인공지능 기법을 적용한 배터리 노화상태 실시간 예측 시뮬레이션

2017010698 오서영
2017010701 이윤녕
2017010709 조지수
2017010706 정유은

목차

문제 배경

Electric Vehicle, Energy Storage System 등
여러 분야에 리튬 이온 배터리 사용

-> 효과적인 SOH 예측 알고리즘 필수

SOH (State of Health) : 배터리 열화 상태

- 전기를 담을 수 있는 용량
- 배터리 충/방전 횟수(Cycle)가 증가할수록 대략적으로 SOH 감소
- 대체로 SOH가 60% ~ 70%로 감소할 때까지 사용

Q_{nom} : 초기 배터리 방전 전하량 (배터리 생산 시 제공) -> 2Ah
Q_m : m번째 Cycle에서의 배터리 방전 전하량

SOH 계산 방법

$$\text{SOH} = \frac{Q_m}{Q_{nom}}$$

-> NASA PCoE Datasets을 활용하여 계산

1. 수행개요

데이터 실험 조건에 따른 3가지 분류

- 데이터 그룹 A: 상온 충/방전 데이터 (B05, B07, B18)
- 데이터 그룹 B: 상온 고출력 충/방전 데이터 (B33, B34)
- 데이터 그룹 C: 저온 충/방전 데이터 (B46, B47, B48)

목표

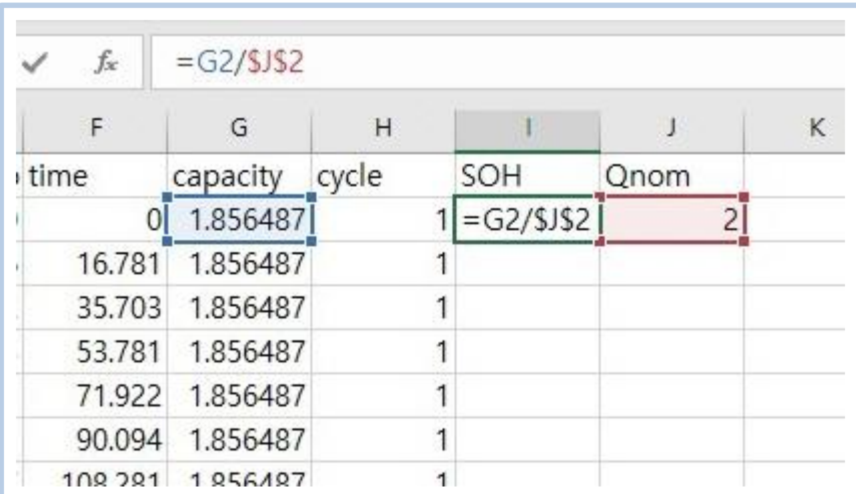
- 선형회귀와 LSTM을 이용한 SOH 예측 시뮬레이션 구현

1) 데이터의 50%를 이용한 학습
2) 데이터의 70%를 이용한 학습

- 예측 시각화
- RMSE, MAE를 이용한 결과분석

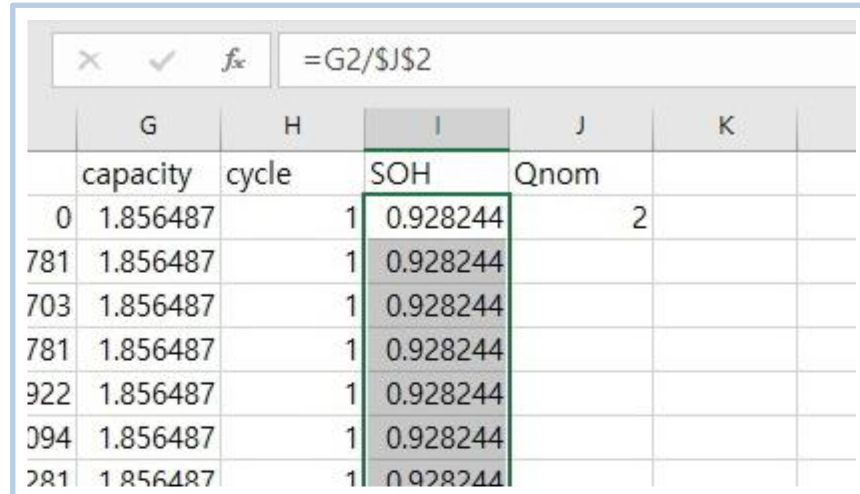
$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(\hat{y}_i - y_i)^2}{n}} \qquad MAE = \frac{1}{n}\sum_{i=1}^{n} |\hat{y}_i - y_i|$$

SOH 계산



=G2/$J$2

F	G	H	I	J	K
time	capacity	cycle	SOH	Qnom	
0	1.856487	1	=G2/$J$2	2	
16.781	1.856487	1			
35.703	1.856487	1			
53.781	1.856487	1			
71.922	1.856487	1			
90.094	1.856487	1			
108.281	1.856487	1			

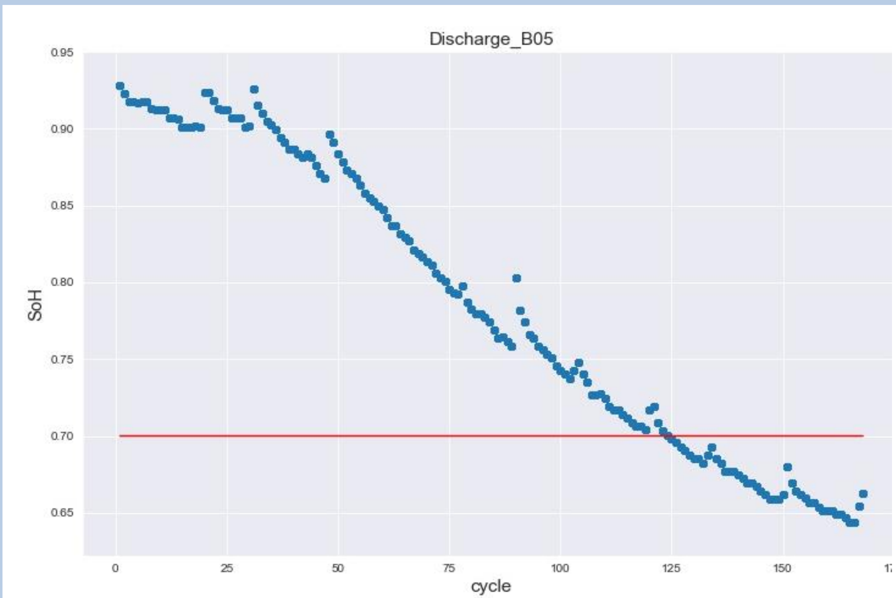


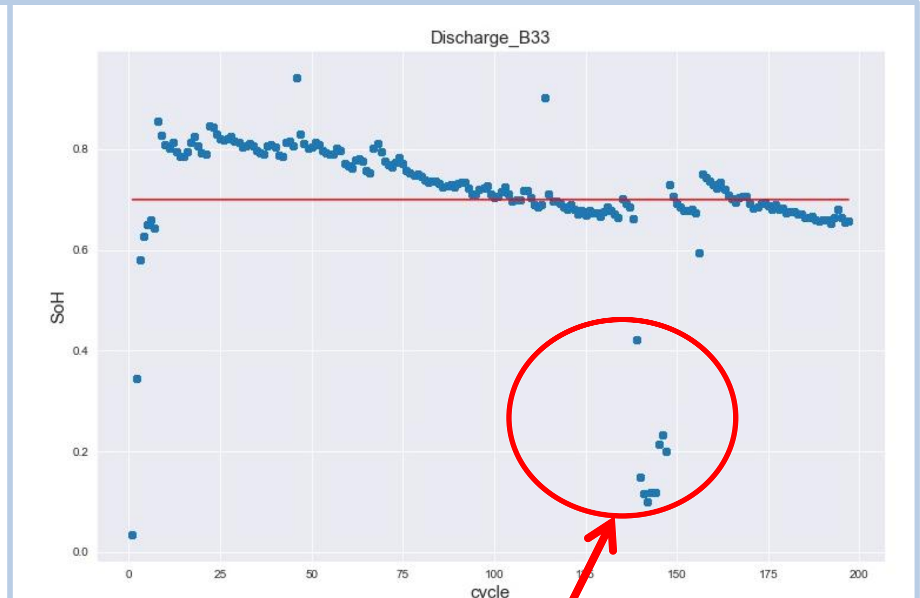
=G2/$J$2

	G	H	I	J	K
	capacity	cycle	SOH	Qnom	
0	1.856487	1	0.928244	2	
781	1.856487	1	0.928244		
703	1.856487	1	0.928244		
781	1.856487	1	0.928244		
922	1.856487	1	0.928244		
094	1.856487	1	0.928244		
281	1.856487	1	0.928244		

2. 수행과정

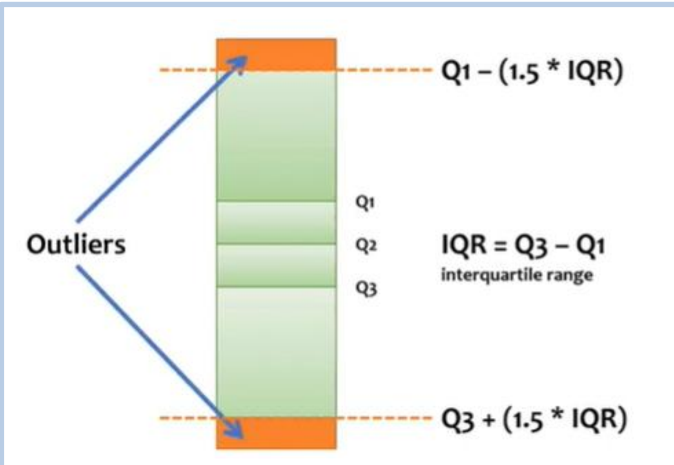
SOH 시각화





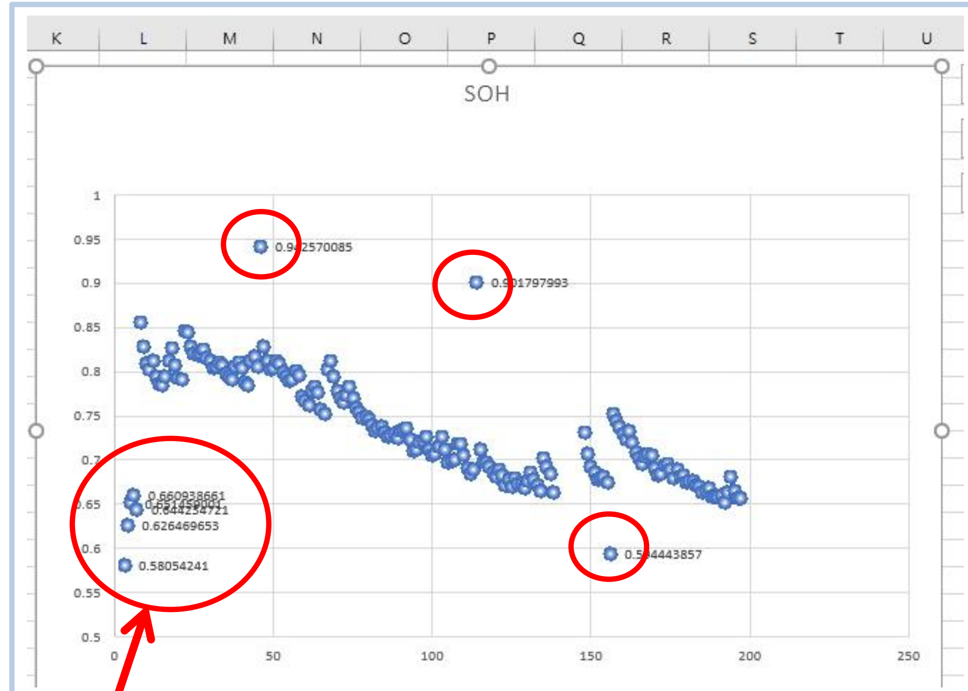
이상치

사분위수를 이용한 이상치 제거



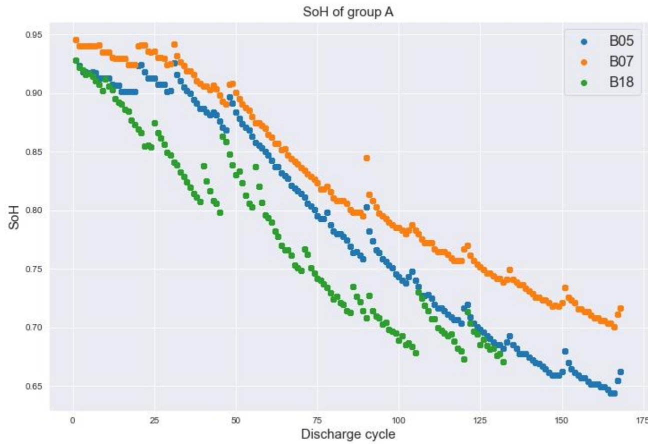
=IF(OR(I2<$M$6,I2>$M$7),"outlier","")

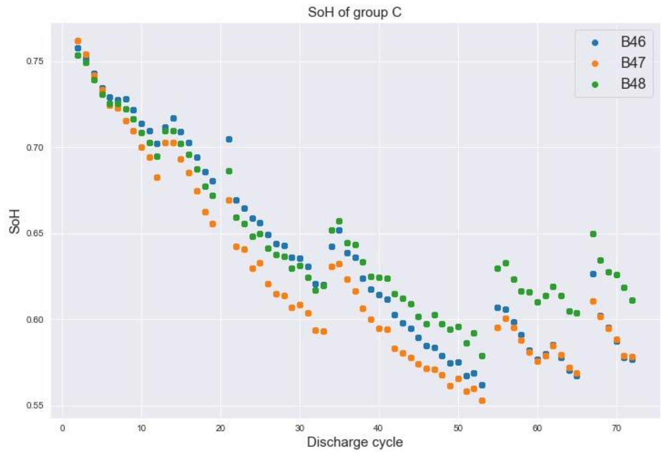
I	J	K	L	M
SOH	find outliers			
0.034213	outlier			
0.034213	outlier		Q1	0.682305
0.034213	outlier		Q3	0.796535
0.034213	outlier		IQR	0.114231
0.034213	outlier		L Bound	0.510959
0.034213	outlier		U Bound	0.967881
0.034213	outlier			

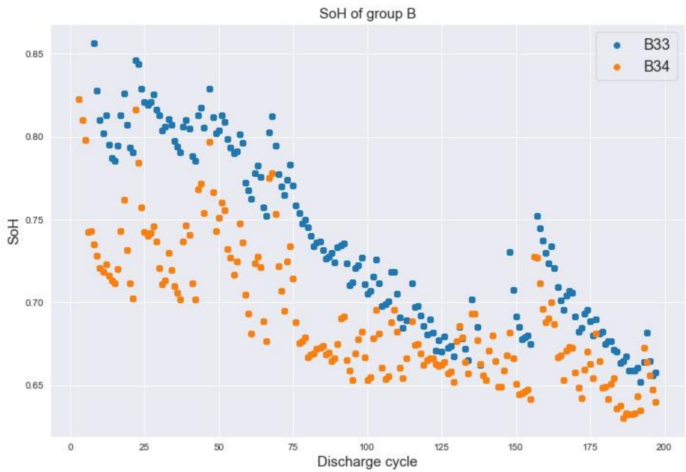


임의로 제거

2. 수행과정


SoH of group A
B05
B07
B18
SoH
Discharge cycle


SoH of group C
B46
B47
B48
SoH
Discharge cycle


SoH of group B
B33
B34
SoH
Discharge cycle

2. 수행과정

선형회귀

$$\hat{y}_i = a_1 x_i + a_0$$

Linear Least Squares

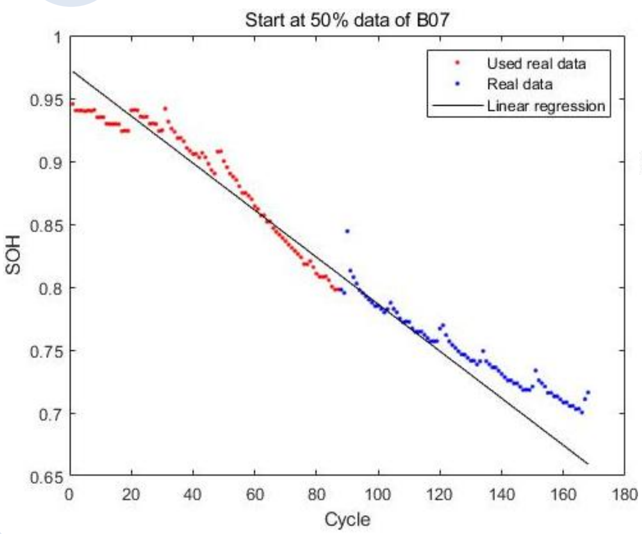
$$E \equiv E_2(a_0, a_1) = \sum_{i=1}^{m} [y_i - (a_1 x_i + a_0)]^2$$

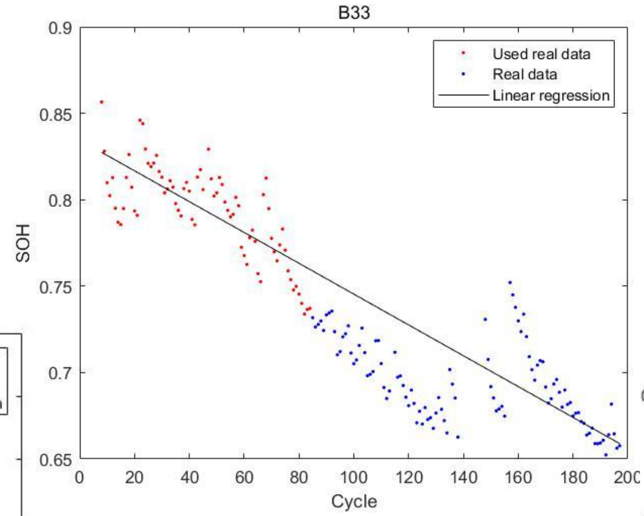
$$a_0 = \frac{\sum_{i=1}^{m} x_i^2 \sum_{i=1}^{m} y_i - \sum_{i=1}^{m} x_i y_i \sum_{i=1}^{m} x_i}{m \sum_{i=1}^{m} x_i^2 - \left(\sum_{i=1}^{m} x_i\right)^2}, \qquad a_1 = \frac{m \sum_{i=1}^{m} x_i y_i - \sum_{i=1}^{m} x_i \sum_{i=1}^{m} y_i}{m \sum_{i=1}^{m} x_i^2 - \left(\sum_{i=1}^{m} x_i\right)^2}.$$

2. 수행과정

데이터의 50%를 이용한 결과

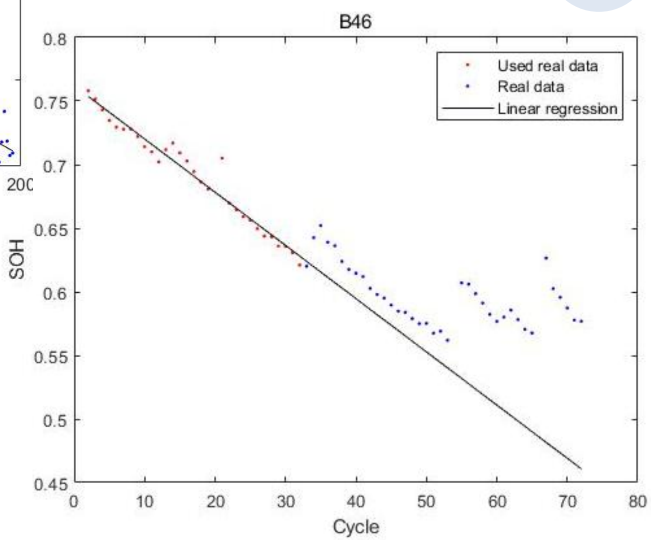
A





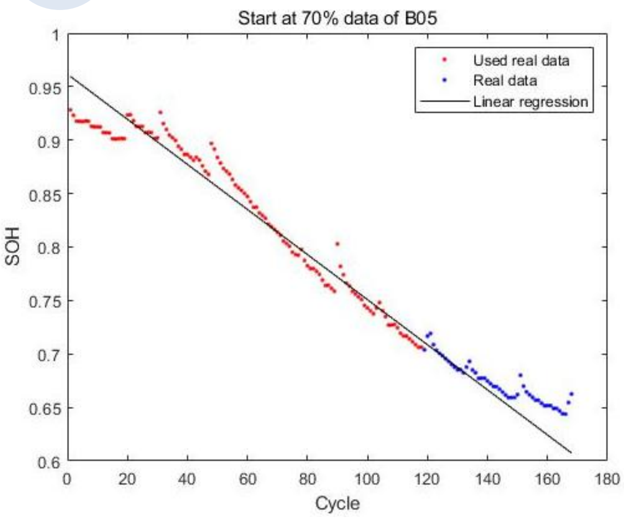
B

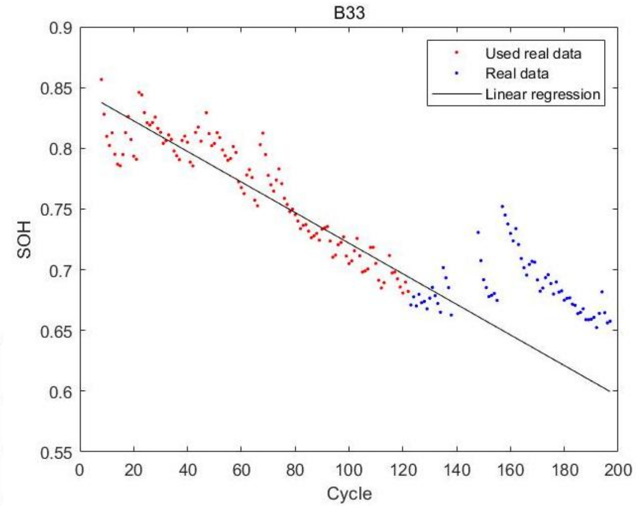
C



데이터의 70%를 이용한 결과

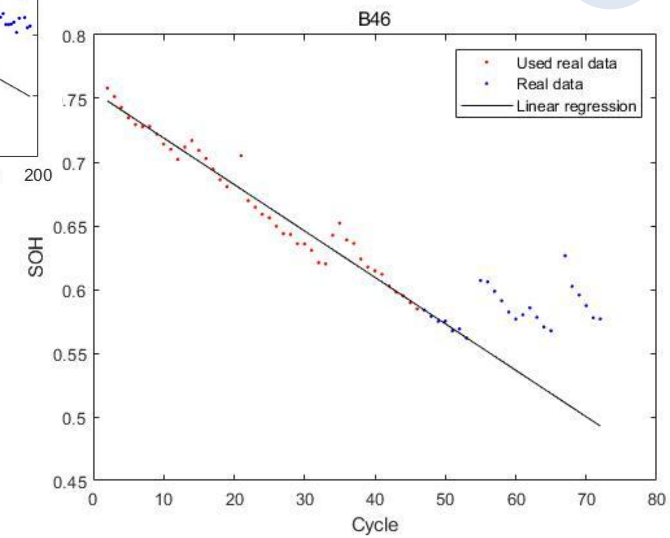
A



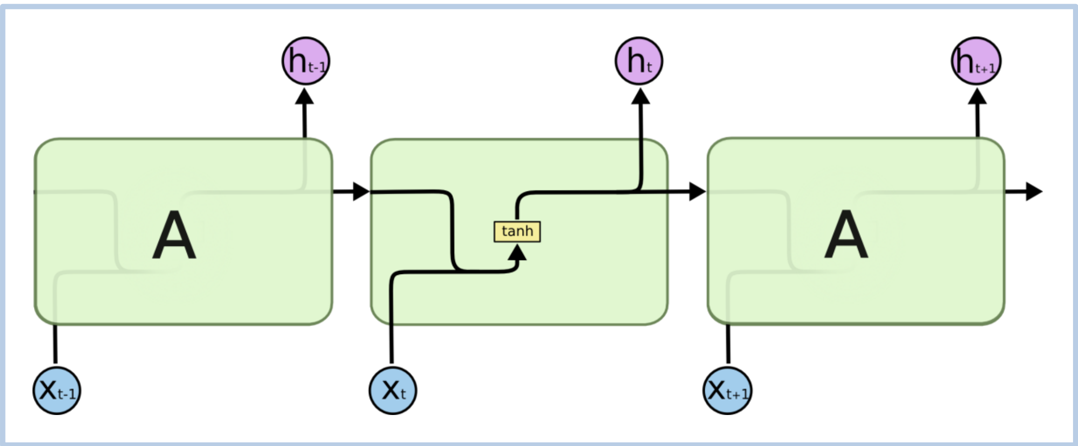


B

C



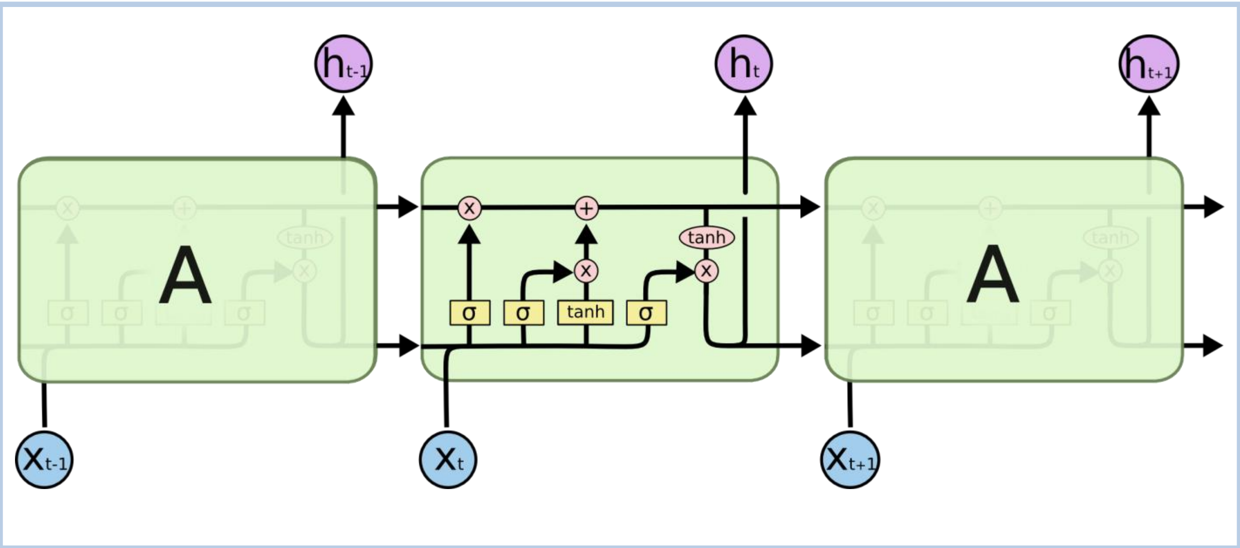
RNN



$$h_t = f_w(h_{t-1},\ x_t)$$
$$= \tanh(w_{hh}h_{t-1} + w_{xh}x_t)$$
$$y_t = w_{hy}h_t$$

x_t : 현재 입력, h_{t-1} : 과거 기억, h_{t-1} : 현재기억

LSTM



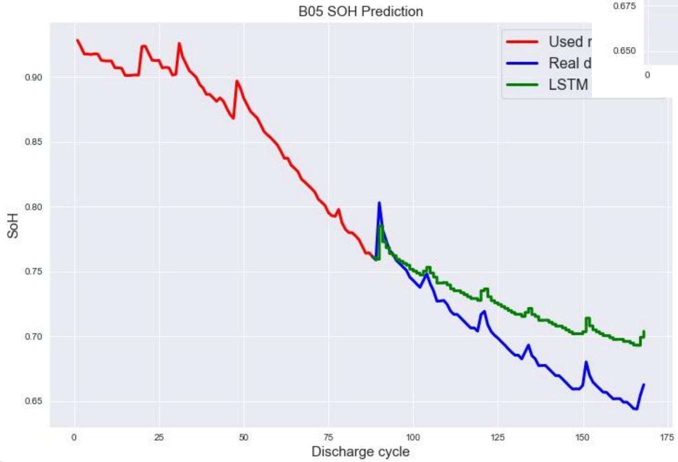
$$f_t = \sigma(W_{xh\_f}x_t + W_{hh\_f}h_{t-1} + b_{h\_f})$$
$$i_t = \sigma(W_{xh\_i}x_t + W_{hh\_i}h_{t-1} + b_{h\_i})$$
$$o_t = \sigma(W_{xh\_o}x_t + W_{hh\_o}h_{t-1} + b_{h\_o})$$
$$\hat{c}_t = tanh(W_{xh\_\hat{c}}x_t + W_{hh\_\hat{c}}h_{t-1} + b_{h\_\hat{c}})$$
$$c_t = f_t \odot c_{t-1} + i_t \odot \hat{c}_t$$
$$h_t = o_t \odot \tanh(c_t)$$

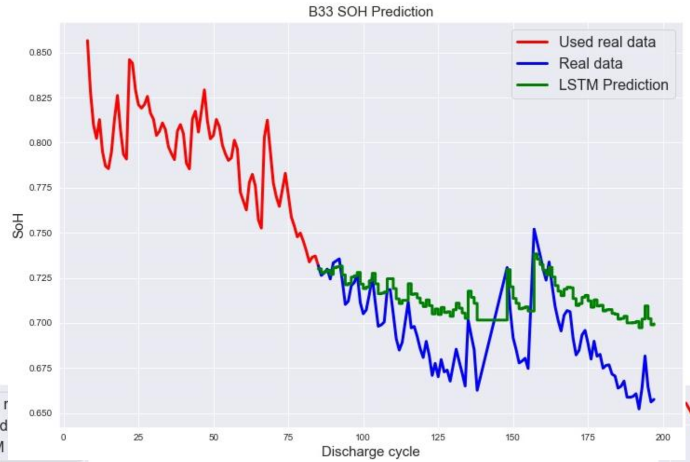
1. **Forget Gate :** 과거 정보를 잊기 위한 게이트
2. **Input Gate :** 현재 정보를 기억하기 위한 게이트
3. **Output Gate**

2. 수행과정

데이터의 50%를 이용한 결과

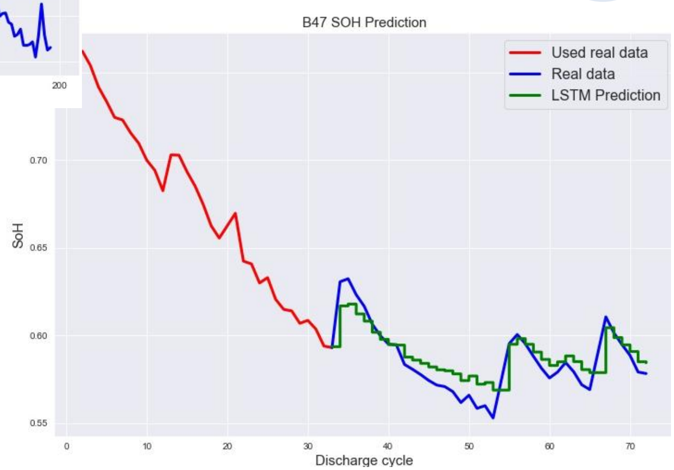
A





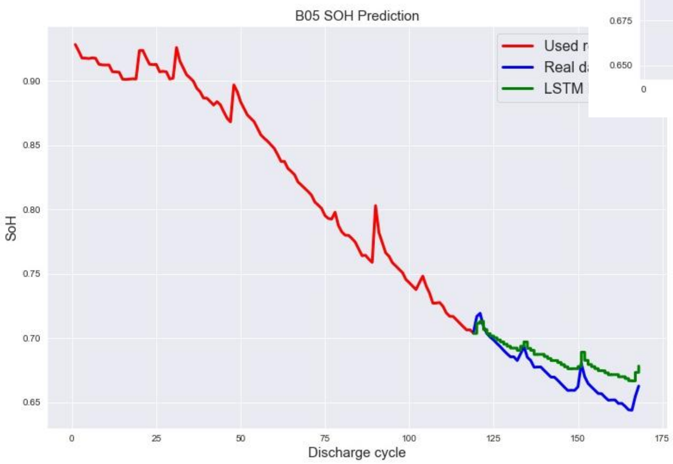
B

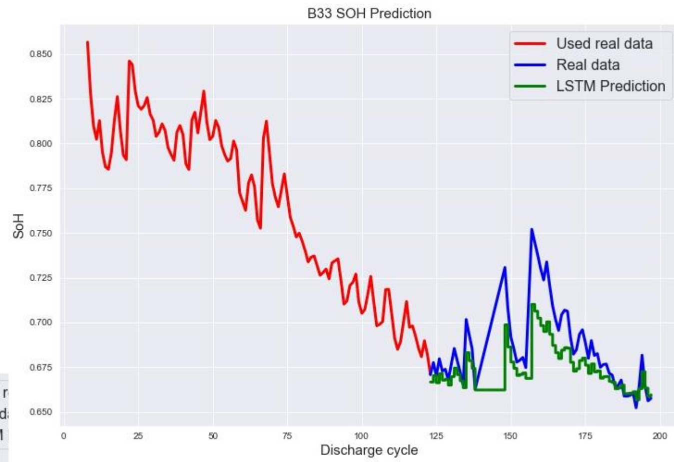
C



데이터의 70%를 이용한 결과

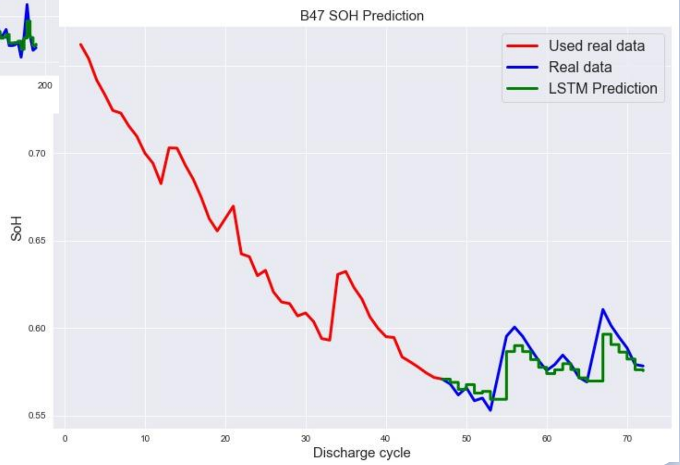
A





B

C



3. 결과분석

RMSE

	A						B				C					
	B05		B07		B18		B33		B34		B46		B47		B48	
	50%	70%	50%	70%	50%	70%	50%	70%	50%	70%	50%	70%	50%	70%	50%	70%
선형회귀	0.1599	0.1431	0.1190	0.1315	0.1389	0.1231	0.0303	0.0351	0.0255	0.0273	0.0654	0.0385	0.1129	0.0543	0.0973	0.0470
LSTM	0.030	0.014	0.026	0.015	0.056	0.009	0.024	0.016	0.008	0.011	0.018	0.007	0.008	0.006	0.009	0.009

MAE

	A						B				C					
	B05		B07		B18		B33		B34		B46		B47		B48	
	50%	70%	50%	70%	50%	70%	50%	70%	50%	70%	50%	70%	50%	70%	50%	70%
선형회귀	0.1595	0.0934	0.0777	0.1307	0.1380	0.0803	0.0258	0.0202	0.0196	0.0154	0.0524	0.0207	0.0979	0.0314	0.0839	0.0266
LSTM	0.026	0.012	0.023	0.013	0.053	0.007	0.020	0.012	0.006	0.008	0.016	0.005	0.007	0.005	0.008	0.007

출처

Dataset

[1] NASA PCoE Datasets: Experiments on Li-ion Batteries,
https://ti.arc.nasa.gov/tech/dash/groups/pcoe/prognostic-data-repository/

Reference

[1] 인공지능 기법을 적용한 배터리 노화 상태 (SOC, SOH) 실시간 예측 시뮬레이션, https://icim.nims.re.kr/platform/question/24.

[2] Pseudo code for LSTM computation
https://gist.github.com/manurastogi/d7656b8ece172c9e614e06dbbdb9e10f

끝