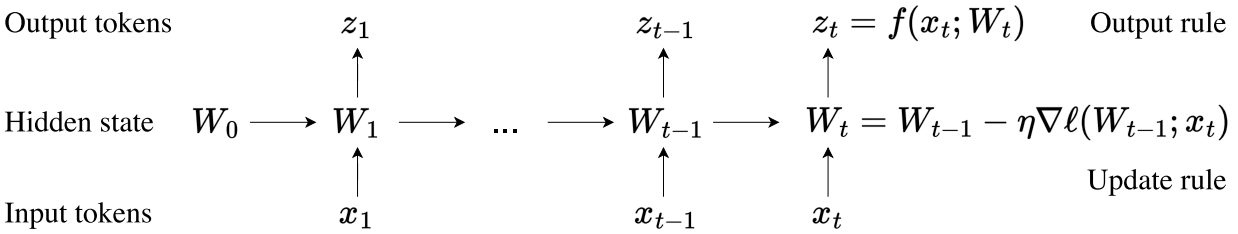


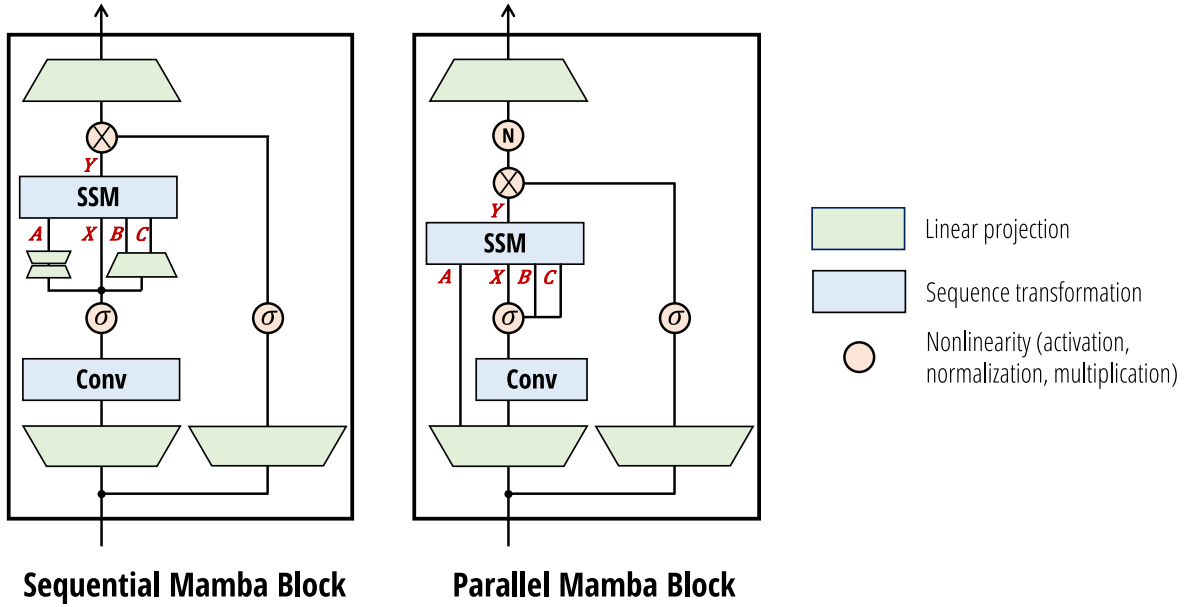




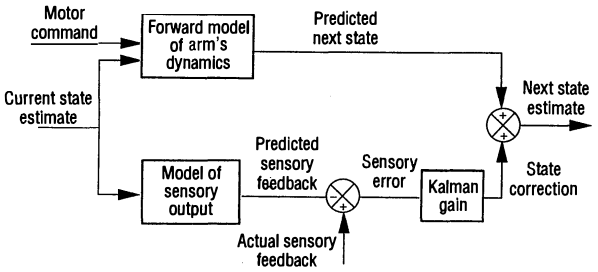


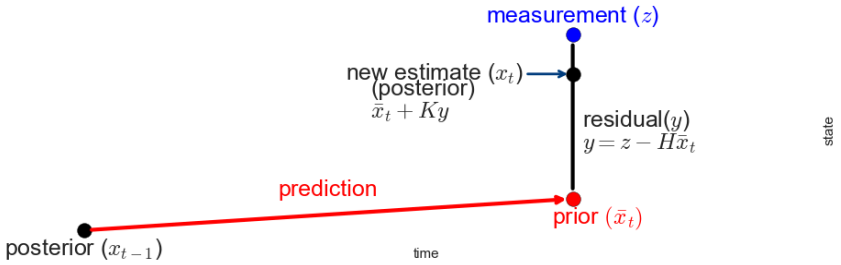
State Space Models



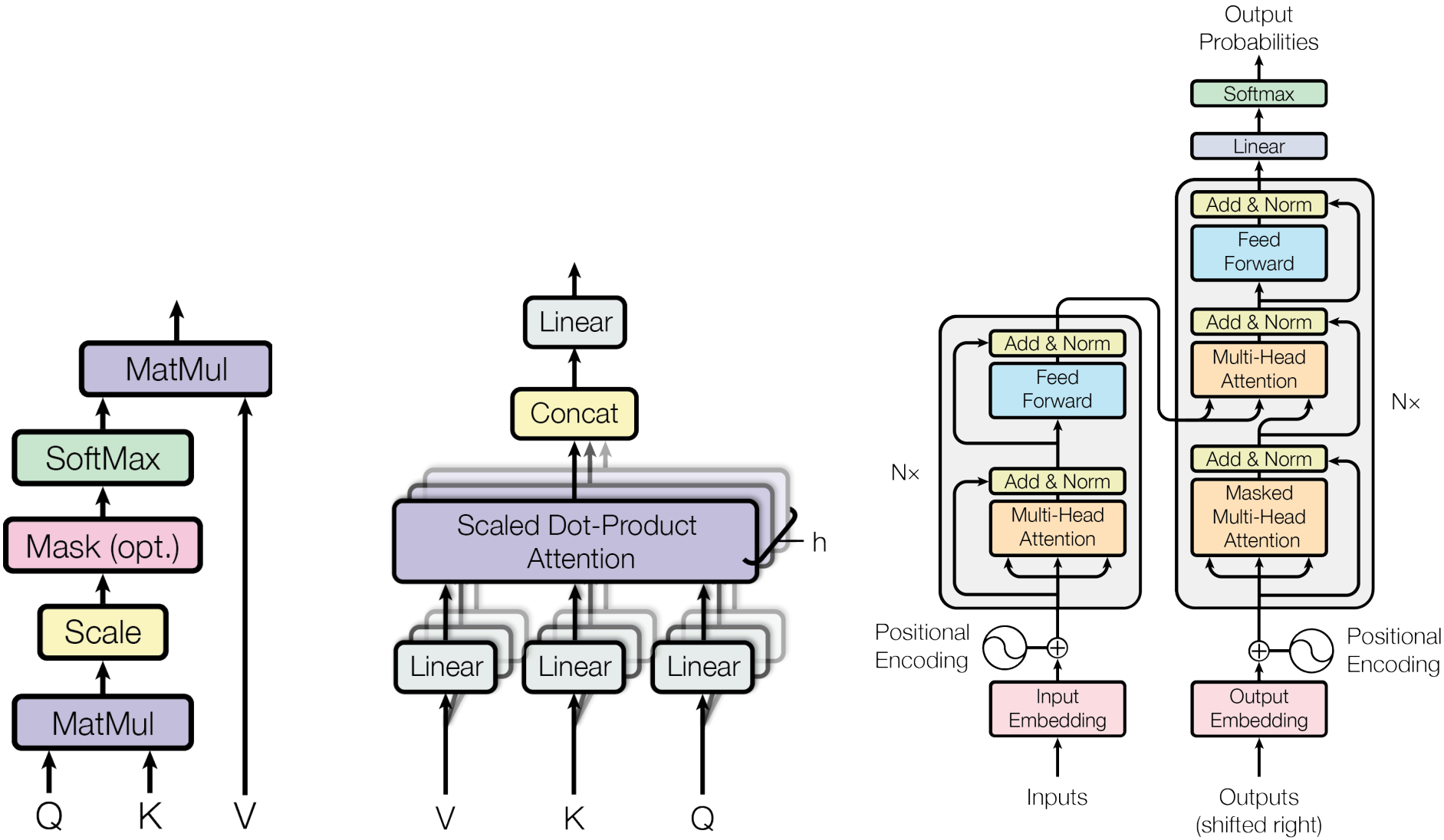


Kalman filter





GPT



Transformer 2017Vaswani++ Fig.2