



E-SAN THAILAND CODING & AI ACADEMY

โครงการวิจัยโมเดลระบบบูรณาการเรียนรู้ Coding & AI สำหรับเยาวชน

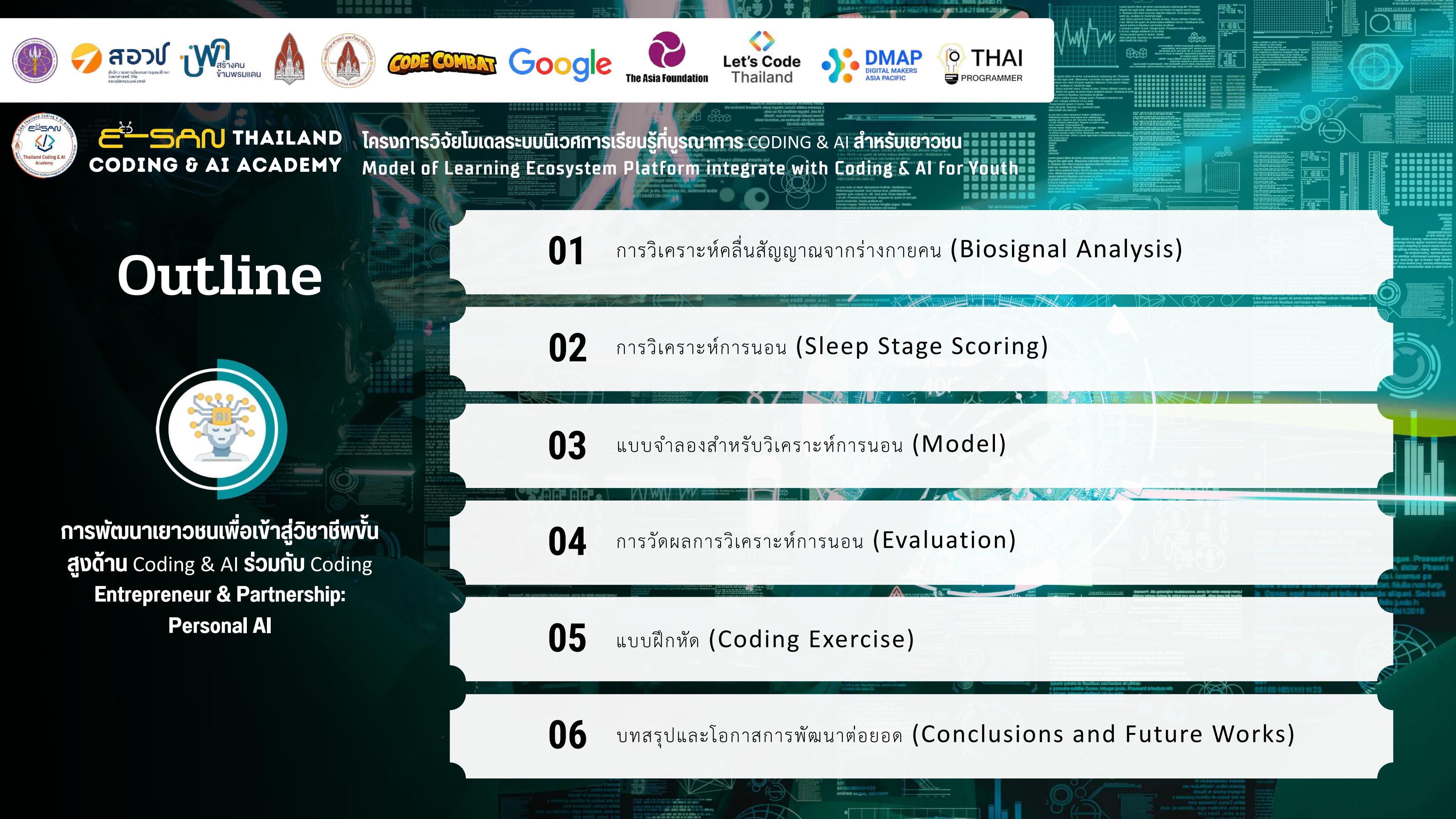
Model of Learning Ecosystem Platform integrate with Coding & AI for Youth

โครงการย่อที่ 6

การพัฒนาเยาวชนเพื่อเข้าสู่วิชาชีพขั้นสูงด้าน Coding & AI
ร่วมกับ Coding Entrepreneur & Partnership: Personal AI

ชื่อหัวข้อ Learning from Biosignals

ดร.อัคติ สุประทักษิ
ผู้เชี่ยวชาญด้าน biosignals



Outline



การพัฒนาเยาวชนเพื่อเข้าสู่วิชาชีพขั้นสูงด้าน Coding & AI ร่วมกับ Coding Entrepreneur & Partnership:

Personal AI

01 การวิเคราะห์คลื่นสัญญาณจากร่างกายคน (Biosignal Analysis)

02 การวิเคราะห์การนอน (Sleep Stage Scoring)

03 แบบจำลองสำหรับวิเคราะห์การนอน (Model)

04 การวัดผลการวิเคราะห์การนอน (Evaluation)

05 แบบฝึกหัด (Coding Exercise)

06 บทสรุปและโอกาสการพัฒนาต่อไป (Conclusions and Future Works)



01 การวิเคราะห์คลื่นสัญญาณจากร่างกายคน (Biosignal Analysis)



Biosignal Analysis

1. Preprocessing
2. Feature extraction
3. Model construction

Biosignal Analysis

1. Preprocessing *សំណងការការពារ*
 - Remove noise or artifacts from signals *សំណងការការពារការពារសម្រាប់សញ្ញាណ*
 2. Feature extraction
 3. Model construction *សំណងការការពារការបង្កើតមែនប្រព័ន្ធ*



Biosignal Analysis

1. Preprocessing
 - Remove noise or artifacts from signals
2. Feature extraction
 - Derive features that are **meaningful** to a **certain problem** are extracted or derived from the preprocessed signals
extract ตัวอย่างที่มีความหมายเฉพาะปัญหานั้นๆ
 - **Hand-engineered** by domain-specific experts who know which features are useful for particular problems
ตัวอย่างเช่น ผู้เชี่ยวชาญด้านการแพทย์จะรู้ว่า รูปแบบของหัวใจ ผู้ป่วยเป็นอย่างไร
3. Model construction



Biosignal Analysis

1. Preprocessing
 - Remove noise or artifacts from signals
2. Feature extraction
 - Derive features that are meaningful to a certain problem are extracted or derived from the preprocessed signals
 - Hand-engineered by domain-specific experts who know which features are useful for particular problems
3. Model construction *→ ต้องหานโยบายที่ extract 7 อย่างใน model*
 - Machine learning algorithms are employed to train models *↑ ML อะไรๆ*
 - Understand relationships between input (i.e., extracted features) and their desired output (i.e., labels or annotations) *↑ ต้องหานโยบายที่ extract 7 อย่างใน model*

ลองๆ กันดู



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Biosignal Analysis

1. Preprocessing

- Remove noise or artifacts from signals

2. Feature extraction

- Derive features that are meaningful to a certain problem are extracted or derived from the preprocessed signals
- Hand-engineered by domain-specific experts who know which features are useful for particular problems

3. Model construction

- Machine learning algorithms are employed to train models
- Understand relationships between input (i.e., extracted features) and their desired output (i.e., labels or annotations)

● ใช้ไฟล์บันทึกที่มี model ที่สร้างไว้ ทดสอบว่า ทำนายได้ดีหรือไม่
ลองใช้ไฟล์บันทึกที่ไม่ได้ใช้ใน model → ทำนายไม่ได้

ขั้นตอนที่ 1, 2 ของ biosignal
จะมีดังนี้ 9 ขั้นตอน

Application-Specific

ขั้นตอนที่ 1 นำ noise ออก
ขั้นตอนที่ 2 นำ noise ออก
ขั้นตอนที่ 3 นำ noise ออก
ขั้นตอนที่ 4 นำ noise ออก

Biosignal Analysis with Deep Learning

1. Preprocessing
 2. Feature extraction
 3. Model construction

different layers produce signal of any form with vector u from different domains (e.g. u from W_1).

Deep Learning

Utilize multiple layers of non-linear transformation to convert from inputs into representations that are useful for subsequent tasks such as classification

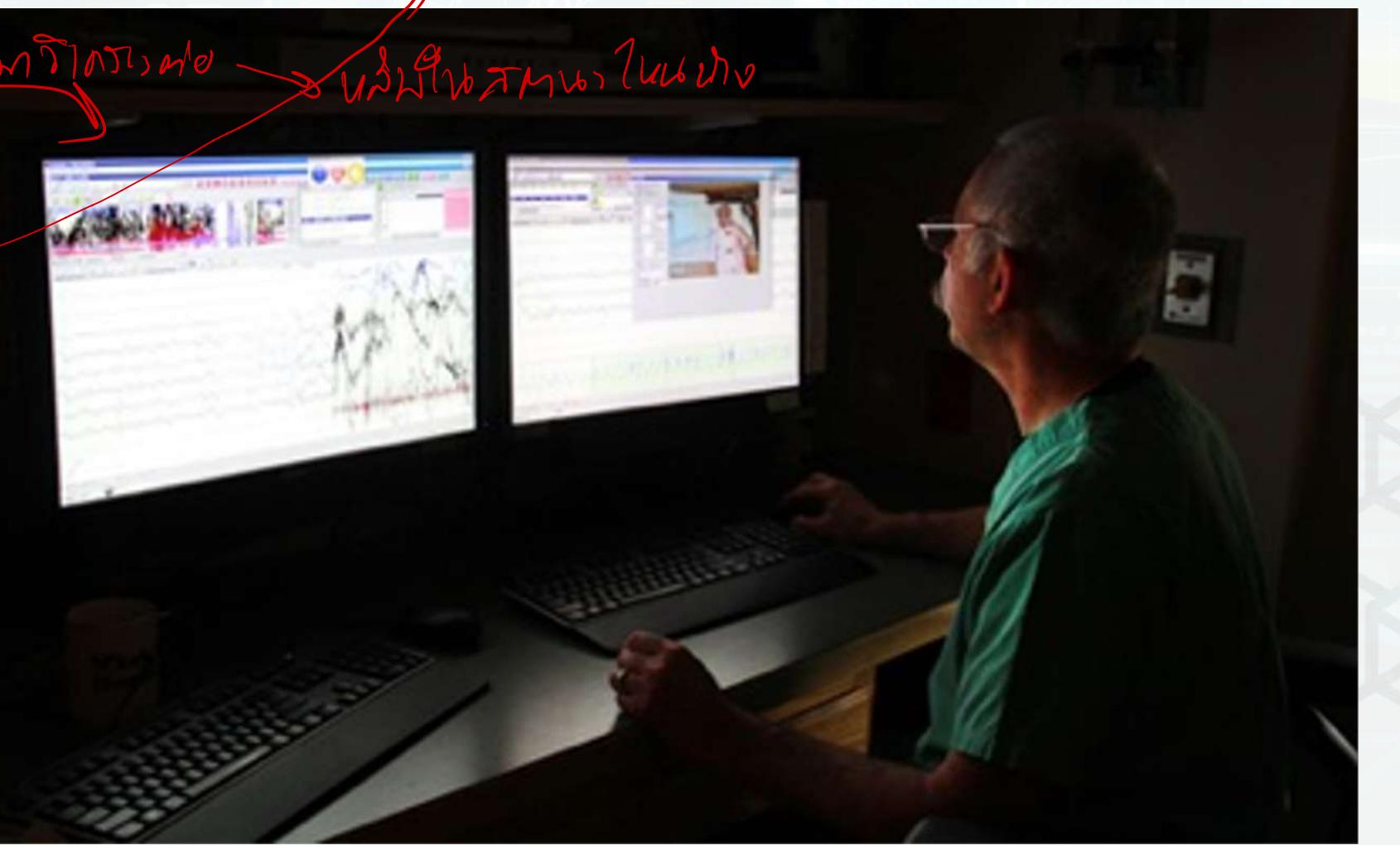
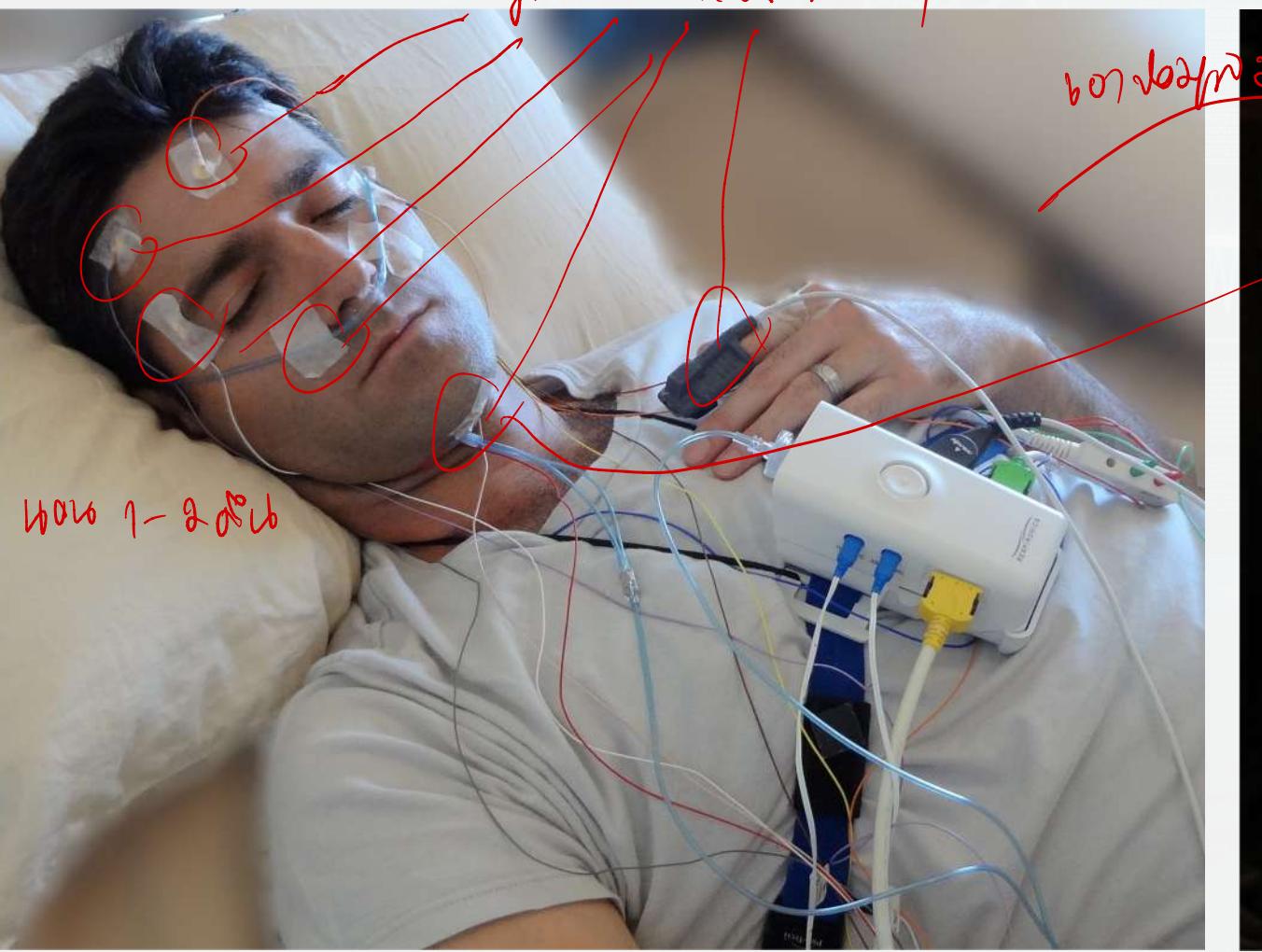
6.2.2 Deep learning and deep learning → model should learn pattern via numerous neurons
(input, output, hidden)
- every layer has its own activation function ①, ② non-linear
function of model



02 การวิเคราะห์การนอน (Sleep Stage Scoring)

Sleep Stage Scoring

- Analyze how well people sleep (e.g., sleep efficiency)
- Collect and score Polysomnogram (PSG): EEG, EOG, ECG, EMG



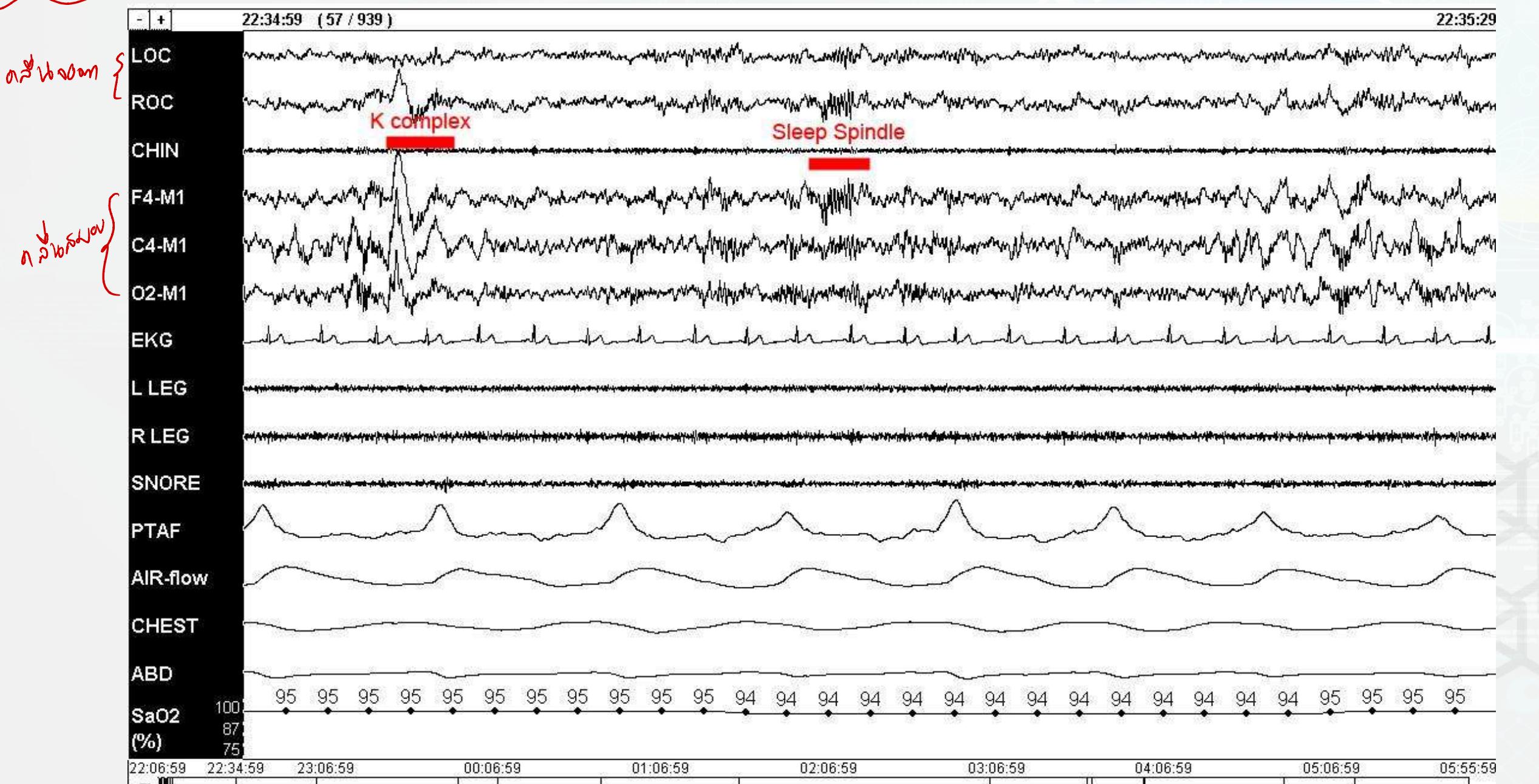
Sleep Stage Scoring



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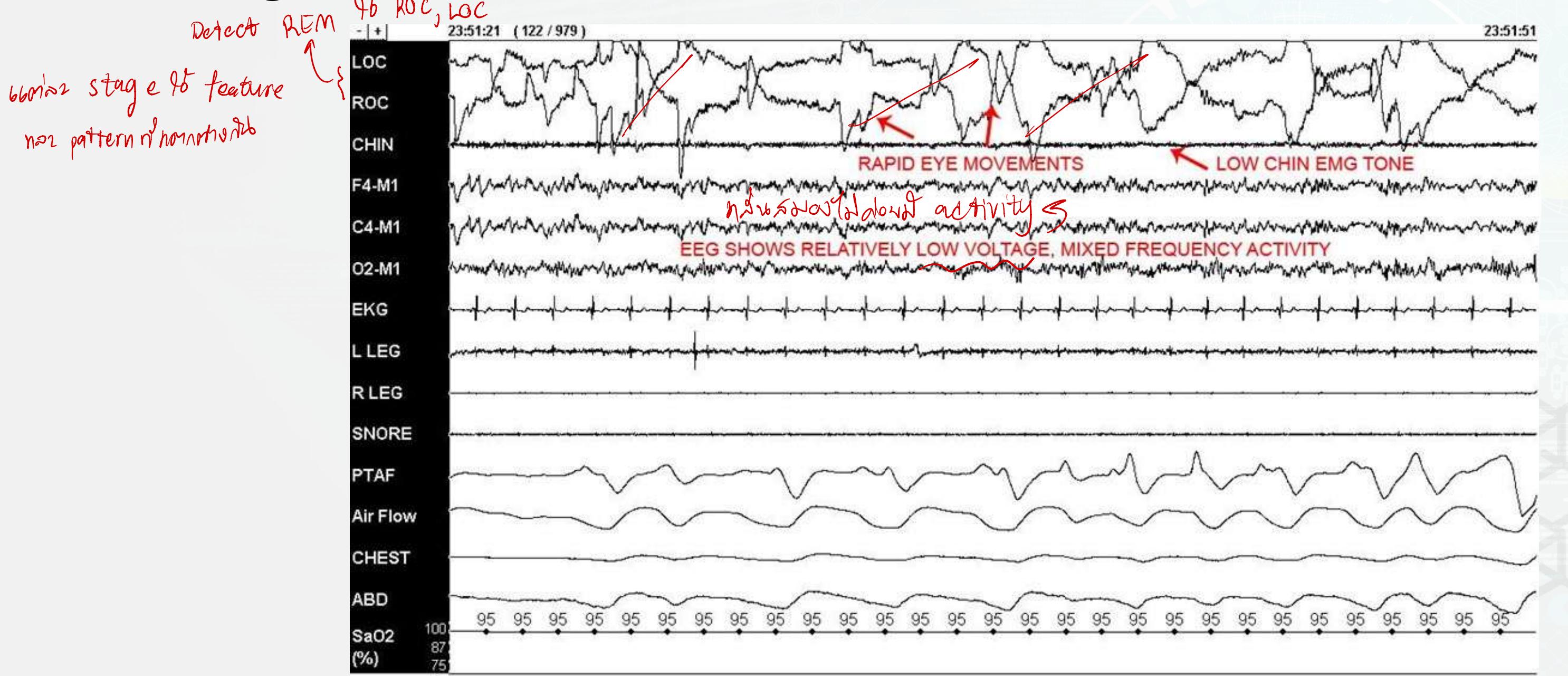
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Signal from
PSG – Stage N2





PSG – Stage REM *ผู้ตื่นนอน* *Rapid eye movement stage*



How good is your sleep?

- Total Sleep Time (TST) = total minutes of sleep (i.e., N1+N2+N3+REM)
- Time in Bed (TIB) = total recording time (i.e., Lights out to lights on)
- Sleep Efficiency (%) = $(TST/TIB) \times 100\%$
- and more ...

↑ นี่คือเวลาที่นอนหลับจริงๆ
 ↓ นี่คือเวลาที่นอนอยู่ในเตียง^{รวมถึงเวลาที่ตื่นแต่ไม่ลุก}
 จึงทำให้เวลาที่นอนหลับจริงๆ น้อยกว่าเวลาที่นอนอยู่ในเตียง

S E
 ถ้าต้องการคำนวณ Sleep Efficiency ให้ใช้

จำนวนชั่วโมงที่นอนหลับจริงๆ
 หารด้วย จำนวนชั่วโมงที่นอนอยู่ในเตียง

Table 1. Normative Sleep Stage Data Across Age Groups.*

Age (y)	20-29	30-39	40-49	50-59	>60
TST (min)	374.9	375.8	370.2	366.6	348.8
Sleep Efficiency (%)	94.4	94.4	90.2	90.4	85.8

Problems

- Labor-intensive and time-consuming
- Too many signals to collect at home → not portable and troublesome device setup

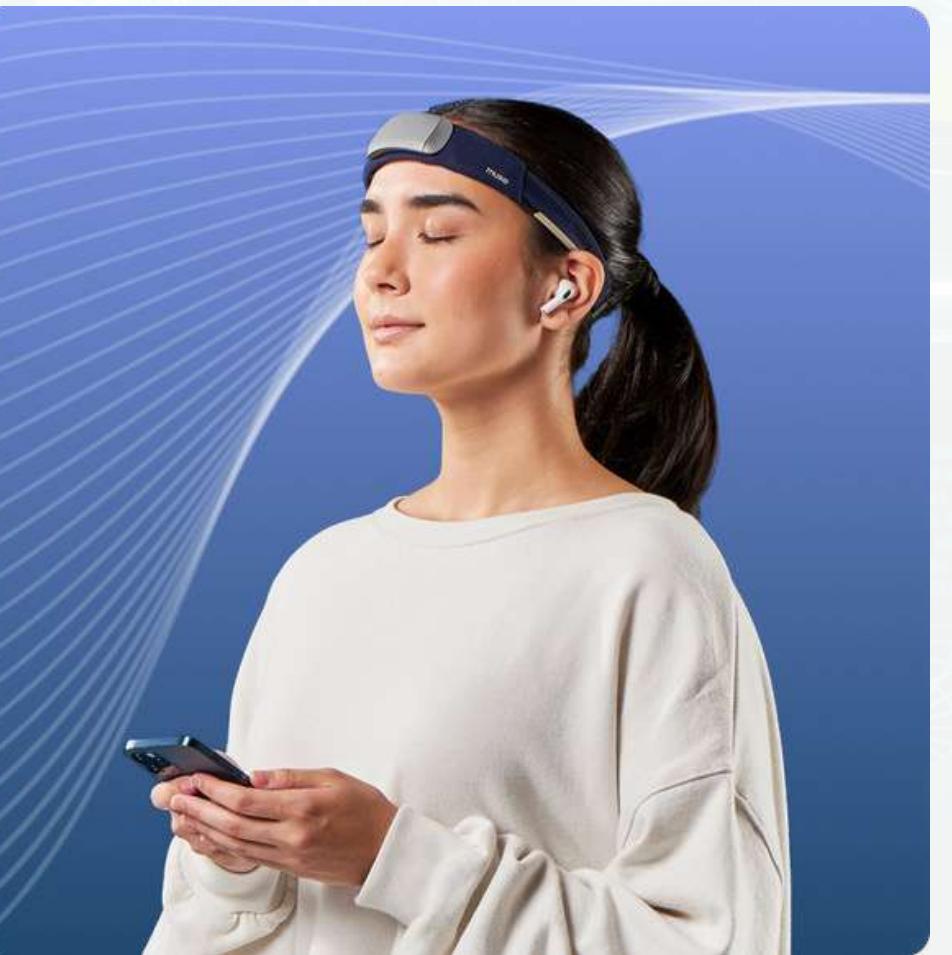
monitor ស្ថាបនុយ នូវការបង្កើតរូប

- Solution: automatic sleep stage scoring in home environment

- Single-channel EEG
- Deep learning model

អ្នកនីង → portable device

ស្ថាបនុយនៃការបង្កើត → model





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Public Sleep Dataset

Dataset

- **SleepEDF** (version 1)
 - 20 healthy subjects (age 28.7 ± 2.9)
 - Signals: 2 EEG (Fpz-Cz and Pz-Cz channels), 1 EOG (horizontal), 1 EMG, and 1 oro-nasal respiration
 - Annotations: W, N1, N2, N3, N4, REM, MOVEMENT, UNKNOWN, Artifacts or Noise, Non REM, UNKNOWN, 72007, 72008, 72009, 72010, 72011, 72012, 72013, 72014, 72015, 72016, 72017, 72018, 72019, 72020, 72021, 72022, 72023, 72024, 72025, 72026, 72027, 72028, 72029, 72030, 72031, 72032, 72033, 72034, 72035, 72036, 72037, 72038, 72039, 72040, 72041, 72042, 72043, 72044, 72045, 72046, 72047, 72048, 72049, 72050, 72051, 72052, 72053, 72054, 72055, 72056, 72057, 72058, 72059, 72060, 72061, 72062, 72063, 72064, 72065, 72066, 72067, 72068, 72069, 72070, 72071, 72072, 72073, 72074, 72075, 72076, 72077, 72078, 72079, 72080, 72081, 72082, 72083, 72084, 72085, 72086, 72087, 72088, 72089, 72090, 72091, 72092, 72093, 72094, 72095, 72096, 72097, 72098, 72099, 720100, 720101, 720102, 720103, 720104, 720105, 720106, 720107, 720108, 720109, 720110, 720111, 720112, 720113, 720114, 720115, 720116, 720117, 720118, 720119, 720120, 720121, 720122, 720123, 720124, 720125, 720126, 720127, 720128, 720129, 720130, 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1 min \rightarrow 60s

model \rightarrow day 16 number 20180411, 1st stage 075





03 แบบจำลองสำหรับวิเคราะห์การนอน (Model)



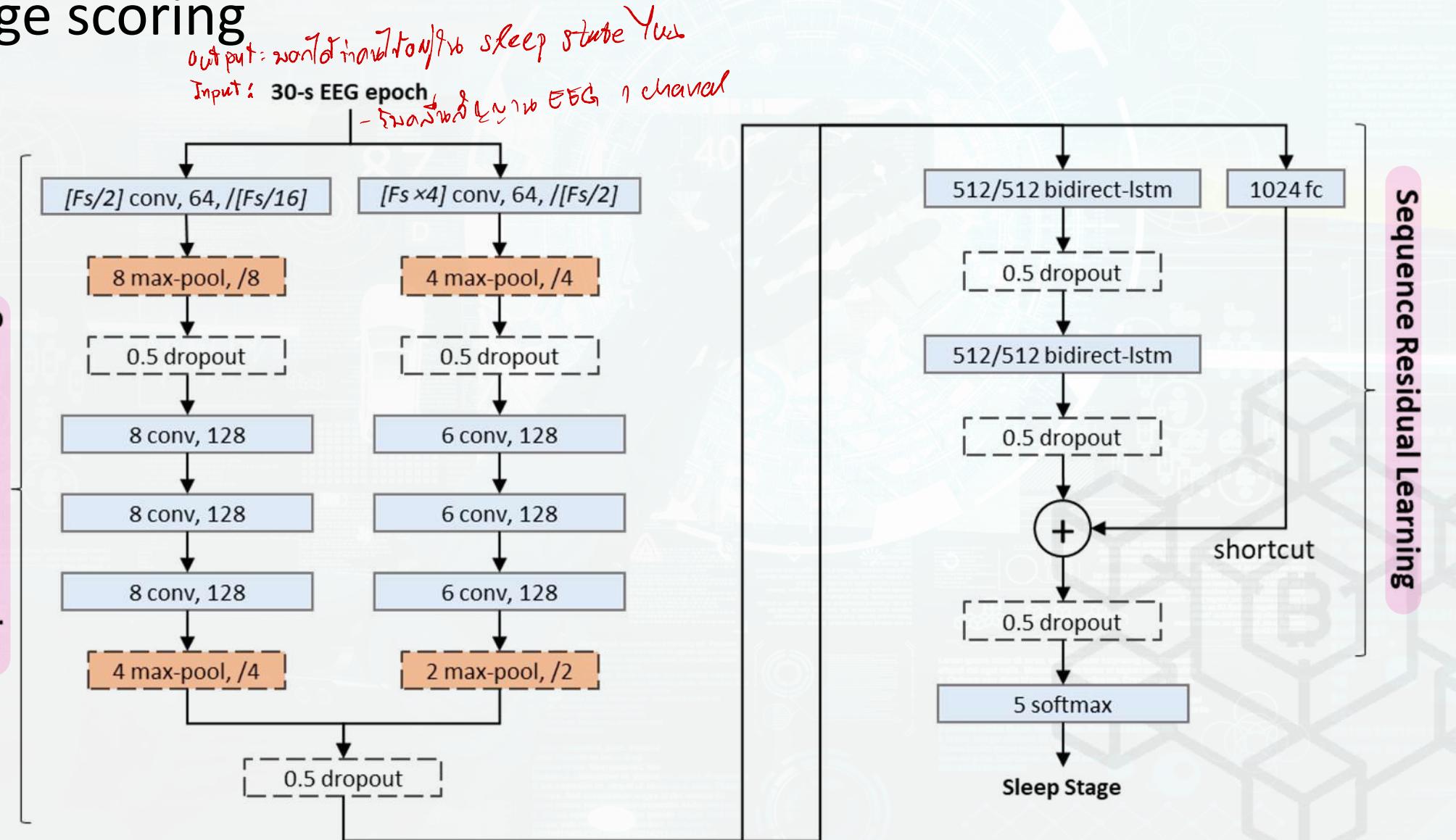
Models

- DeepSleepNet (Supratak et al., 2017)
- TinySleepNet (Supratak and Guo, 2020)

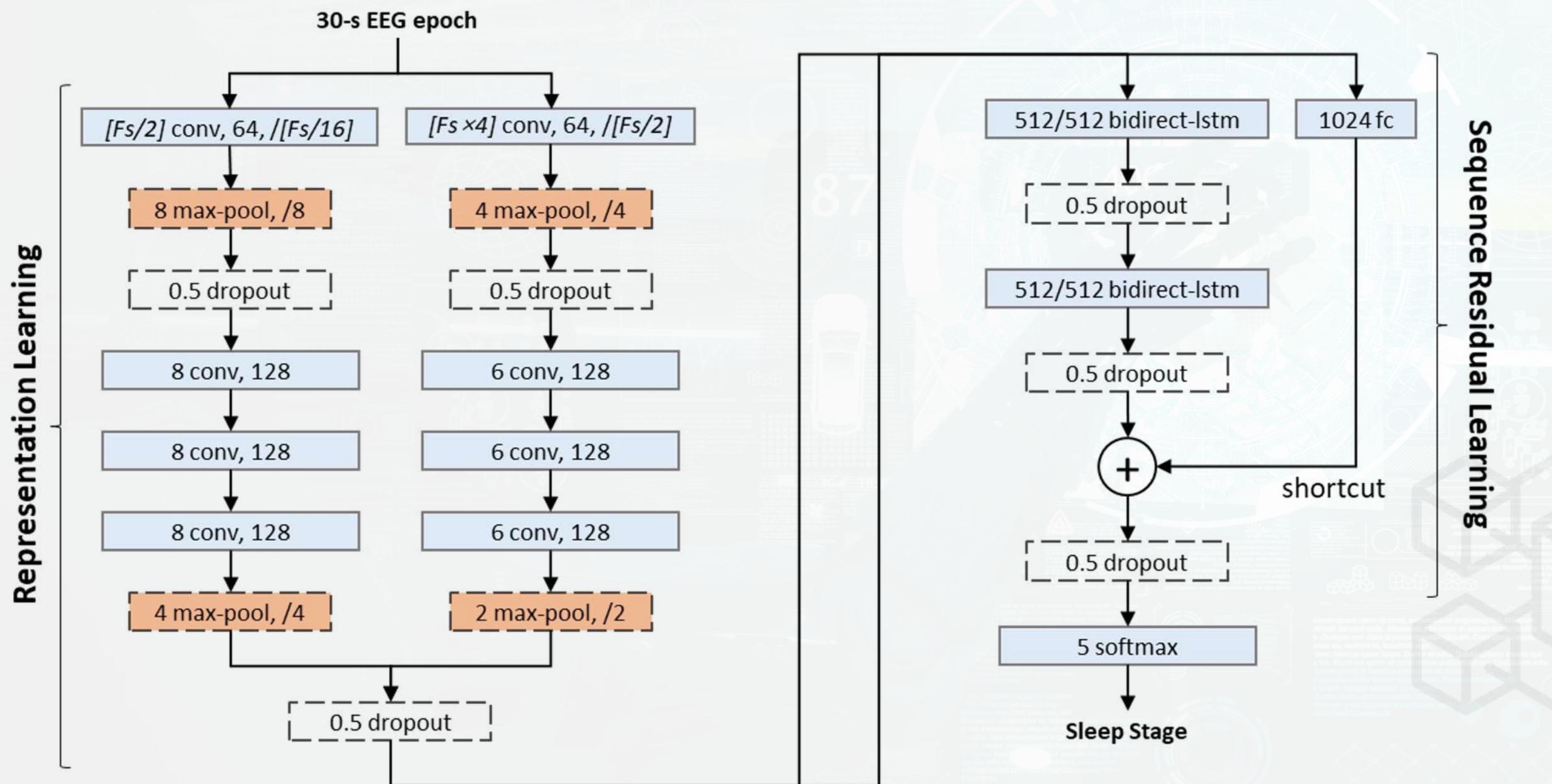
2nd version of DeepSleepNet → ทดสอบแล้ว, ทำงานได้ดีมาก

DeepSleepNet

- Deep learning model for sleep stage scoring
- Single-channel EEG
- Consist of two main parts
 - Representation Learning
 - Sequence Learning



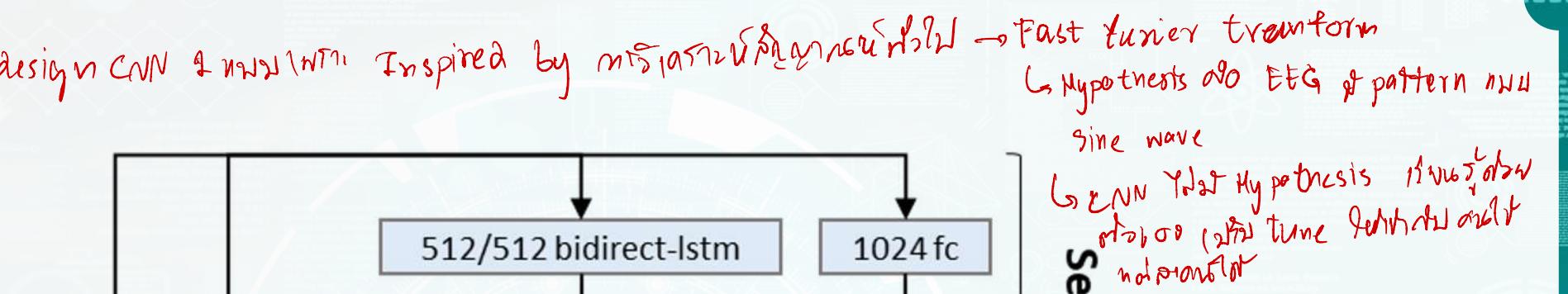
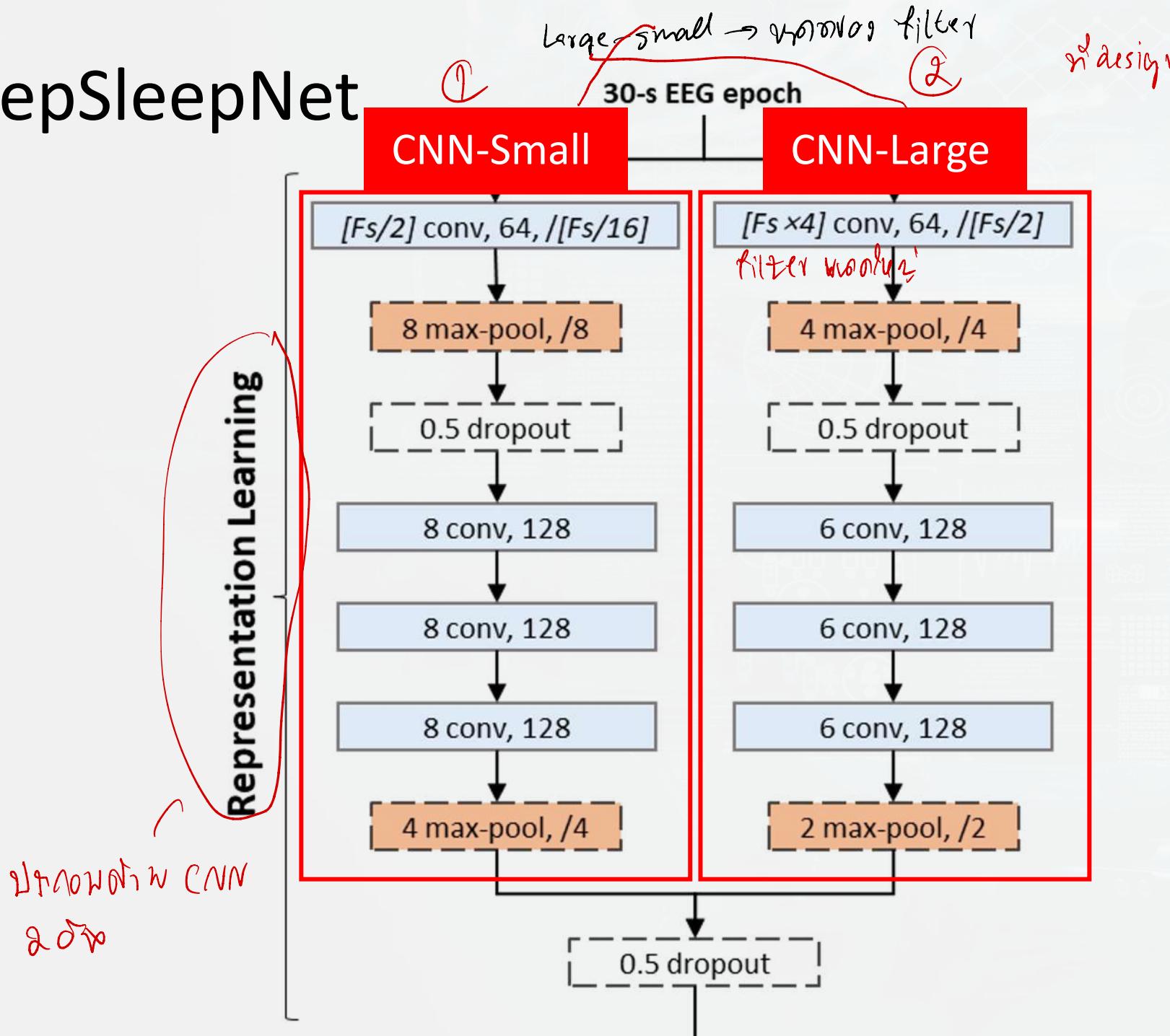
DeepSleepNet



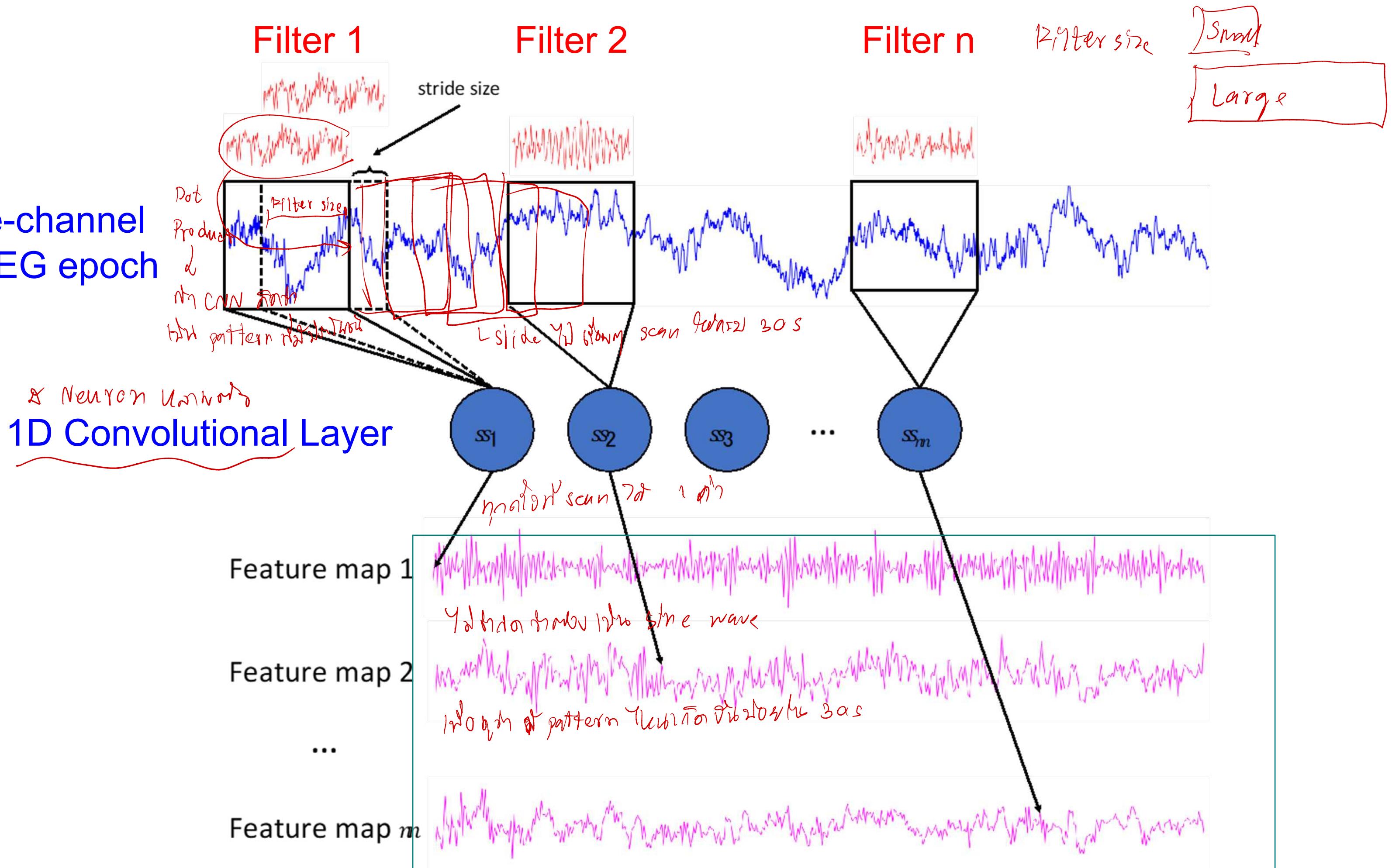


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DeepSleepNet



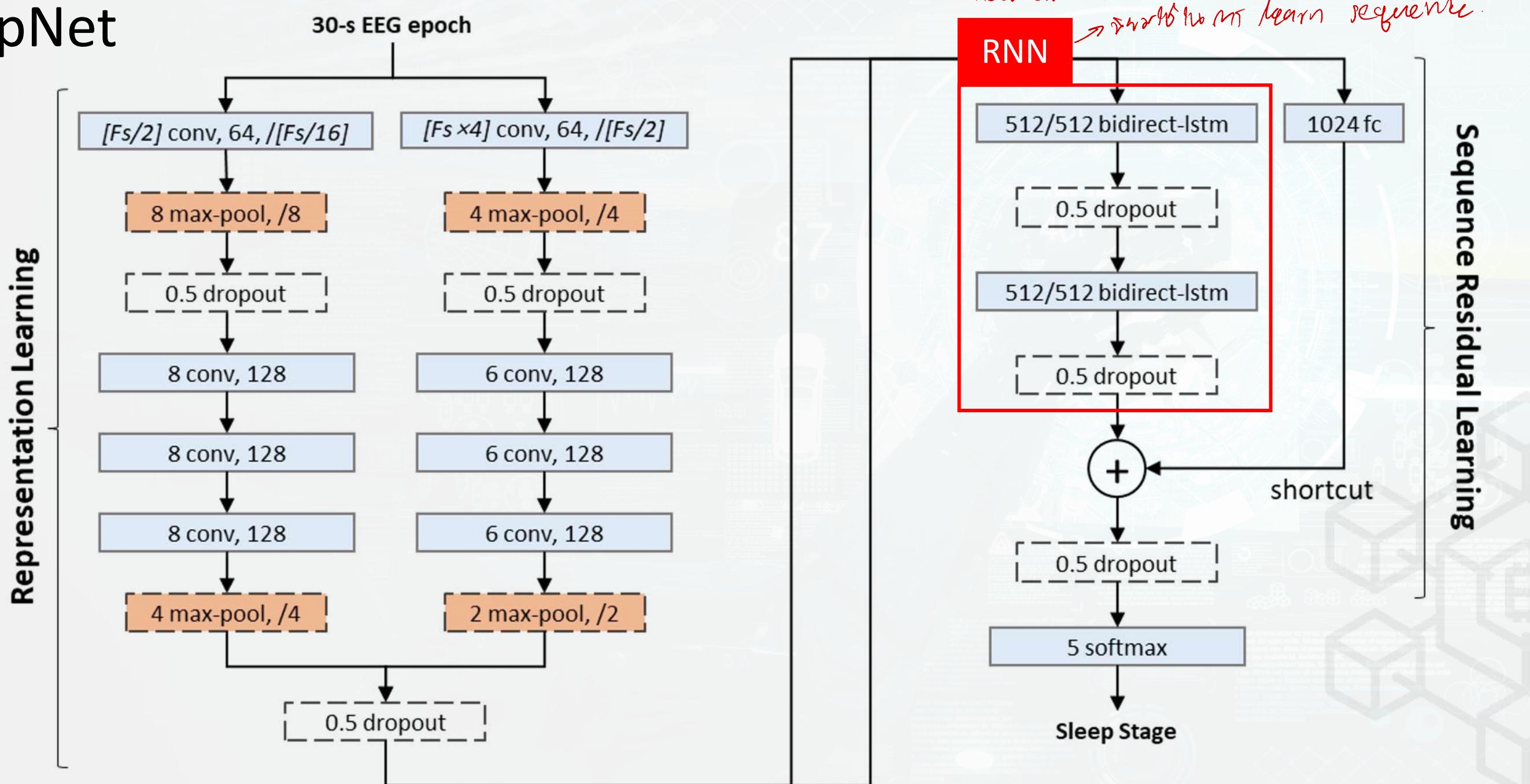
Single-channel
30-s EEG epoch



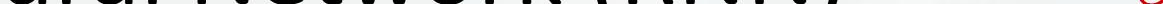


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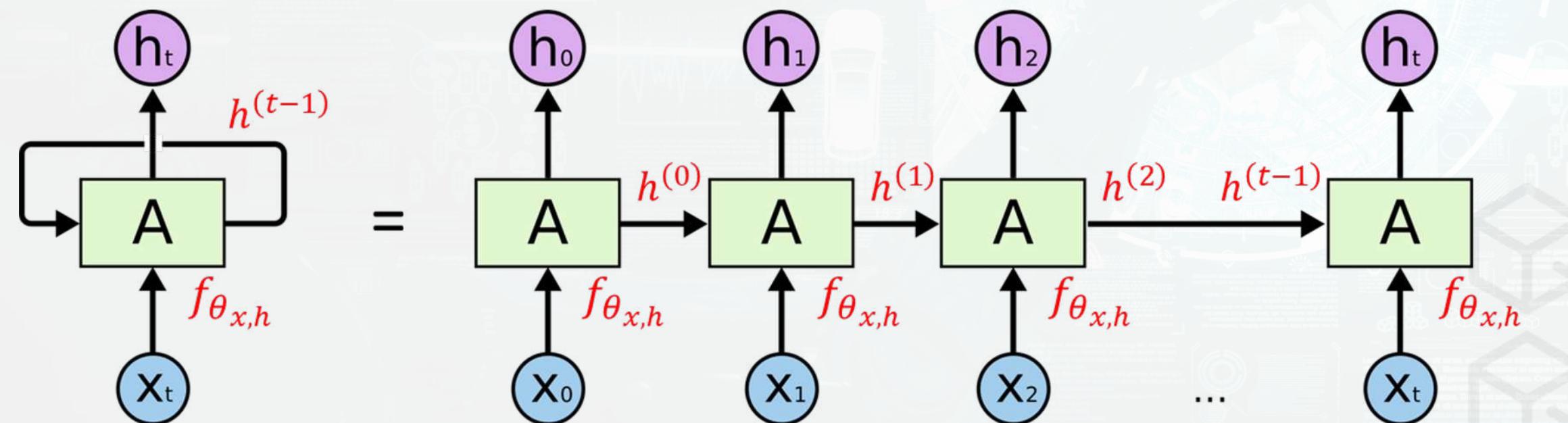
DeepSleepNet



Recurrent Neural Network (RNN)

Recurrent Network (RNN) 

- Learn **stage transition rules** that sleep experts use to determine the next possible sleep stages
 - AASM Manual (Iber et al., 2007) suggests that if a subject is in sleep stage **N2**, **continue to score epochs** with low amplitude and mixed frequency EEG activity as N2 **even though K complexes or sleep spindles are not present**

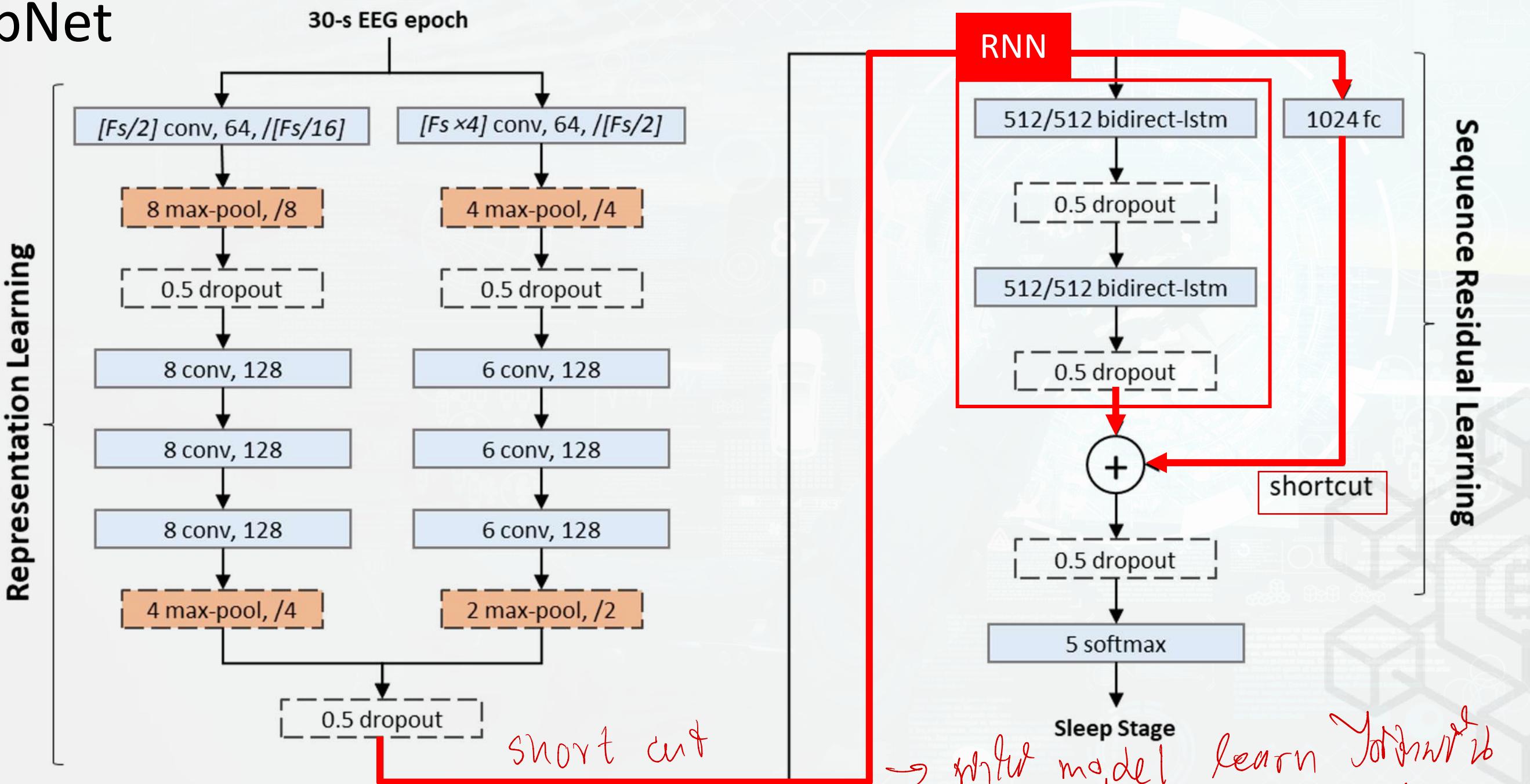


RNNs have feedback
connections

an **unrolled** RNN (no feedback connections)

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DeepSleepNet



DeepSleepNet

- Cross-entropy loss *standard loss*
- Adam optimizer *optimize parameter*
- f_θ is the DeepSleepNet *عن θ* $\theta^* = \arg \min_{\theta} J(\theta) = \arg \min_{\theta} \frac{1}{m} \sum_{i=1}^m L(f_\theta(x^{(i)}), y^{(i)})$
- $x^{(i)}$ is a 30-s EEG epoch
- $y^{(i)}$ is a sleep stage label

30 → 3 EEG epoch

อะก้า θ น

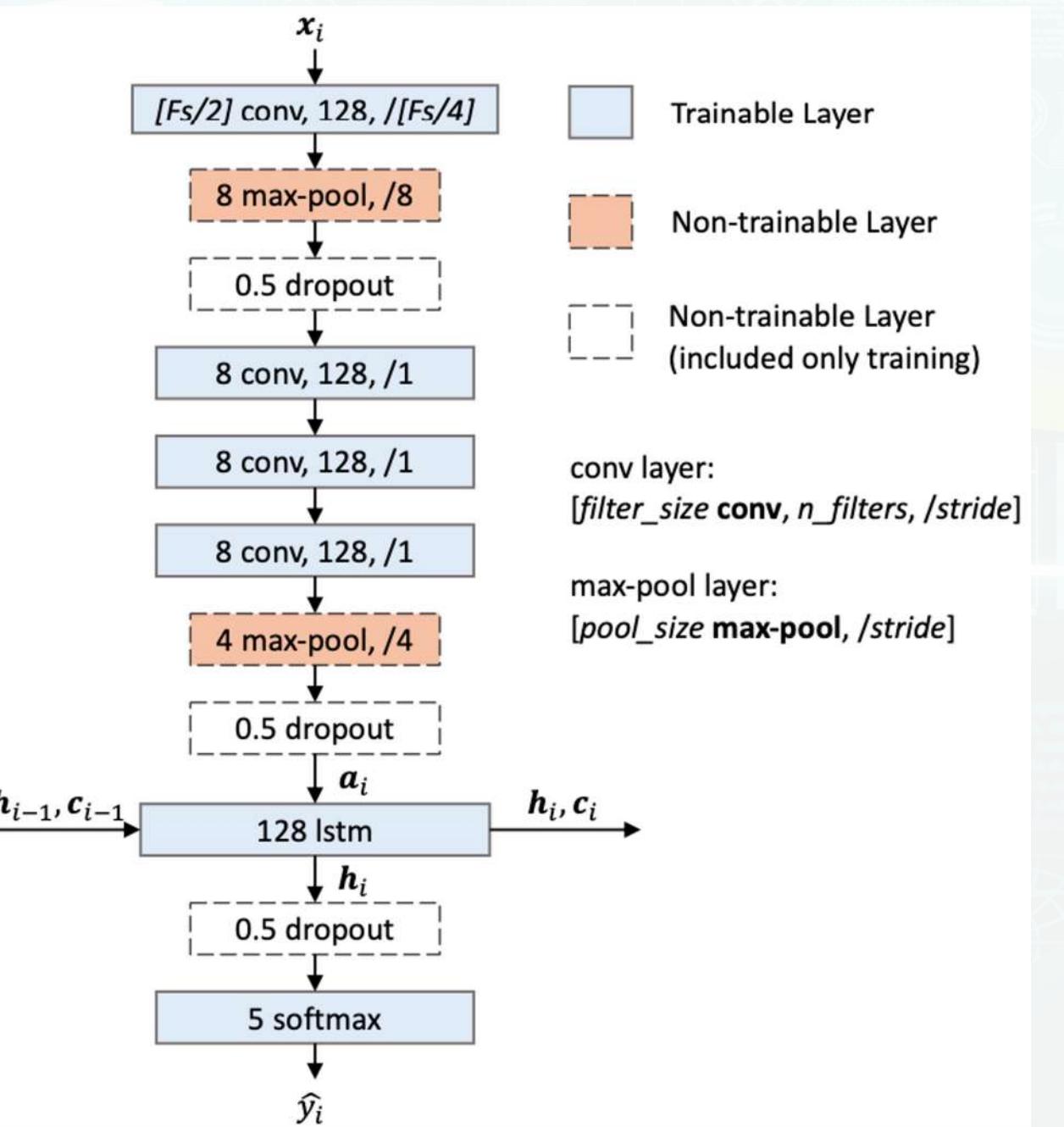
$$\theta^* = \arg \min_{\theta} \frac{1}{m} \sum_{i=1}^m L(f_\theta(x^{(i)}), y^{(i)})$$

Cross entropy loss

Sleep stage

Dev from DSN
TinySleepNet \rightarrow size (Layer) \rightarrow model 13 raw \rightarrow 10 labels

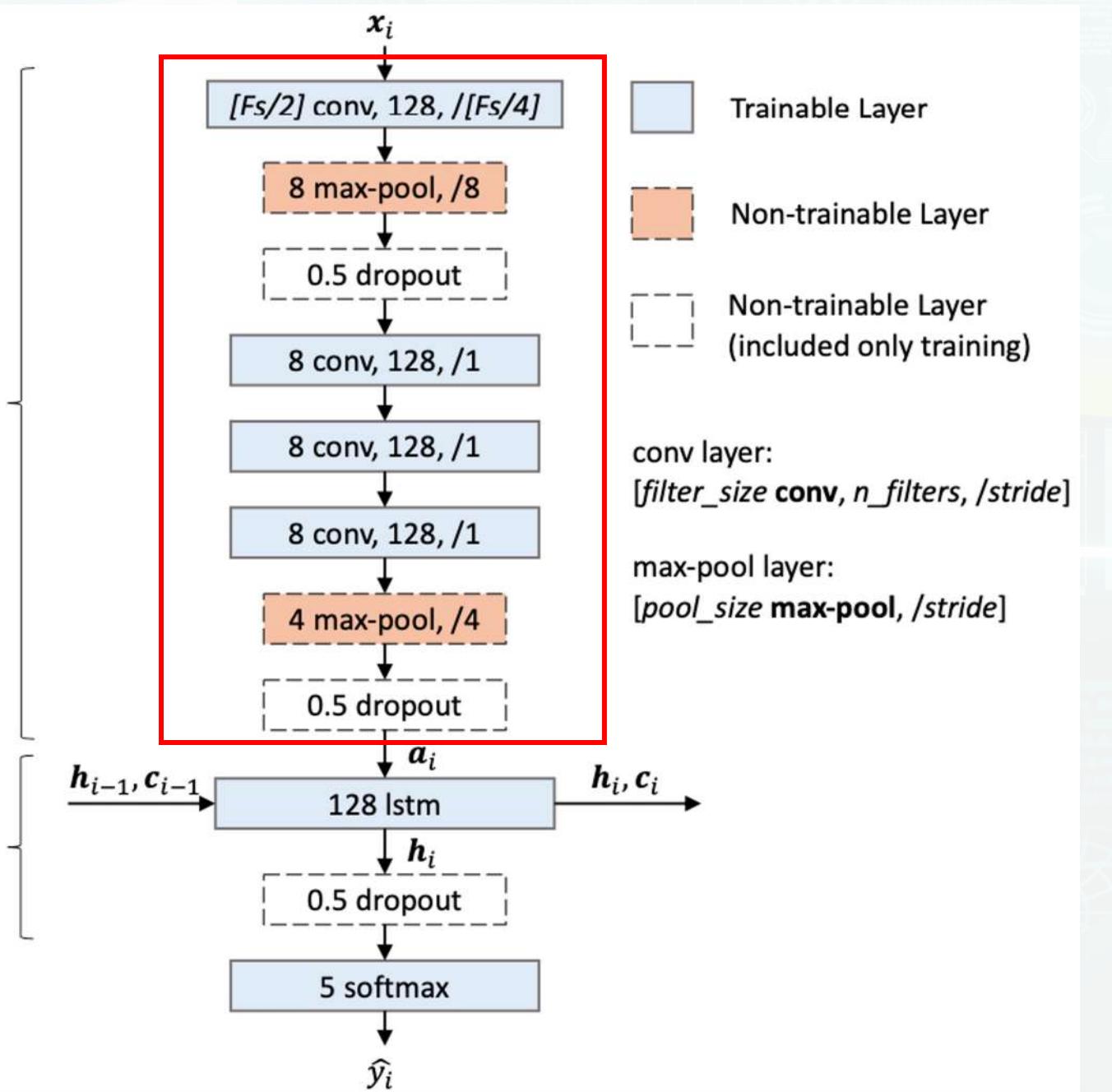
- Improved version of DeepSleepNet (Supratak et al. 2017)
 - Consist of two main parts
 - ① ○ Representation Learning
 - ② ○ Sequence Learning



TinySleepNet

- Representation Learning
 - Extract **time-invariant** features from raw EEG signals
 - Unlike DeepSleepNet
 - Only use **one branch** of CNNs, instead of two with small and large filters
 - The model can learn to **construct a larger filter** by **combining several conv layers** at the top layers, but **using a fewer number of parameters**

if ໃໝ່ ຂົ້ນ ຂົ້ນ filter ຕ່າງໆ ໂດຍ 1 ບັນດາ



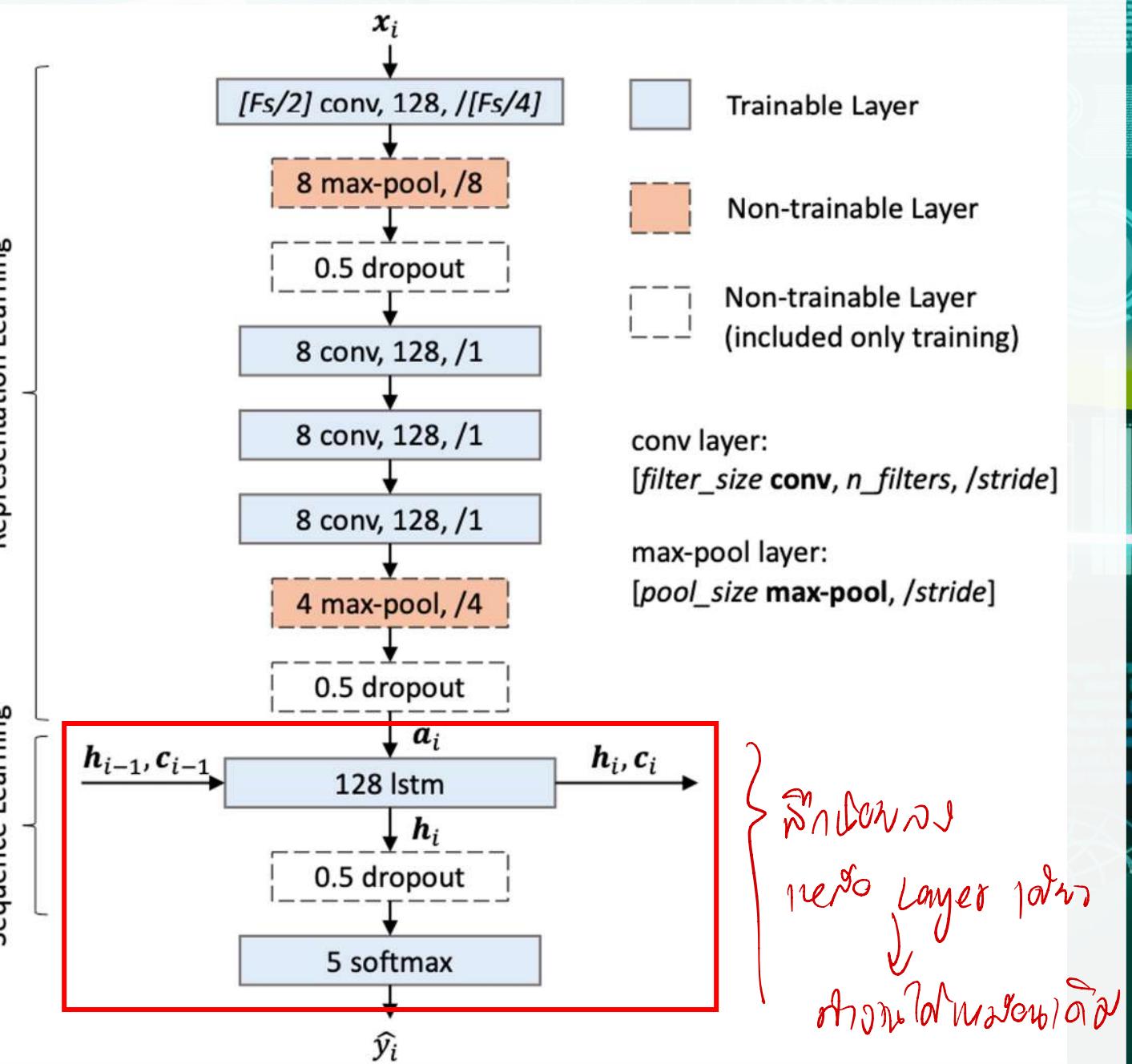


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Model of Learning Ecosystem Platform integrate with Coding & AI for Youth

TinySleepNet

- Sequence Learning RNN
 - Learn temporal information of the input signals, such as **sleep stage transition rules**
 - Unlike DeepSleepNet
 - Use **uni-directional RNNs**, instead of bi-directional ones
 - No need to buffer a chunk of EEG signals for processing in the backward direction
 - **Reduce** computational resources approximately by half





TinySleepNet

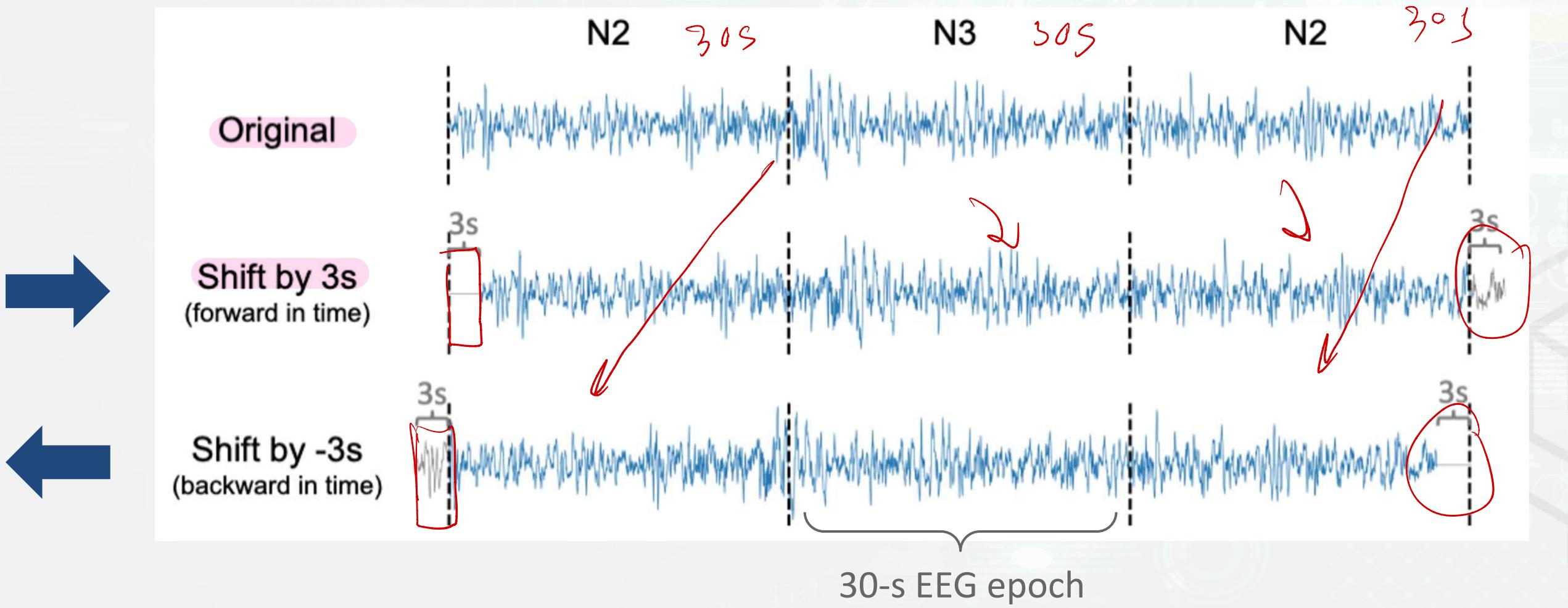
สืบสาน คุณภาพ ความคิด ความคิด → parameter ดีๆ กัน

- Train the model **end-to-end** via minibatch gradient descent
- Data augmentation: help generate new training data for **every** training epoch
 - Signal augmentation
 - Sequence augmentation
- **Weighted** cross-entropy loss → ถ้า model ใจดี หัวใจ N1 มากกว่า หัวใจ stage อย่างอื่น
 - Prioritize on the **minority** class such as N1
 - Alleviate the class imbalance problems
- Unlike DeepSleepNet
 - **No pre-training** the model with an oversampled, class-balanced data

↑ train ง่ายขึ้นมาก

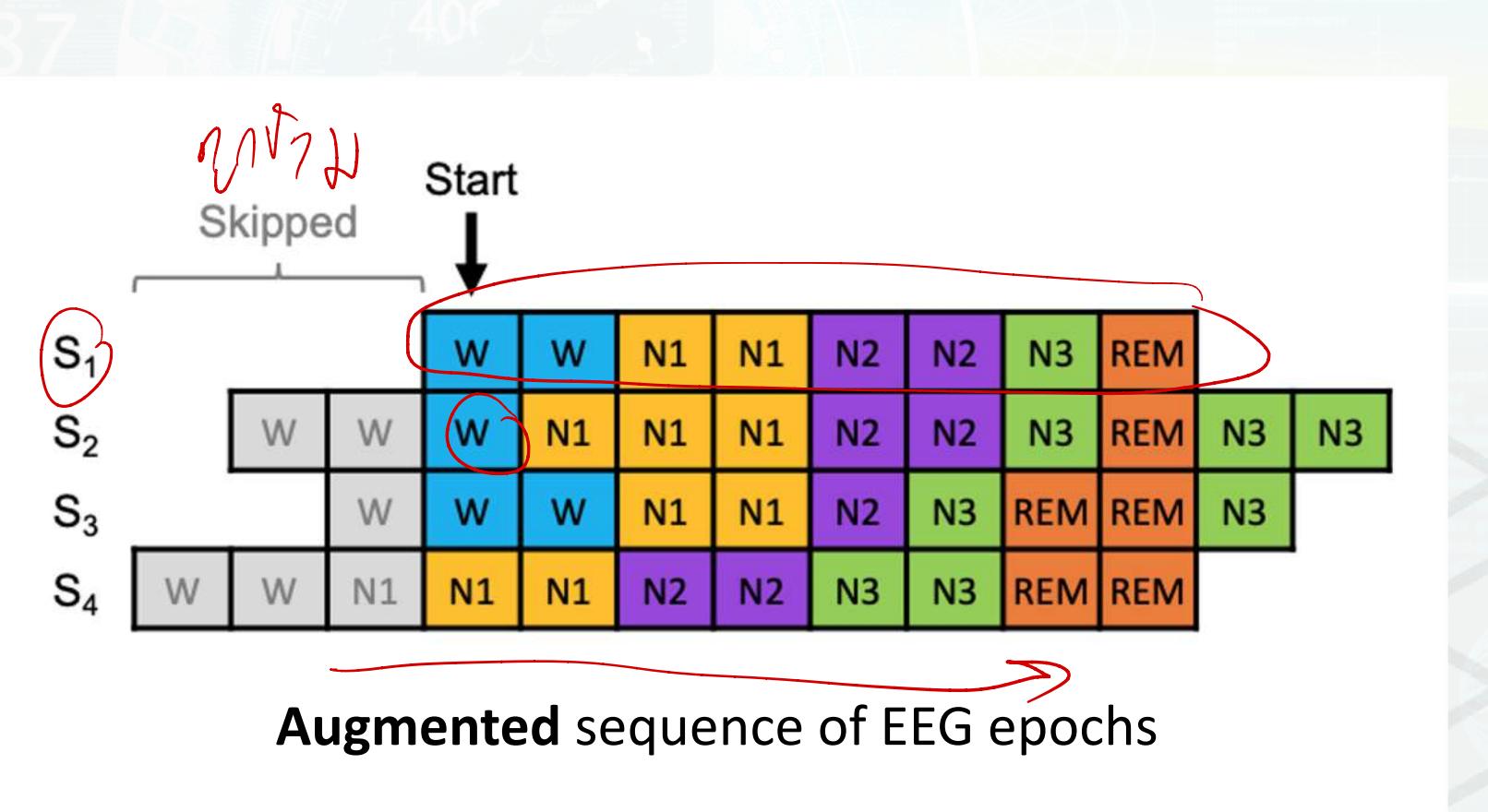
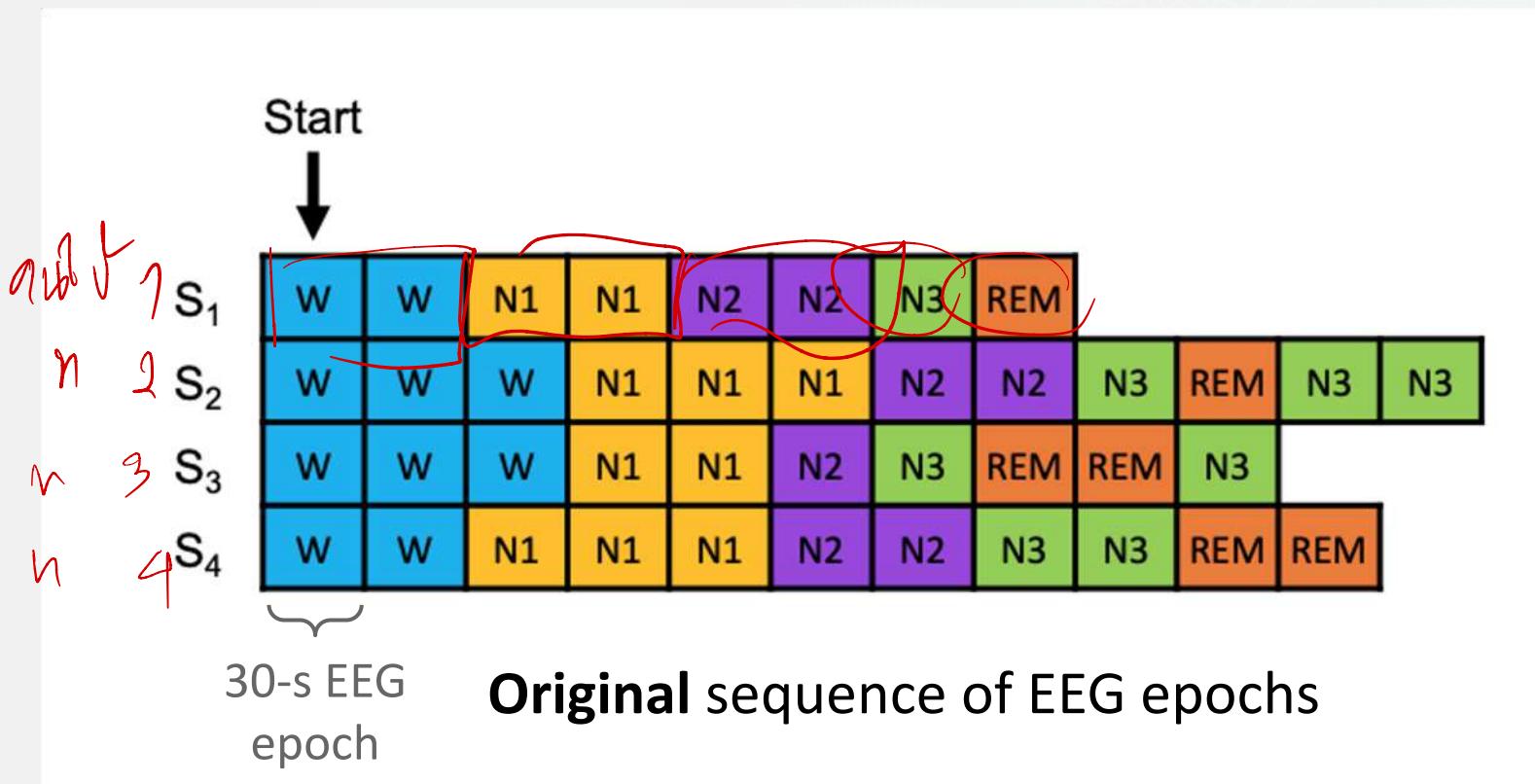
TinySleepNet

- Signal Augmentation
 - Randomly **shift** signals forward or backward in time



TinySleepNet

- Sequence Augmentation *→ ข้อมูลของกามนากา แล้วทัว sleep data มาก*
 - A few EEG epochs at the beginning of each sleep sequence are **skipped** by a random amount





04 การวัดผลการวิเคราะห์การนอน (Evaluation)



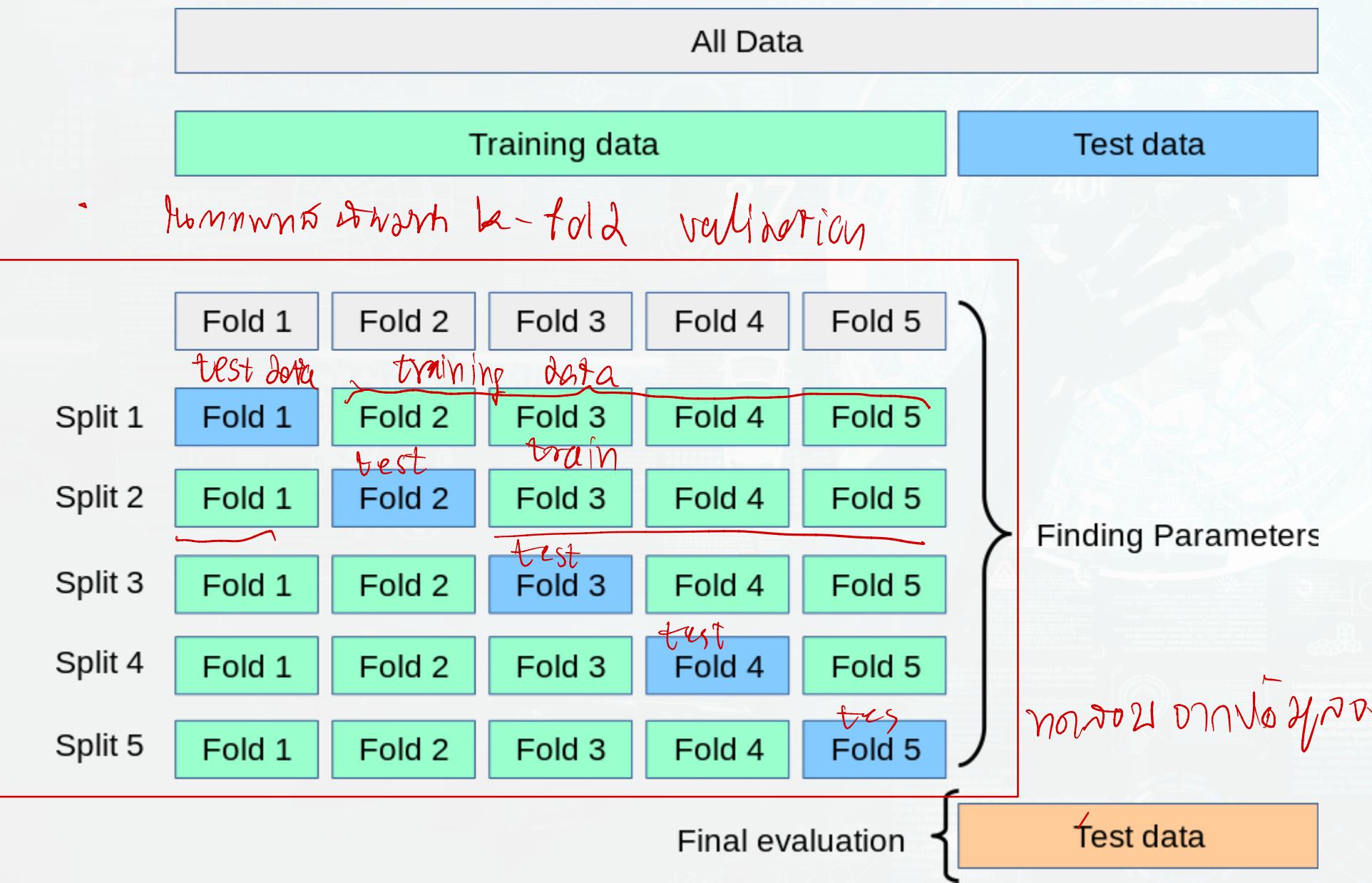
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Model Evaluation

- ① Experimental Setup แบบตัดต่อตัวอย่าง → แบบตัดต่อตัวอย่าง 1 ห้องนอน กับ 2 ห้องนอน
 - k-fold cross-validation (non-overlapping patient split) → 2 ห้องนอน ตัด
by the training, test, valid dataset
 - Performance Metrics ตัวชี้วัด
 - Overall: accuracy (ACC), macro-averaged F1-Score (MF1), Cohen's Kappa (κ)
 - Per-class: precision (PR), recall (RE), F1-Score (F1)
 - Visualization รูปแบบ model ที่ทำอยู่ต่อไป stage ต่อไป ↓ จัดทำ睡眠 sleep stage ทั้ง 5
 - Hypnogram
- รูปแบบของ Hypnogram

ମଧ୍ୟବୟବୋଦୟକୁ କିମ୍ବା କିମ୍ବା କିମ୍ବା
k-fold cross-validation





Confusion Matrix

07/02/2022

		ACTUAL	
		P	N
PREDICTED	P	TP	FP
	N	FN	TN

Positive : Model 100 รุ่น 19/2690

True Positives: Hit

True Negative: Correct rejection

False Positive: False alarm

False Negative: Miss

Example: Confusion Matrix for Cancer

Positive → มะนาวที่ดี๊ด๊า๊บ

		ACTUAL	
		P	N
PREDICTED	P	A patient has cancer and predict cancer.	A patient does not have cancer, but predict cancer. ↗ P
	N	A patient has cancer, but predict no cancer.	A patient does not have cancer, and predict not cancer.

Performance Metrics

1. Accuracy:

$$\frac{TP + TN}{TOTAL}$$

Good when classes are **approximately balance**

2. Precision:

$$\frac{TP}{TP + FP}$$

Good when **FN is less important**, e.g. spam filter

3. Recall:

$$\frac{TP}{TP + FN}$$

Good when **FP is less important**, e.g. cancer screening

4. F1 Score:

$$\frac{2 * Precision * Recall}{Precision + Recall}$$

Good when we care about **both precision and recall**

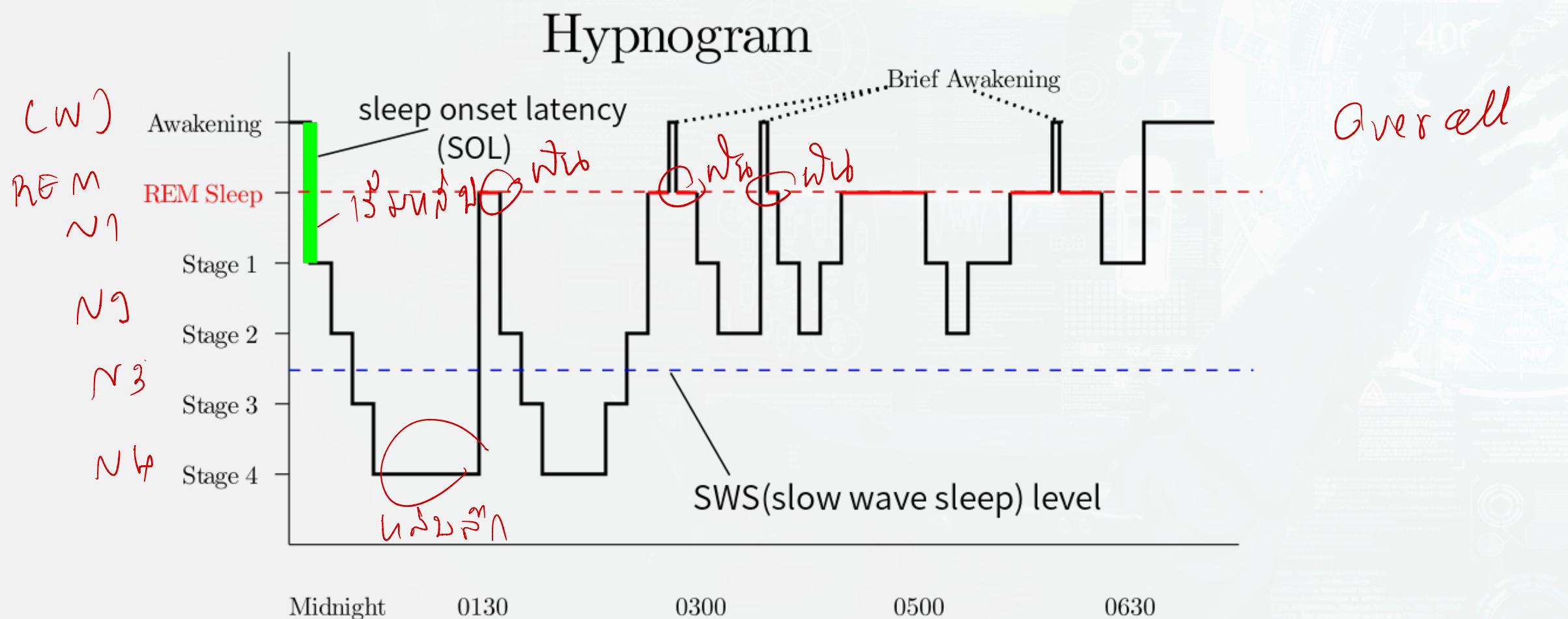
1. F1 score 2. Precision 3. Recall

9 10 2 10 (1, 2)

7 10

Hypnogram

A graph that represents the **stages of sleep** as a function of time



Model Evaluation

- Achieve a *similar (if not better)* performance compared to the state-of-the-art methods on **all** datasets
- tiny sleep Net ສະໜັບສິນ ມີການ 10 of 16 Dataset ອົບຕາວ*
ເລີ່ມຕົ້ນການນັກງານ (ການນັກງານ)

Methods	Datasets	Manual	EEG Channels	F_s (Hz)	Epoch (sec)	k -fold CV	Test Epochs	Overall Metrics			W	Per-class F1-Score (F1)			
								ACC	MF1	κ		N1	N2	N3	REM
IITNet [6]	Sleep-EDF-v1	R&K	Fpz-Cz	100	30	20	42308	84.0	77.7	0.78	87.9	44.7	88.0	85.7	82.1
SeqSleepNet+ (FT) [9]	Sleep-EDF-v1	R&K	Fpz-Cz	100	30	20	-	85.2	79.6	0.79	-	-	-	-	-
SleepEEGNet [7]	Sleep-EDF-v1	R&K	Fpz-Cz	100	30	20	42308	84.3	79.7	0.79	89.2	52.2	86.8	85.1	85.0
DeepSleepNet [5]	Sleep-EDF-v1	R&K	Fpz-Cz	100	30	20	41950	82.0	76.9	0.76	84.7	46.6	85.9	84.8	82.4
Our method	Sleep-EDF-v1	R&K	Fpz-Cz	100	30	20	44220	85.4	80.5	0.80	90.1	51.4	88.5	88.3	84.3
SleepEEGNet [7]	Sleep-EDF	R&K	Fpz-Cz	100	30	10	195479	80.0	73.6	0.73	91.7	44.1	82.5	73.5	76.1
Our method	Sleep-EDF	R&K	Fpz-Cz	100	30	10	199352	83.1	78.1	0.77	92.8	51.0	85.3	81.1	80.3
Our method	MASS-SS1	AASM	F4-EOG (L)	256	30	27	51293	83.1	79.3	0.76	90.0	60.6	87.4	73.2	85.1
Our method	MASS-SS2	R&K	F4-EOG (L)	256	20	19	26711	82.6	75.5	0.75	76.6	48.2	87.8	80.5	84.3
IITNet [6]	MASS-SS3	AASM	F4-EOG (L)	256	30	31	57395	86.6	80.8	0.80	86.1	54.4	91.3	86.0	86.2
DeepSleepNet [5]	MASS-SS3	AASM	F4-EOG (L)	256	30	31	58600	86.2	81.7	0.80	87.3	59.8	90.3	81.5	89.3
Our method	MASS-SS3	AASM	F4-EOG (L)	256	30	31	59317	87.5	83.2	0.82	87.3	62.7	91.8	85.5	88.6
Our method	MASS-SS4	R&K	C4-EOG (L)	256	20	20	55310	84.0	78.0	0.77	79.8	50.2	88.9	82.4	88.5
Our method	MASS-SS5	R&K	F4-EOG (L)	256	20	26	36409	86.6	80.9	0.81	85.5	55.0	89.9	86.6	87.7

Model Evaluation

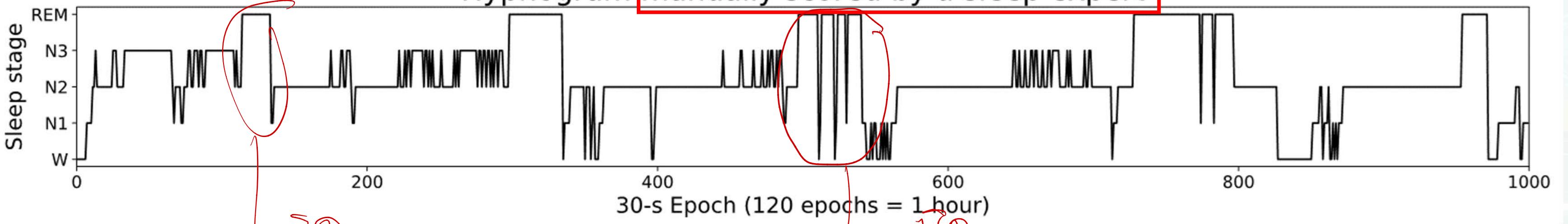
- NO sacrificing the performance on *any* sleep stage, especially **N1** (the most difficult sleep stage to classify)

Methods	Datasets	Manual	EEG Channels	F_s (Hz)	Epoch (sec)	k -fold CV	Test Epochs	Overall Metrics			Per-class F1-Score (F1)				
								ACC	MF1	κ	W	N1	N2	N3	REM
IITNet [6]	Sleep-EDF-v1	R&K	Fpz-Cz	100	30	20	42308	84.0	77.7	0.78	87.9	44.7	88.0	85.7	82.1
SeqSleepNet+ (FT) [9]	Sleep-EDF-v1	R&K	Fpz-Cz	100	30	20	-	85.2	79.6	0.79	-	-	-	-	-
SleepEEGNet [7]	Sleep-EDF-v1	R&K	Fpz-Cz	100	30	20	42308	84.3	79.7	0.79	89.2	52.2	86.8	85.1	85.0
DeepSleepNet [5]	Sleep-EDF-v1	R&K	Fpz-Cz	100	30	20	41950	82.0	76.9	0.76	84.7	46.6	85.9	84.8	82.4
Our method	Sleep-EDF-v1	R&K	Fpz-Cz	100	30	20	44220	85.4	80.5	0.80	90.1	51.4	88.5	88.3	84.3
SleepEEGNet [7]	Sleep-EDF	R&K	Fpz-Cz	100	30	10	195479	80.0	73.6	0.73	91.7	44.1	82.5	73.5	76.1
Our method	Sleep-EDF	R&K	Fpz-Cz	100	30	10	199352	83.1	78.1	0.77	92.8	51.0	85.3	81.1	80.3
Our method	MASS-SS1	AASM	F4-EOG (L)	256	30	27	51293	83.1	79.3	0.76	90.0	60.6	87.4	73.2	85.1
Our method	MASS-SS2	R&K	F4-EOG (L)	256	20	19	26711	82.6	75.5	0.75	76.6	48.2	87.8	80.5	84.3
IITNet [6]	MASS-SS3	AASM	F4-EOG (L)	256	30	31	57395	86.6	80.8	0.80	86.1	54.4	91.3	86.0	86.2
DeepSleepNet [5]	MASS-SS3	AASM	F4-EOG (L)	256	30	31	58600	86.2	81.7	0.80	87.3	59.8	90.3	81.5	89.3
Our method	MASS-SS3	AASM	F4-EOG (L)	256	30	31	59317	87.5	83.2	0.82	87.3	62.7	91.8	85.5	88.6
Our method	MASS-SS4	R&K	C4-EOG (L)	256	20	20	55310	84.0	78.0	0.77	79.8	50.2	88.9	82.4	88.5
Our method	MASS-SS5	R&K	F4-EOG (L)	256	20	26	36409	86.6	80.9	0.81	85.5	55.0	89.9	86.6	87.7

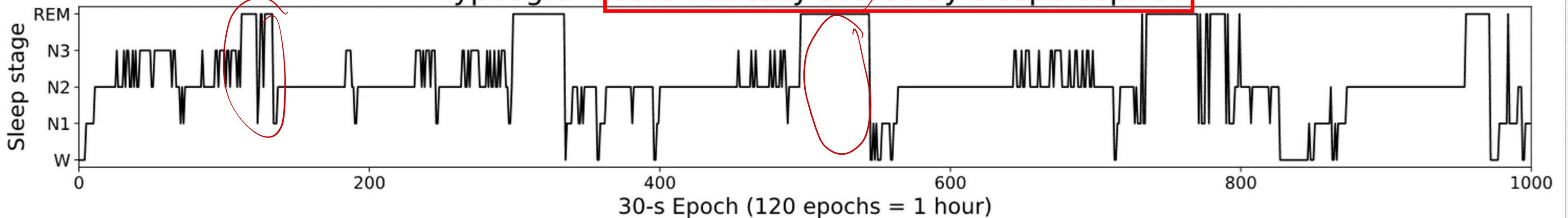
Hypnogram

กามล พุฒิมา

Hypnogram manually scored by a sleep expert



Hypnogram automatically scored by DeepSleepNet



Cells becomes inactive during trains of REM stage

an Ahmed 1970 path

R: REM Sleep
→ 20h 8, 120M3/2000
Stage 8

Cells becomes active for W or N1 stages

Not easily interpretable cells

Yachtiform
model built 01/15



05 แบบฝึกหัด (Coding Exercise)



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Model of Learning Ecosystem Platform integrate with Coding & AI for Youth

Code Exercise

- Download the exercise from Github
 - <https://github.com/akaraspt/pmub-learning-biosignals/tree/main>
- Setup Environment
- Download the SleepEDF dataset
- Signal extraction
 - Select frontal EEG channel
 - Generate dataset for model and evaluation
 - Pair of (30-s single-channel EEG, {0,1,2,3,4})
- Define a 1D CNN model for sleep stage scoring (Exercise)
- Train the model in 20-fold cross validation
- Use the trained model for predictions



06 บทสรุปและโอกาสการพัฒนาต่อไป (Conclusion and Future Works)



Conclusions

- Deep Learning are typically applied to biosignal in the **supervised** cases
 - Not for everything !!!
- Alternatively, we can transform from raw signals into **spectrogram** or **image-based representations** *→ วิธีนี้ต้องมีสัญญาณที่ชัดเจน เช่น ECG, EEG ถ้าไม่ชัดเจน ต้องมีการ preprocess ด้วย CNN จึงสามารถ → ทำให้ model สามารถพิจารณาสัญญาณที่ไม่ชัดเจน ได้*
 - Can use CNN that processes images
 - However, this is not an ideal end-to-end training
- Not many cases that can successfully apply deep learning directly on “**raw**” signals
 - Only for the domain that have **clear patterns of the signals** for each class, and sufficient amount of training examples
 - ต้องมีสัญญาณที่ชัดเจน มากพอ
- Promising area of research for **remote monitoring**
 - Different characteristics of the **wearable devices**
 - Transfer the knowledge learned in the clinic into the wearable device
 - ถ่ายทอดความรู้จากคลินิกไปยังอุปกรณ์ใส่ตัว

Future Works and Impacts

- Doctors can see
 - Sleep hours, walking performance, body temperature and blood pressure
- Patients save time and money from revisiting hospitals
- Early sign for harmful diseases and save lives

Smart eye-mask



อุปกรณ์ที่สามารถเฝ้าระวังสุขภาพผู้คน
ทันท่วงทัน → ตรวจร่างกาย → รักษาโรค



More Details ...

- Paper
 - A. Supratak, H. Dong, C. Wu, and Y. Guo, “**DeepSleepNet: a Model for Automatic Sleep Stage Scoring based on Raw Single-Channel EEG**,” *IEEE Trans. Neural Syst. Rehabil. Eng.*, pp. 1–10, 2017.
 - A. Supratak and Y. Guo, “**TinySleepNet: An Efficient Deep Learning Model for Sleep Stage Scoring based on Raw Single-Channel EEG**,” *2020 42nd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC)*, 2020.
- Code that can be used and extended for future works
 - Github: <https://github.com/akaraspt/deepsleepnet>
 - Github: <https://github.com/akaraspt/tinysleepnet>

