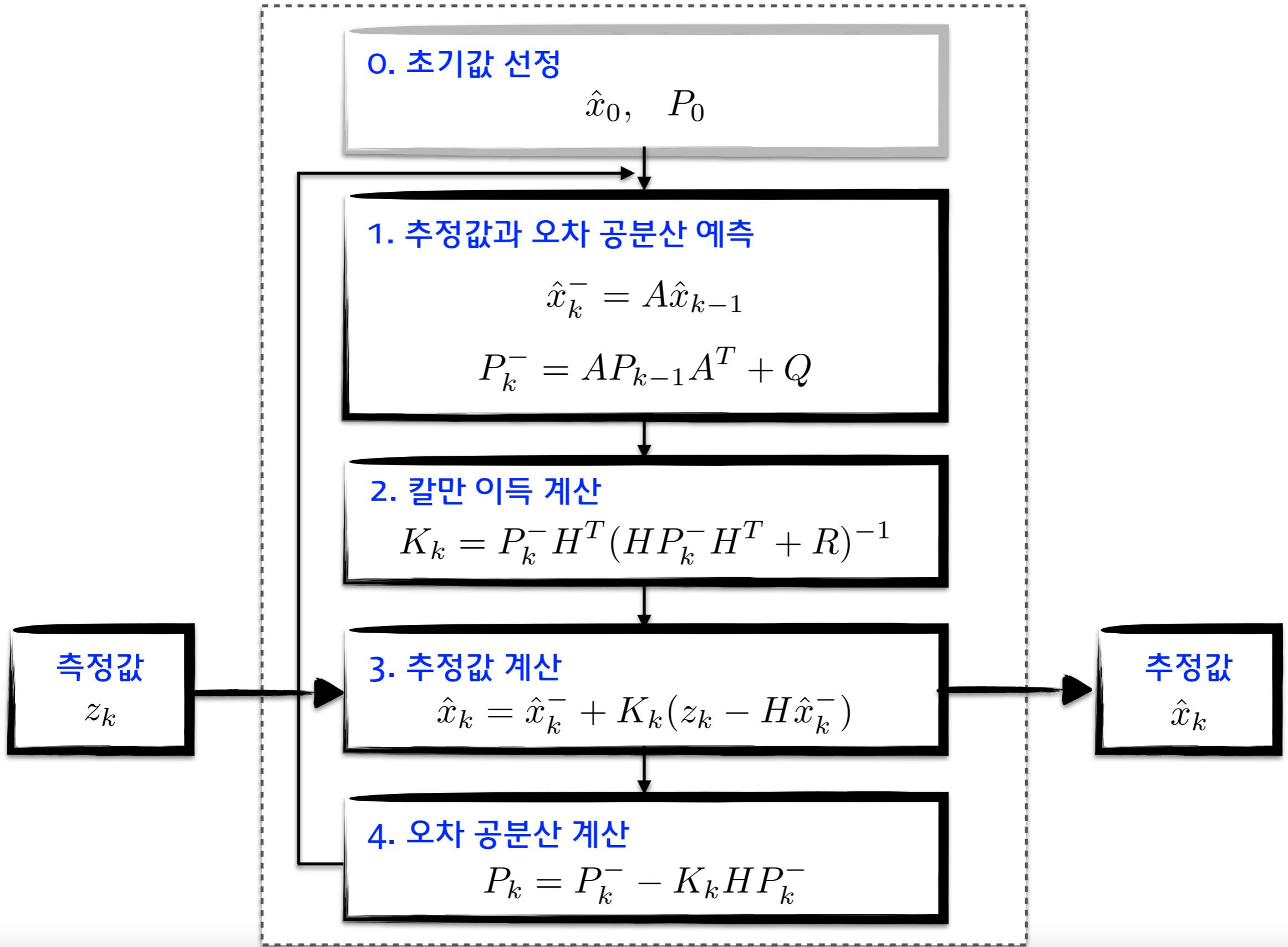


칼만 필터 & 초간단 예제

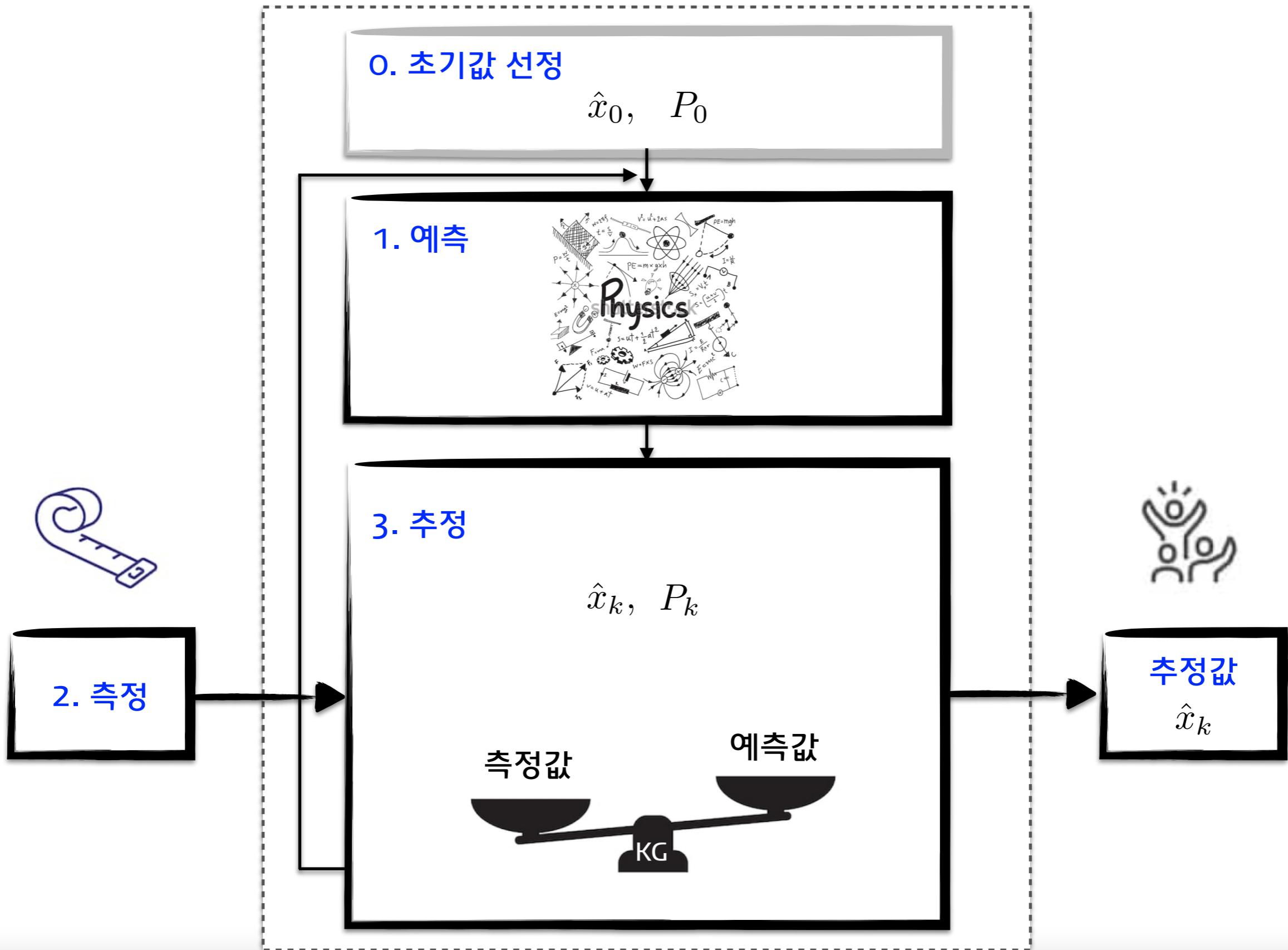
문태봉

2020.01.15 (수)

칼만 필터 알고리즘



칼만 필터 알고리즘

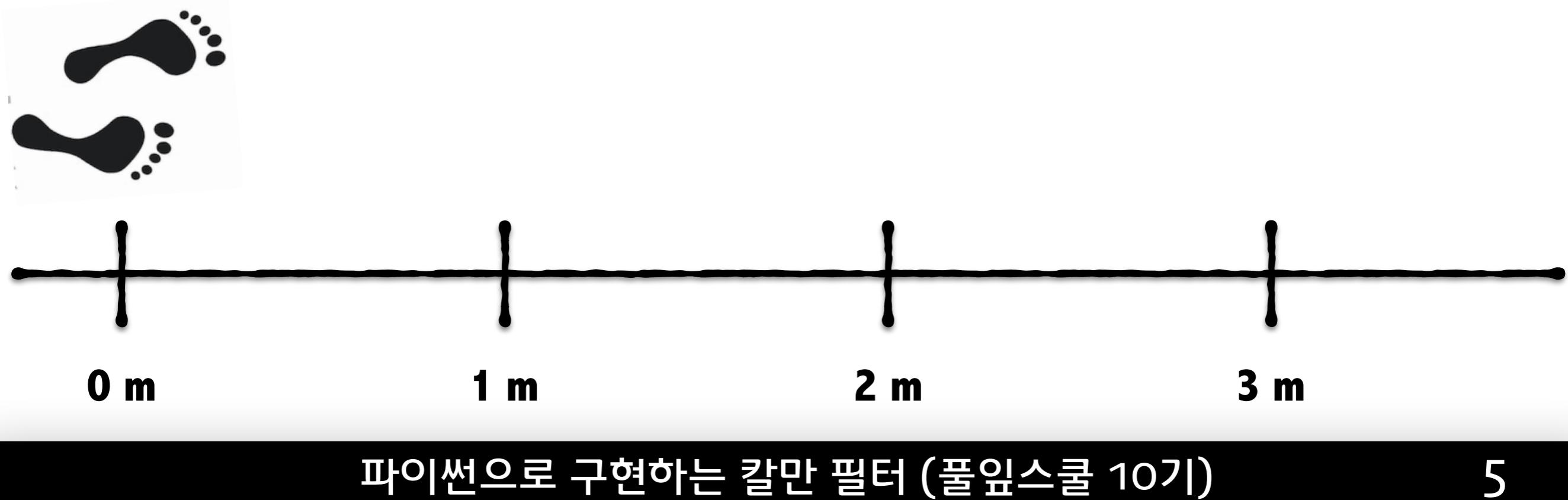


칼만 필터 흐름 예시

1차원에서 실제 이동 경로 추정을 해봐요!

트랙킹

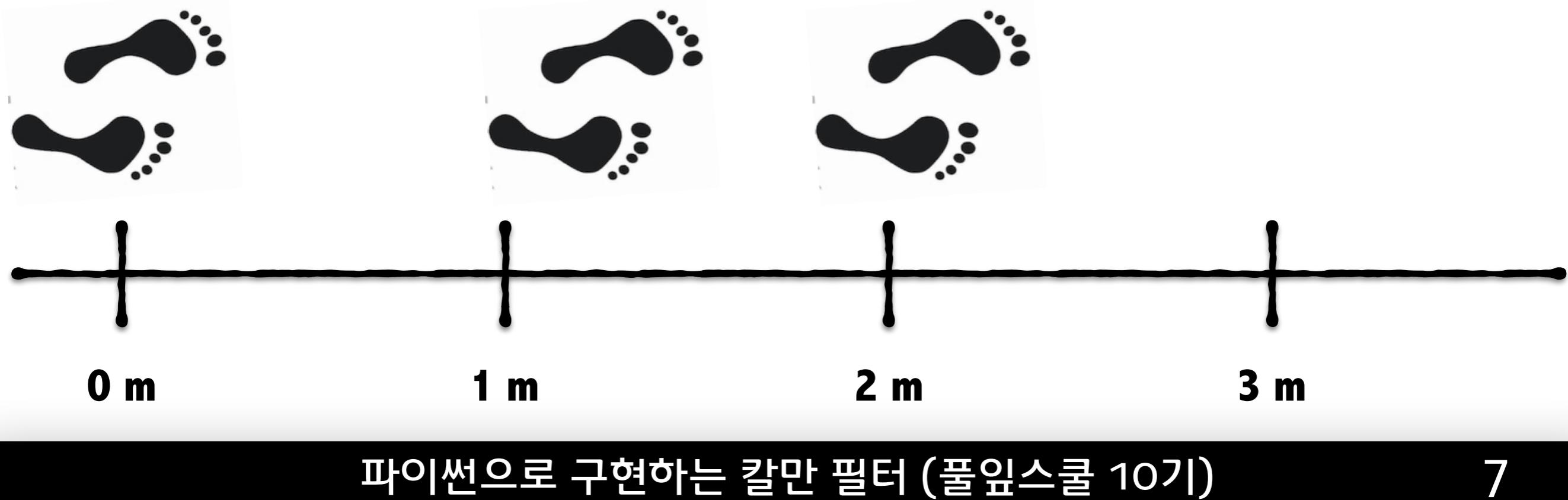
실제 이동 경로



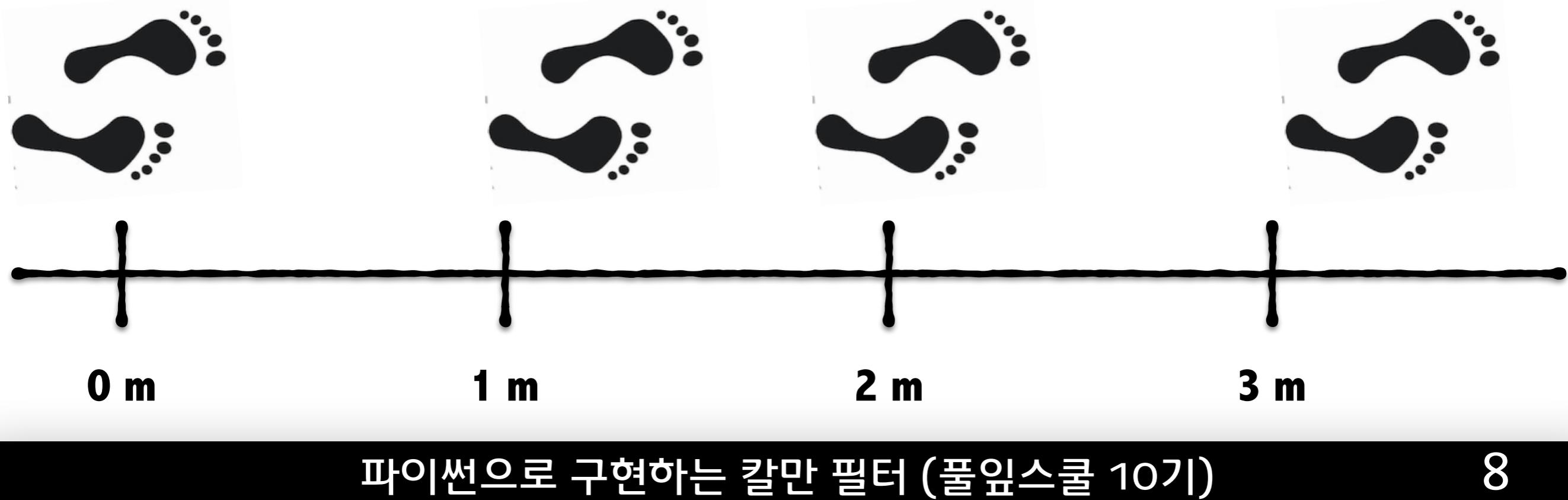
실제 이동 경로



실제 이동 경로

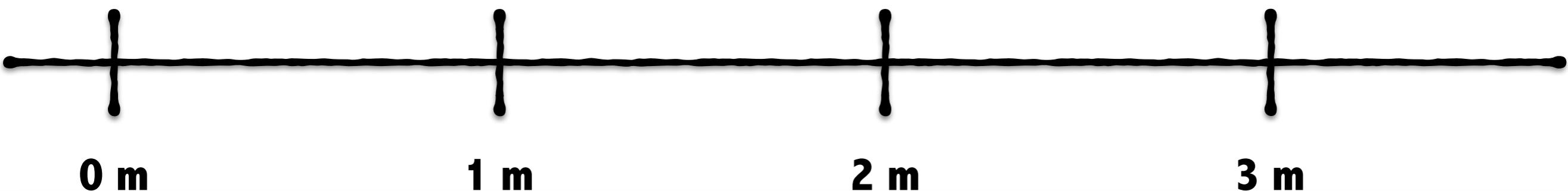
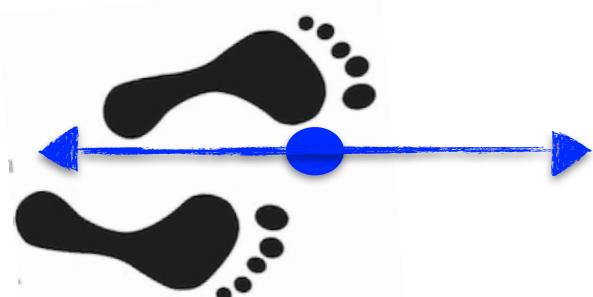
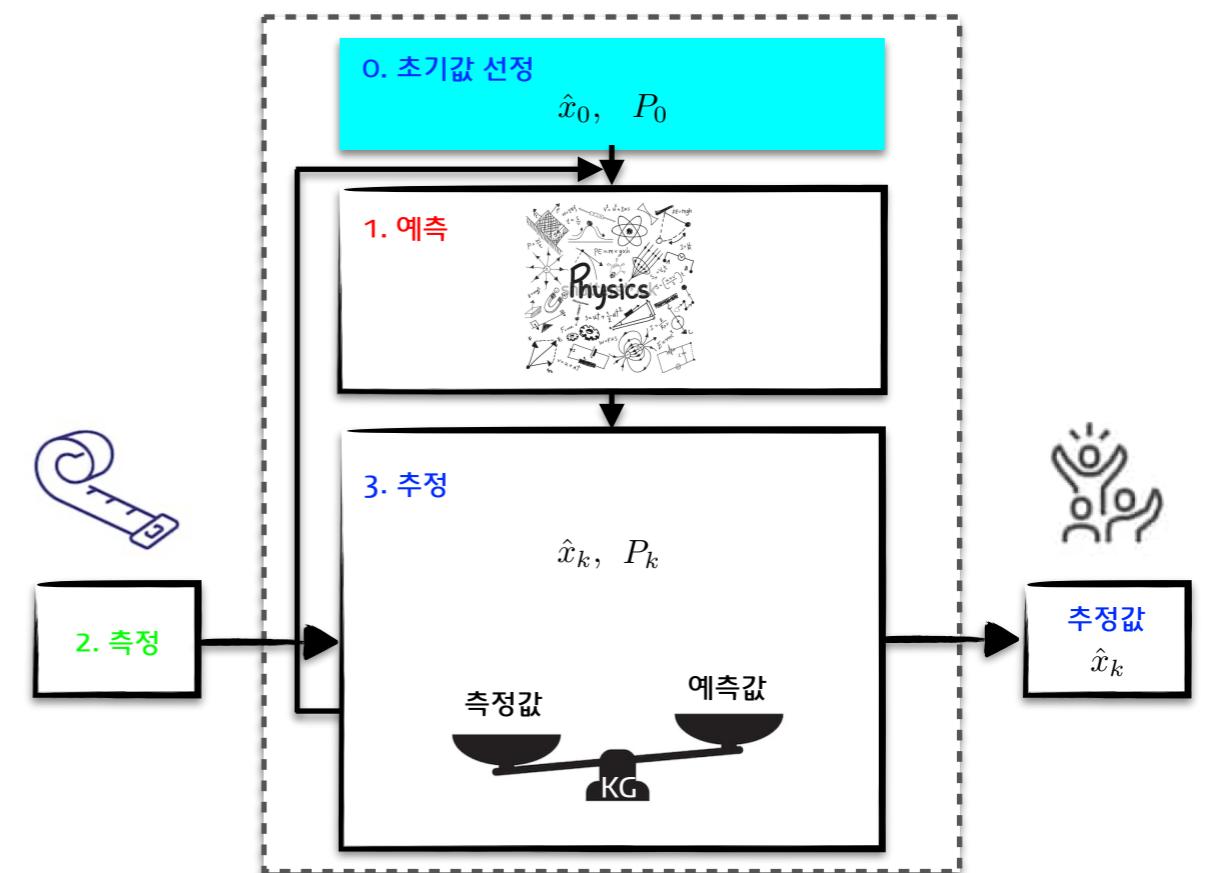
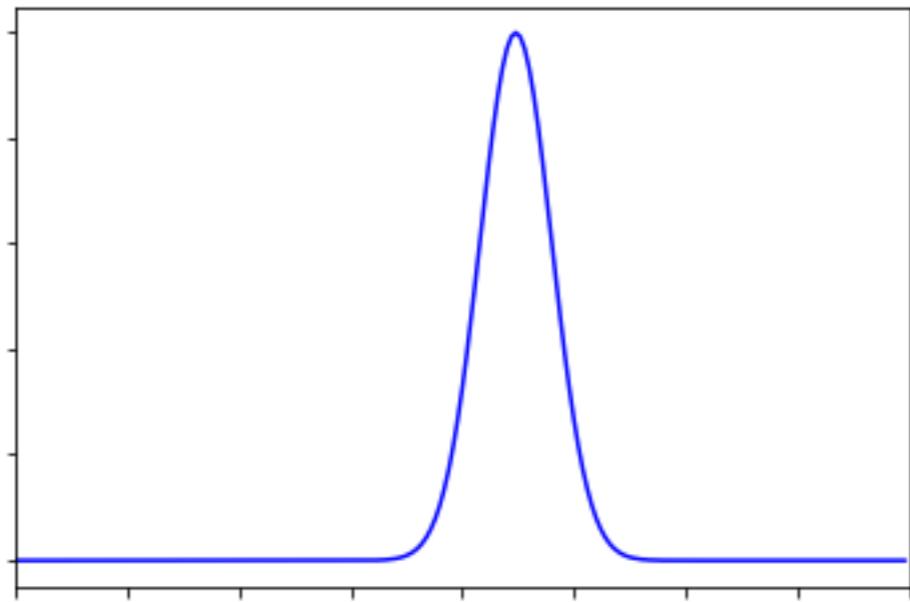


실제 이동 경로



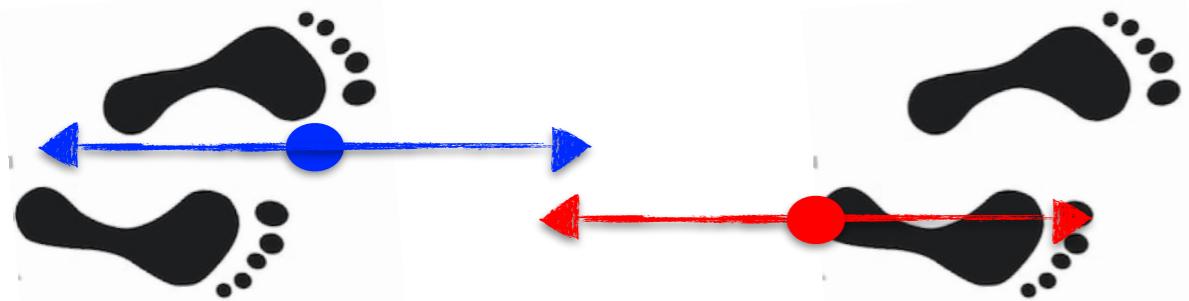
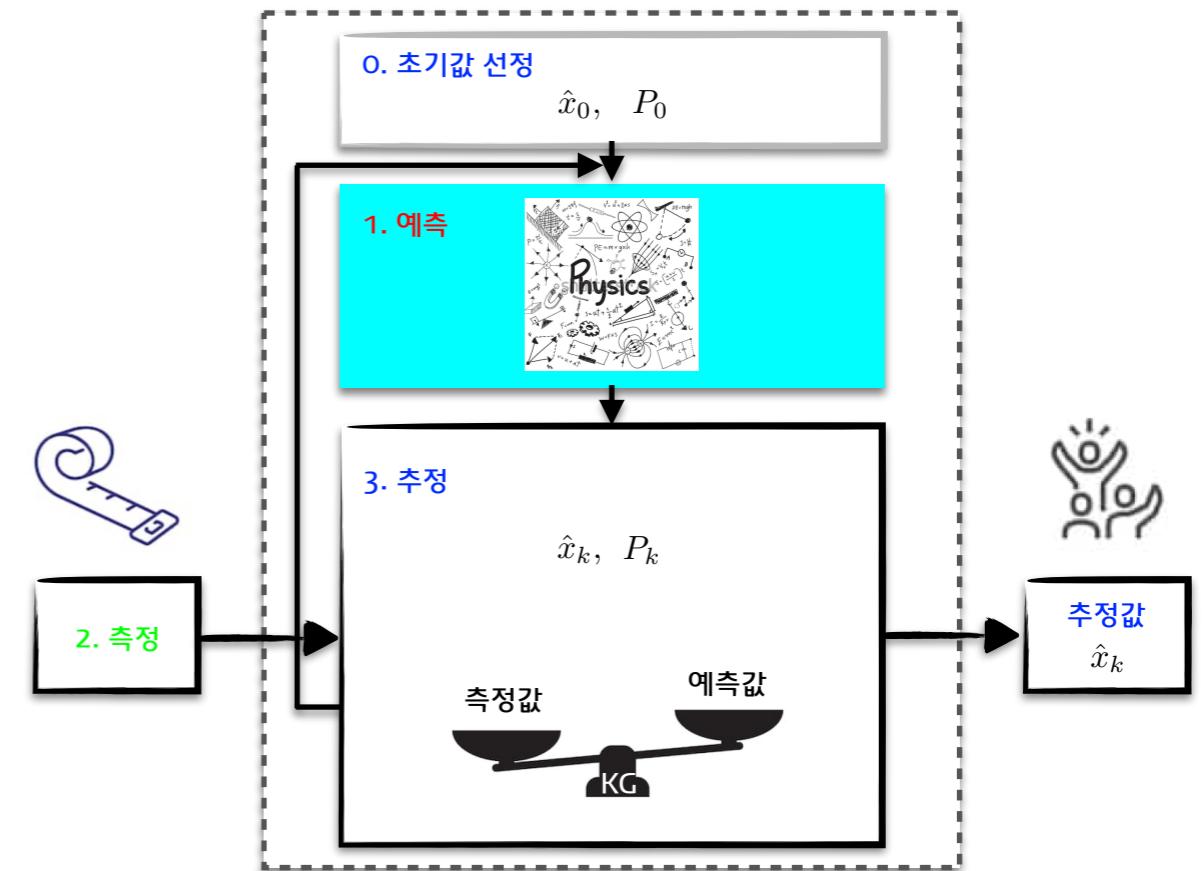
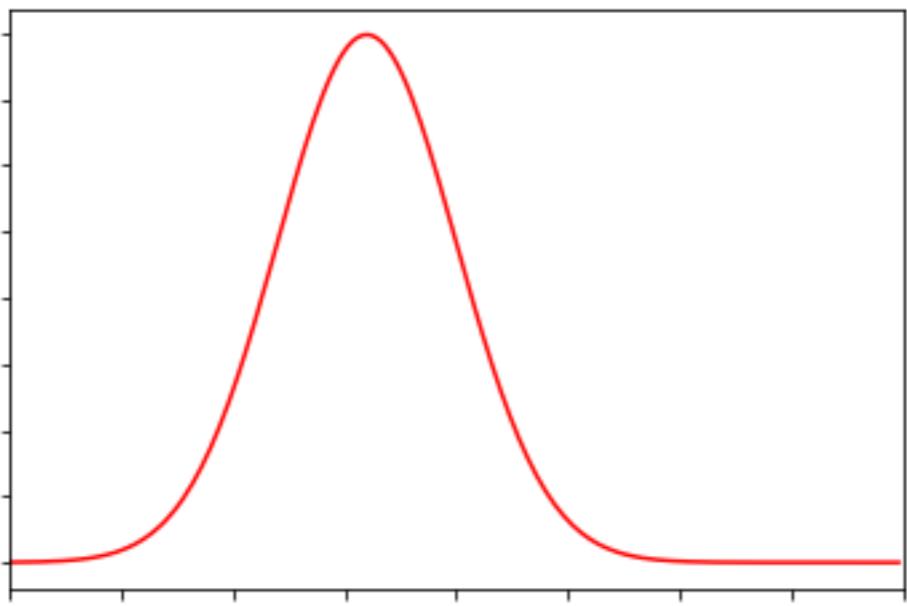
경로 추정 과정

대략적으로 보아요!



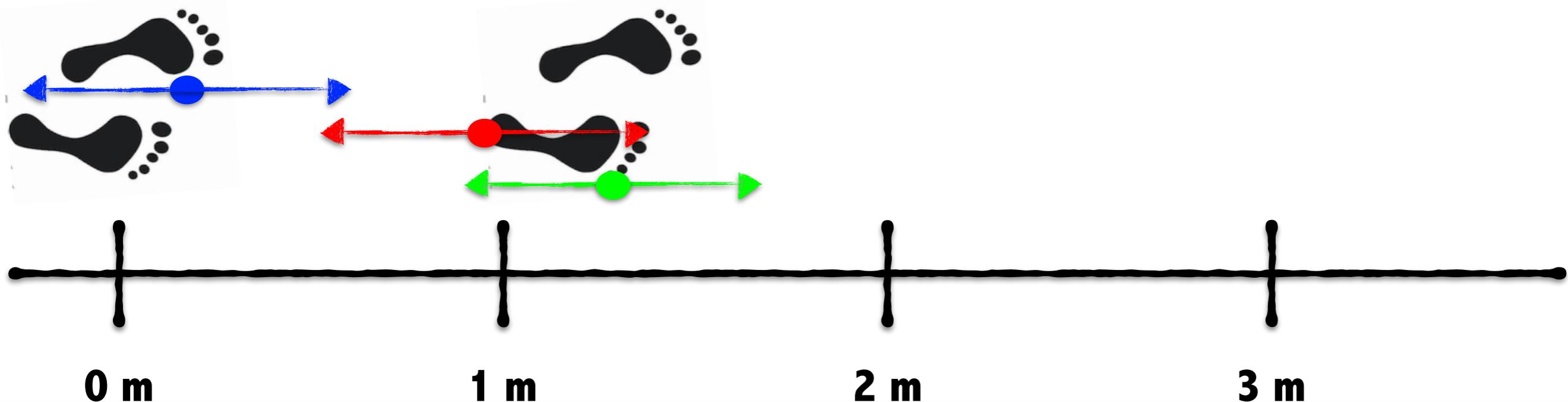
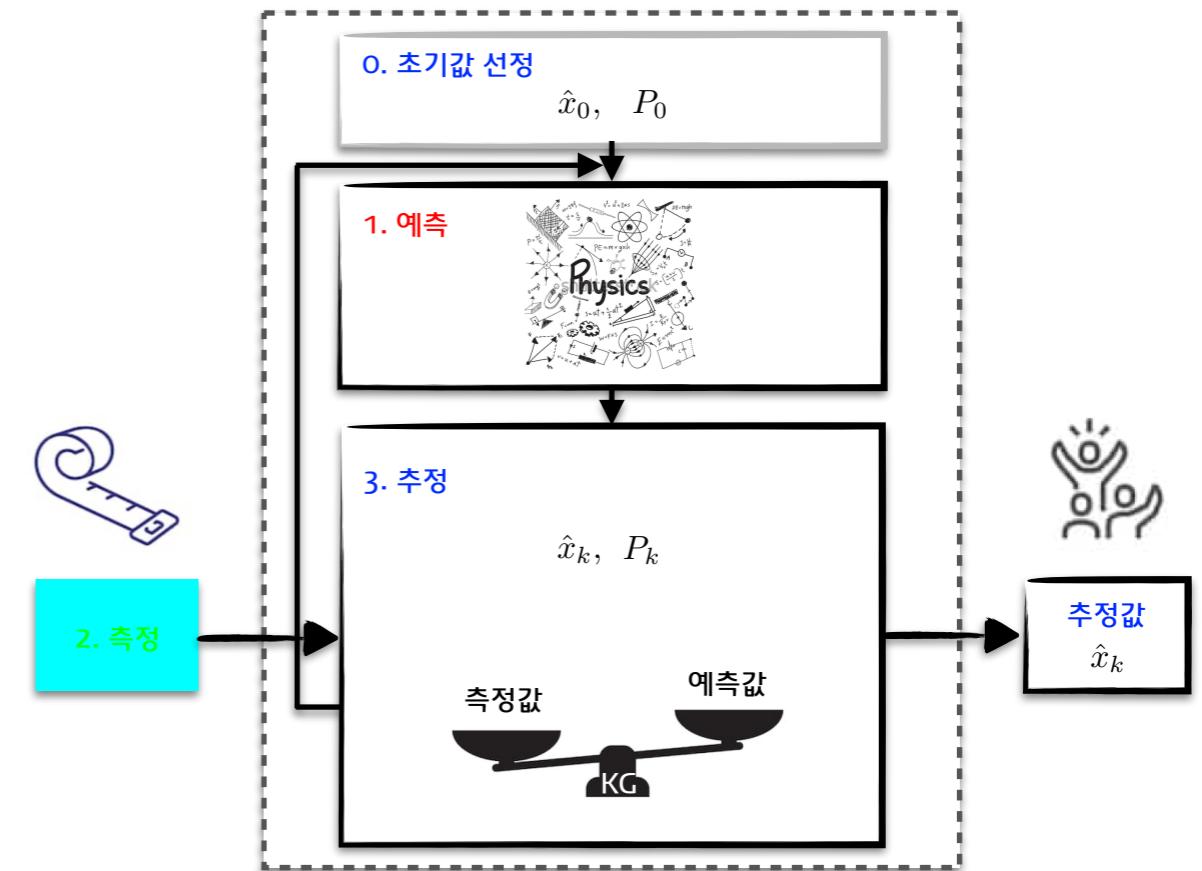
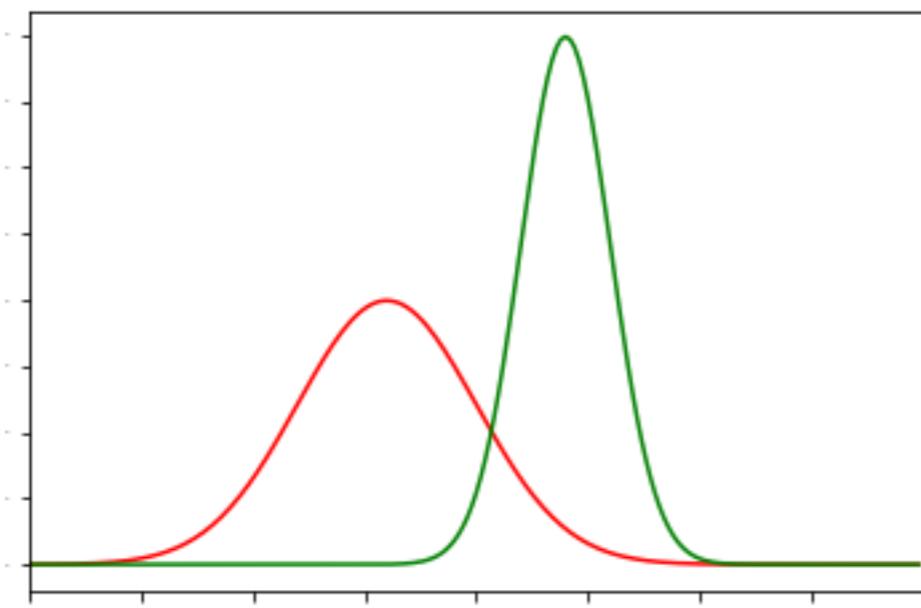
파이썬으로 구현하는 칼만 필터 (풀잎스쿨 10기)

경로 추정 과정

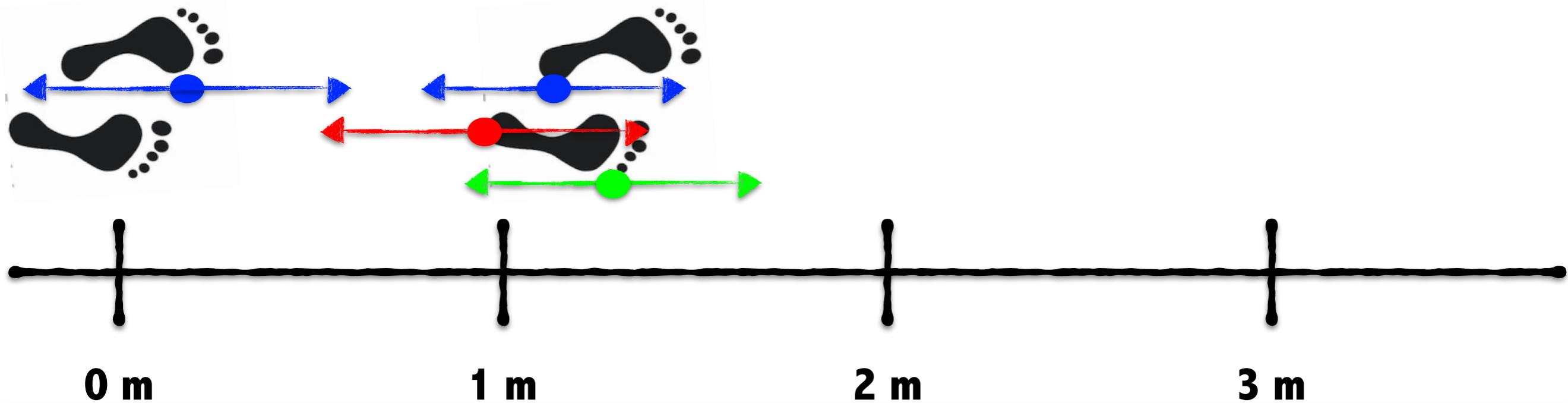
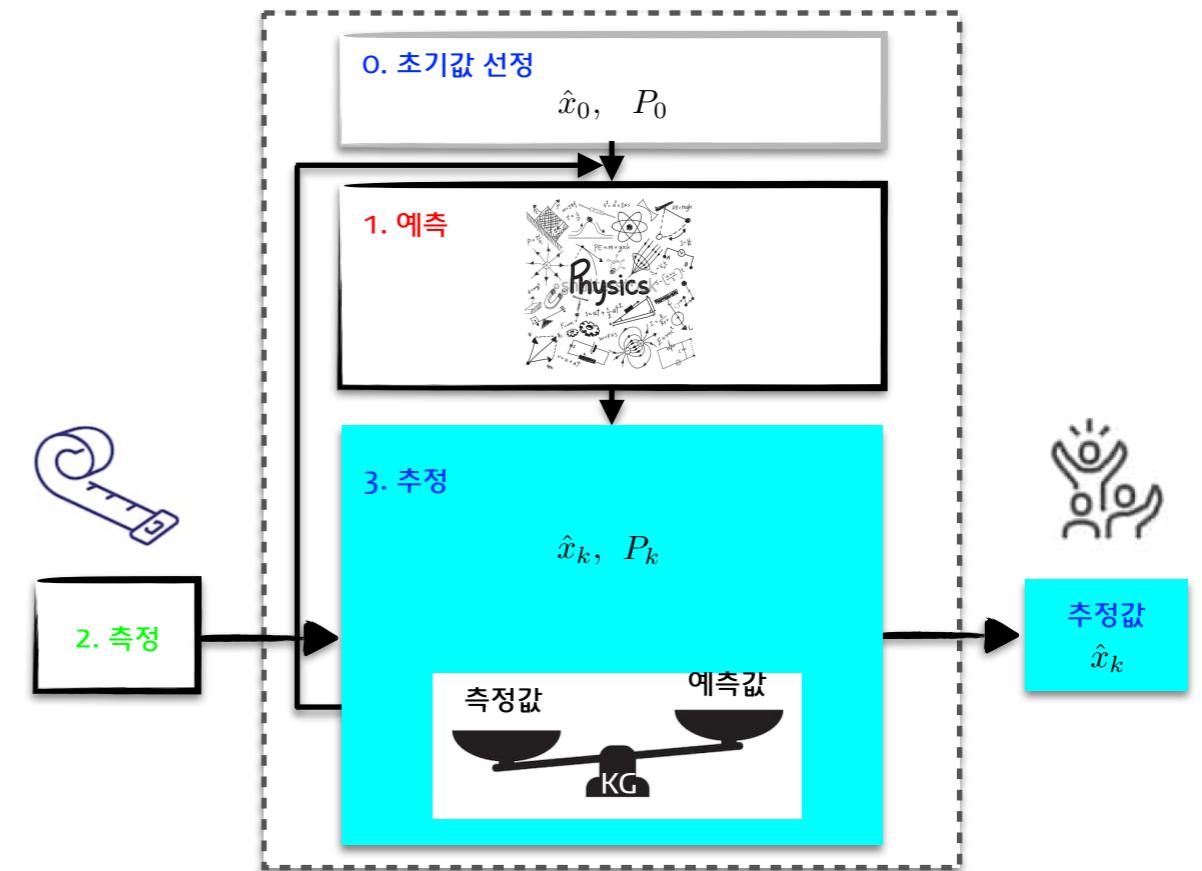
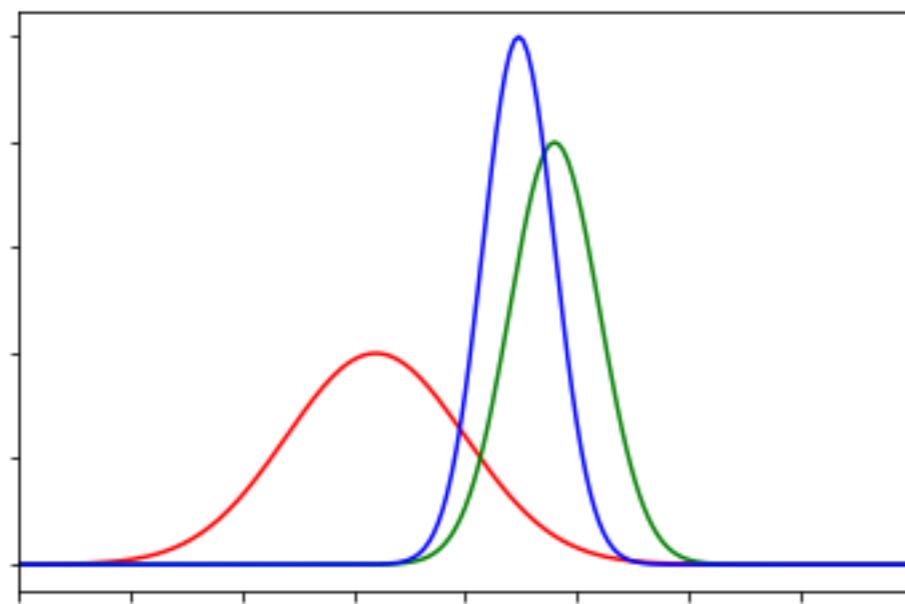


파이썬으로 구현하는 칼만 필터 (풀잎스쿨 10기)

경로 추정 과정

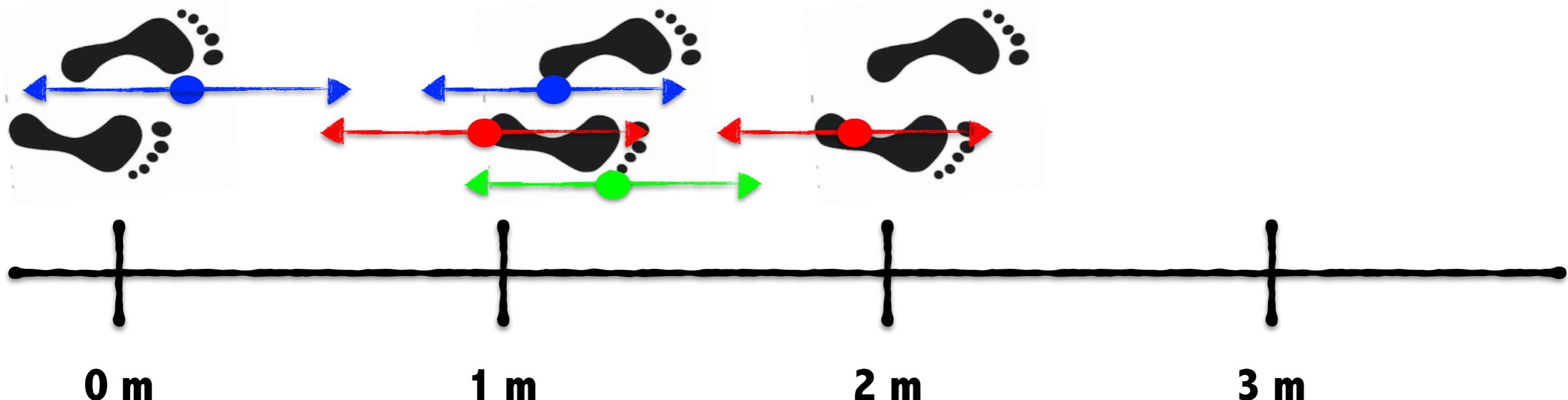
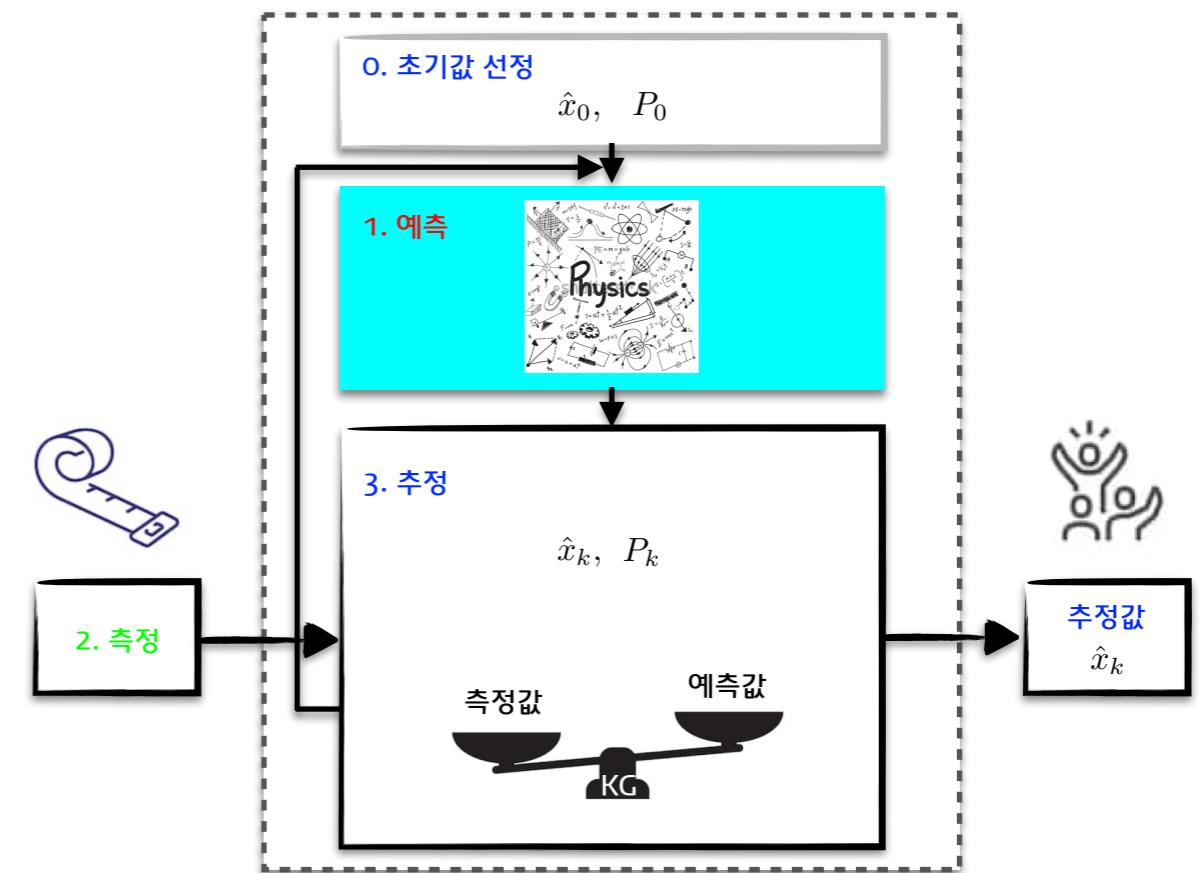
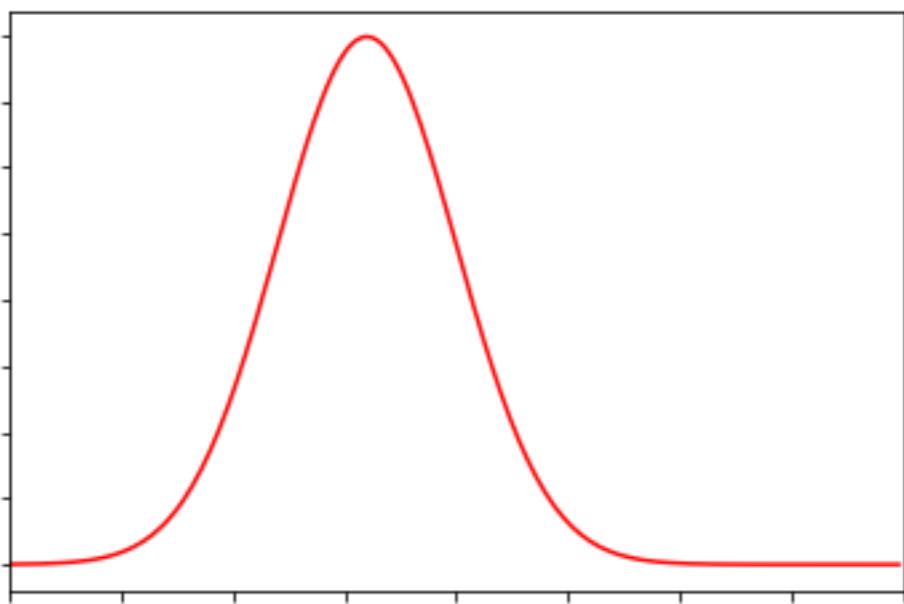


경로 추정 과정

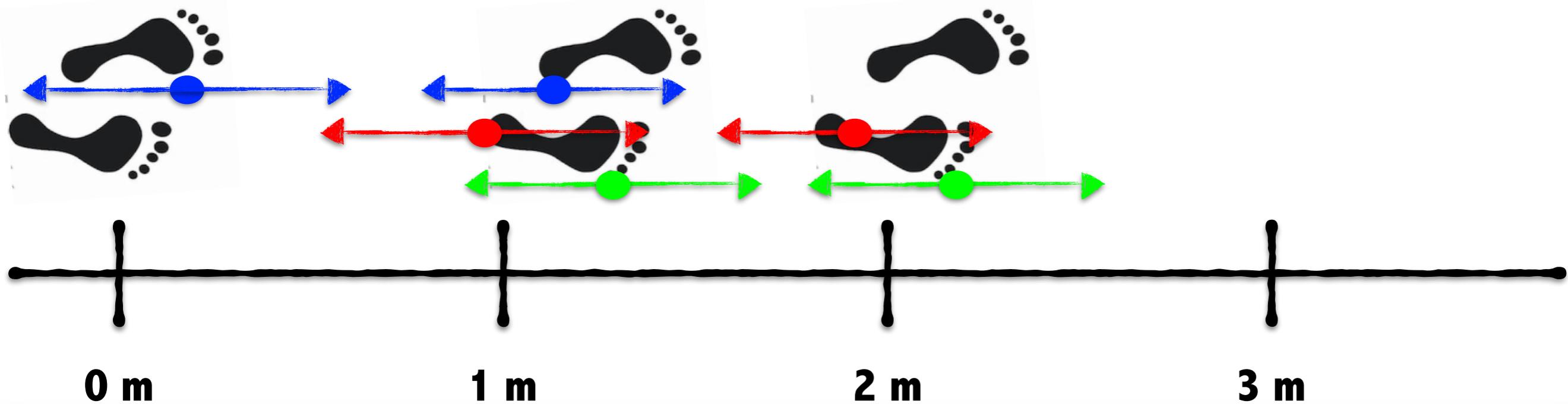
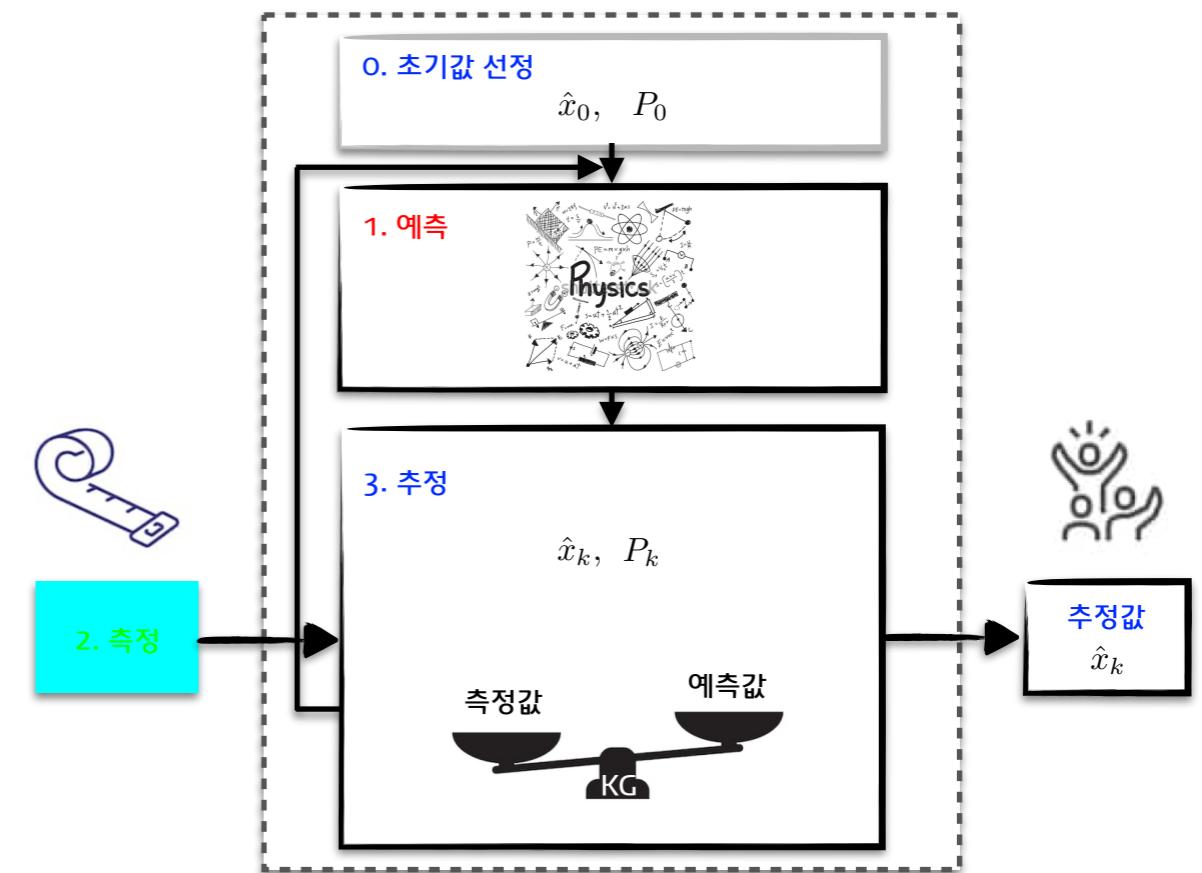
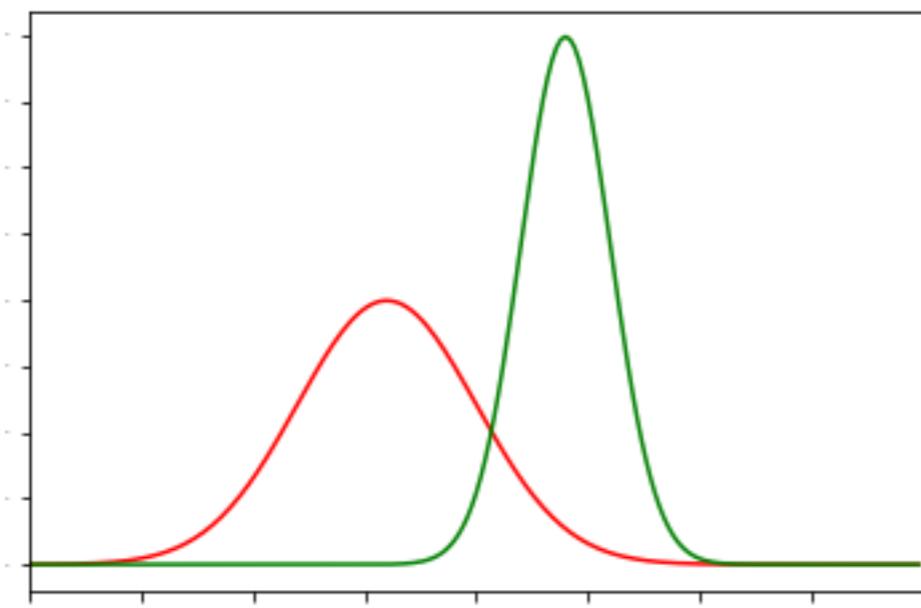


파이썬으로 구현하는 칼만 필터 (풀잎스쿨 10기)

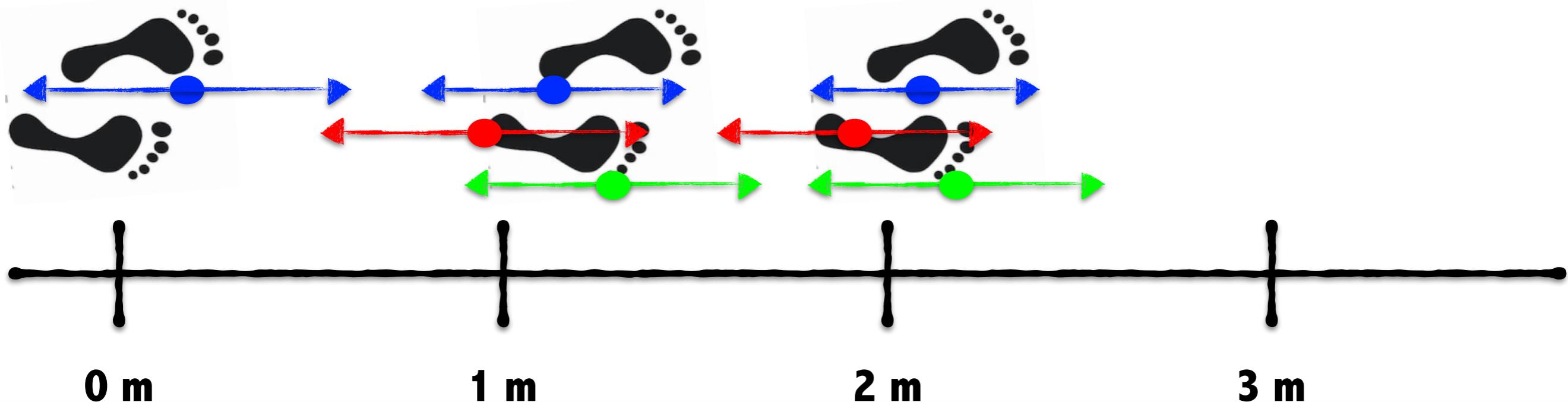
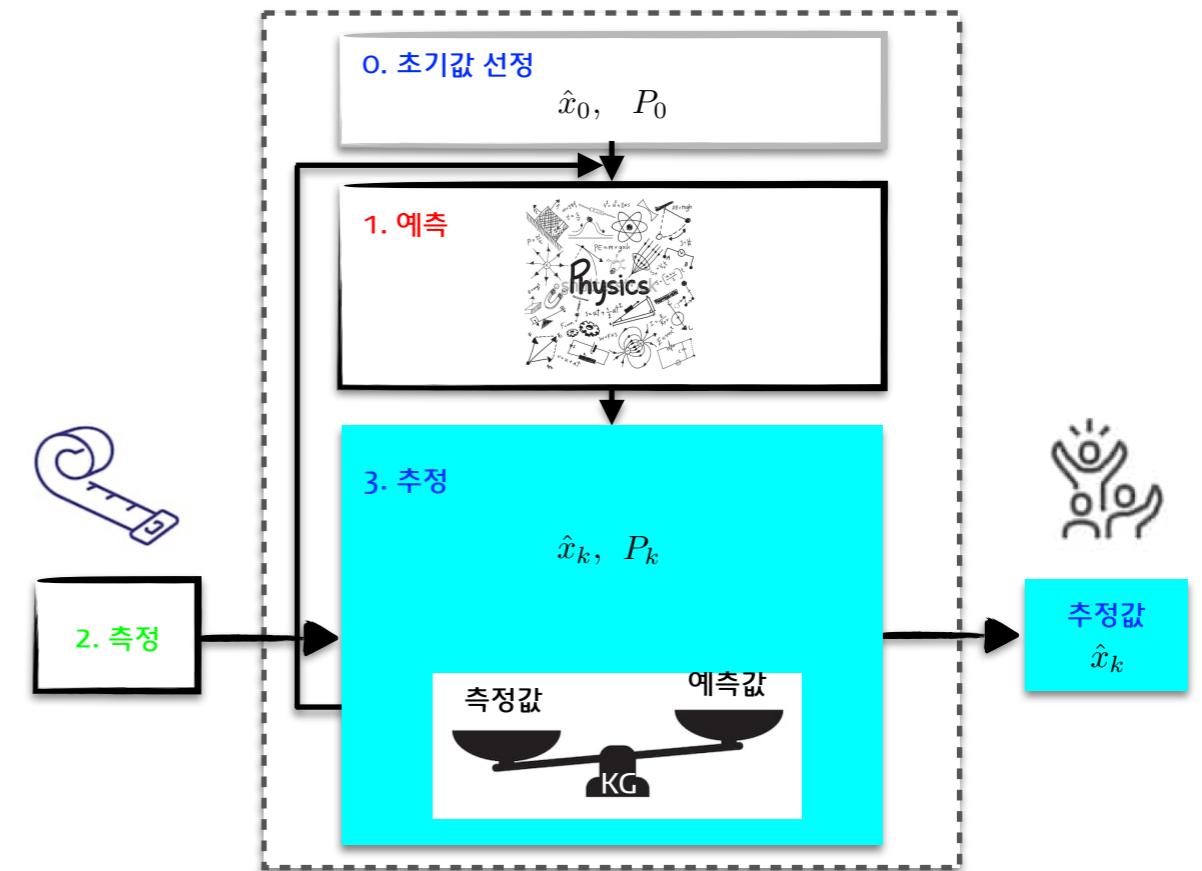
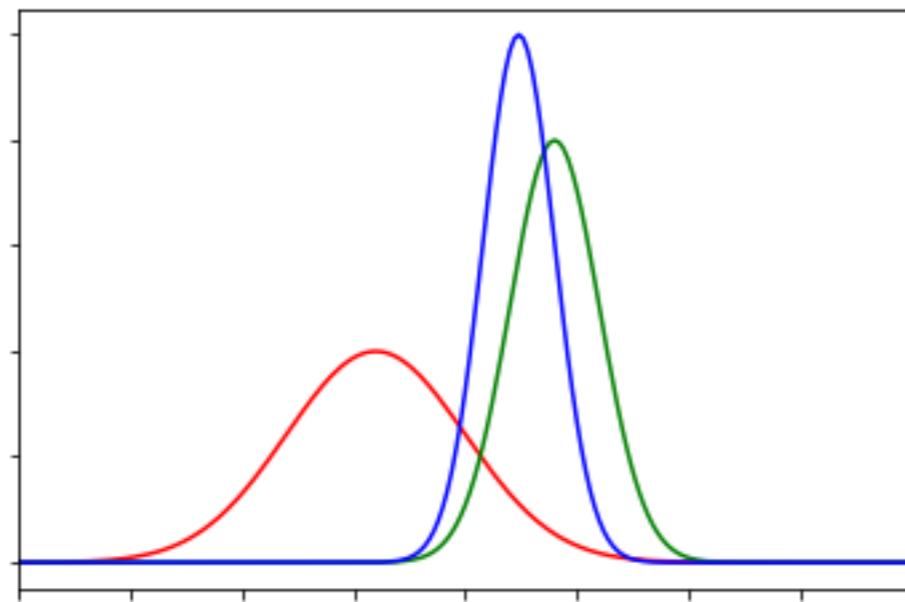
경로 추정 과정



경로 추정 과정

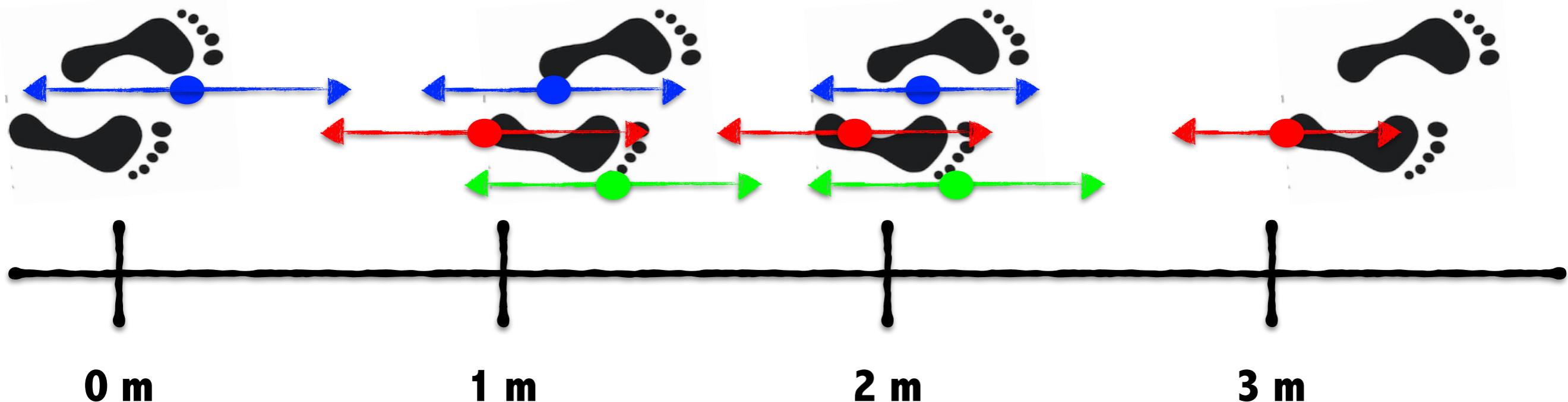
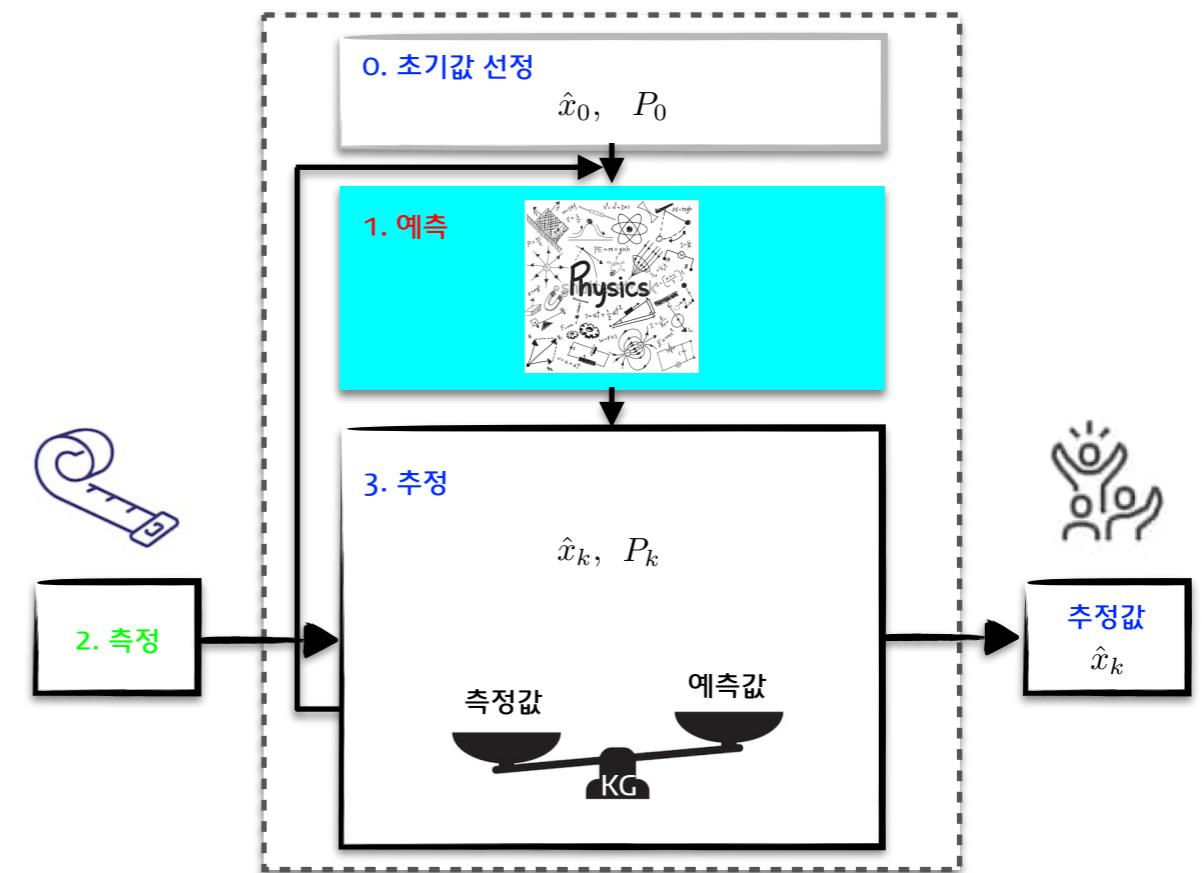
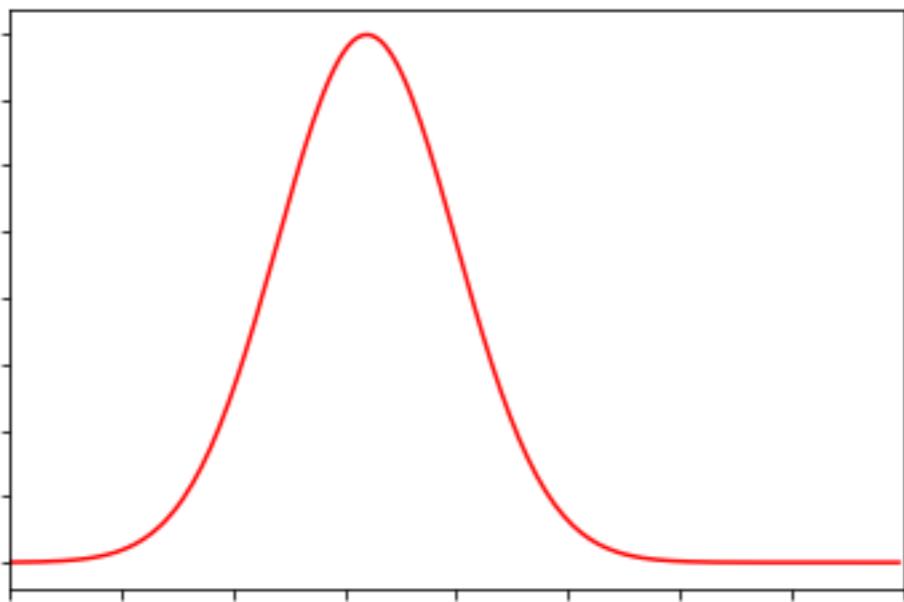


경로 추정 과정



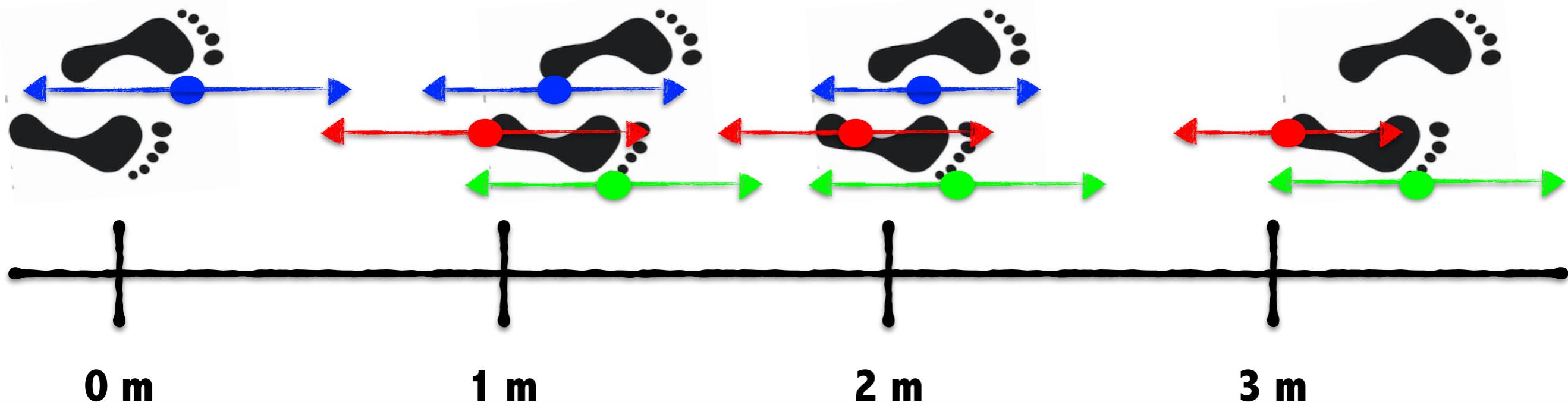
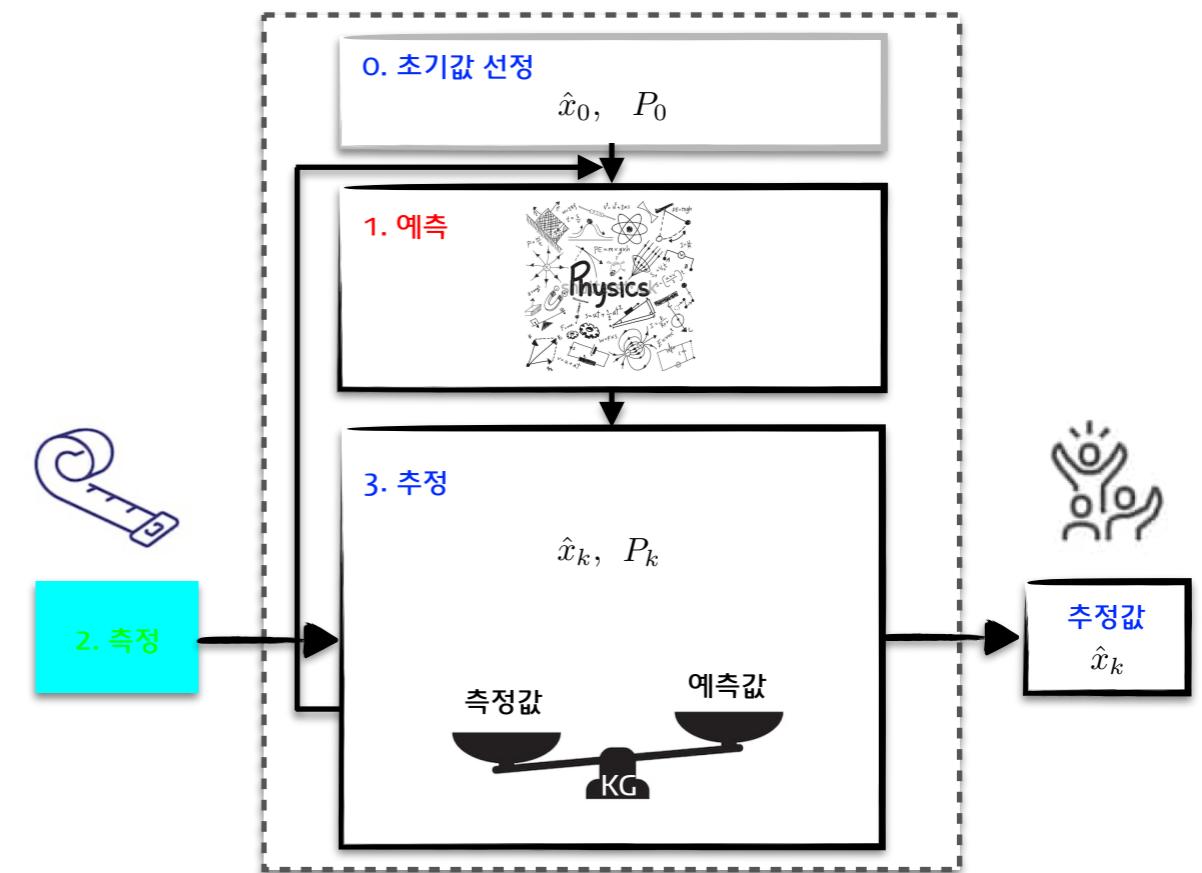
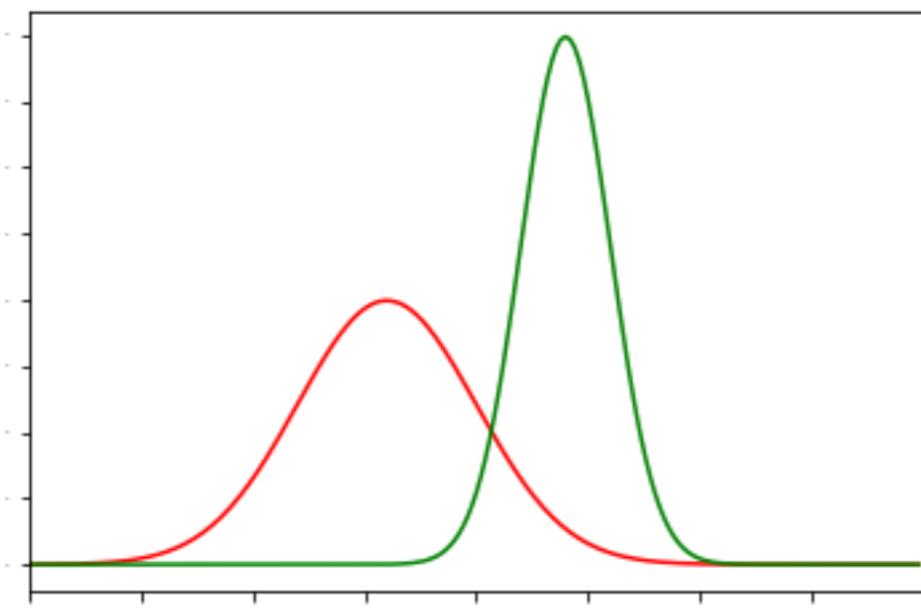
파이썬으로 구현하는 칼만 필터 (풀잎스쿨 10기)

경로 추정 과정



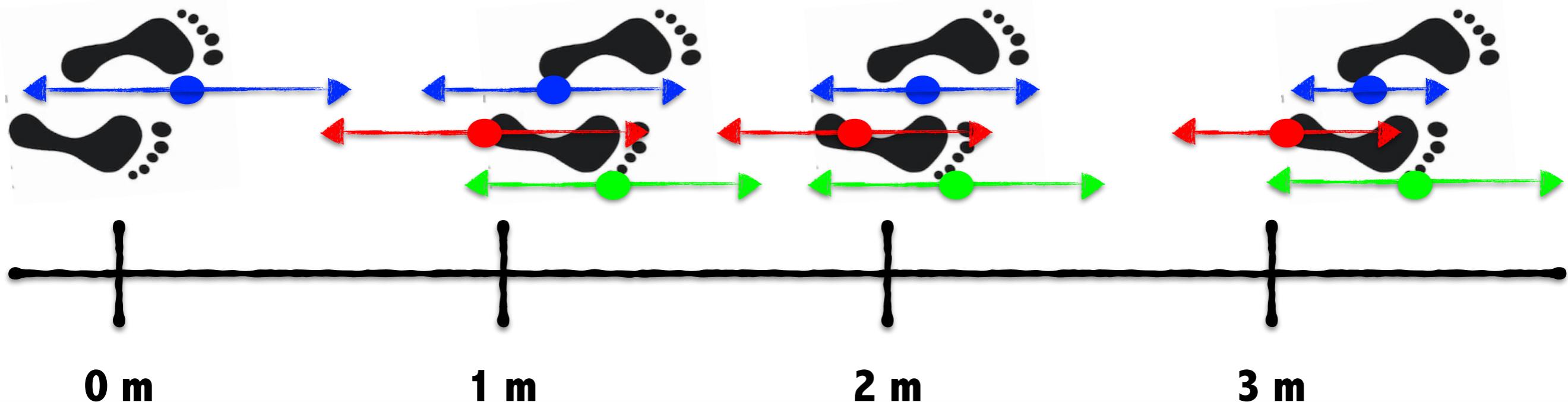
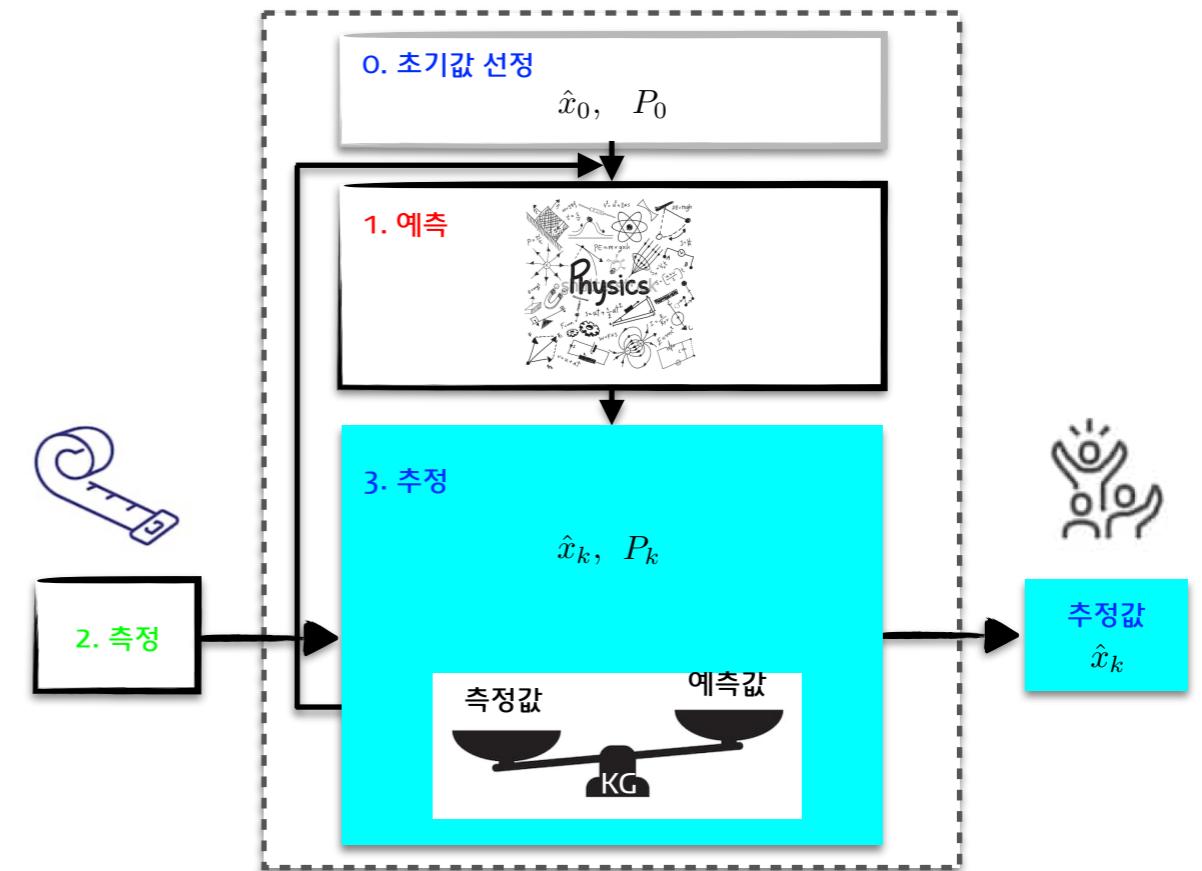
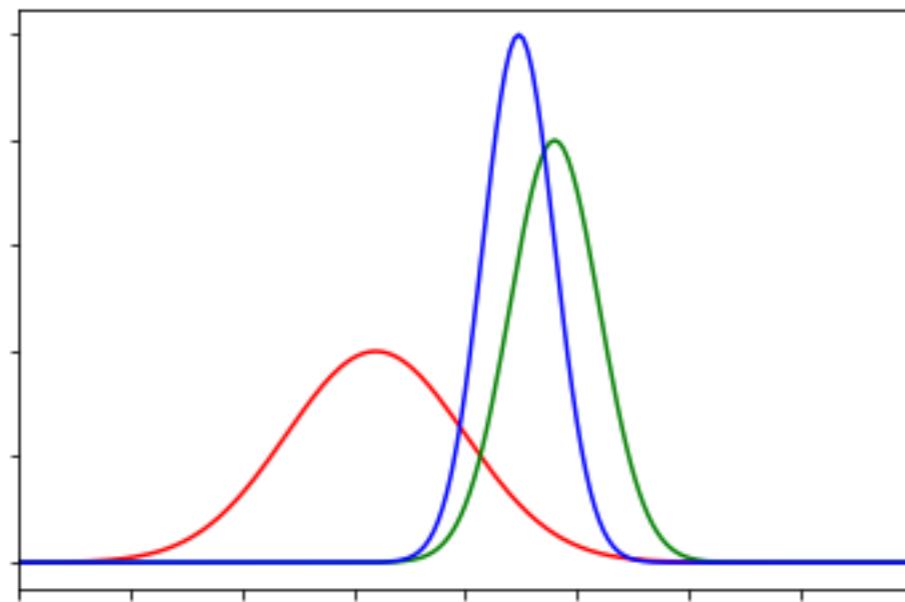
파이썬으로 구현하는 칼만 필터 (풀잎스쿨 10기)

경로 추정 과정

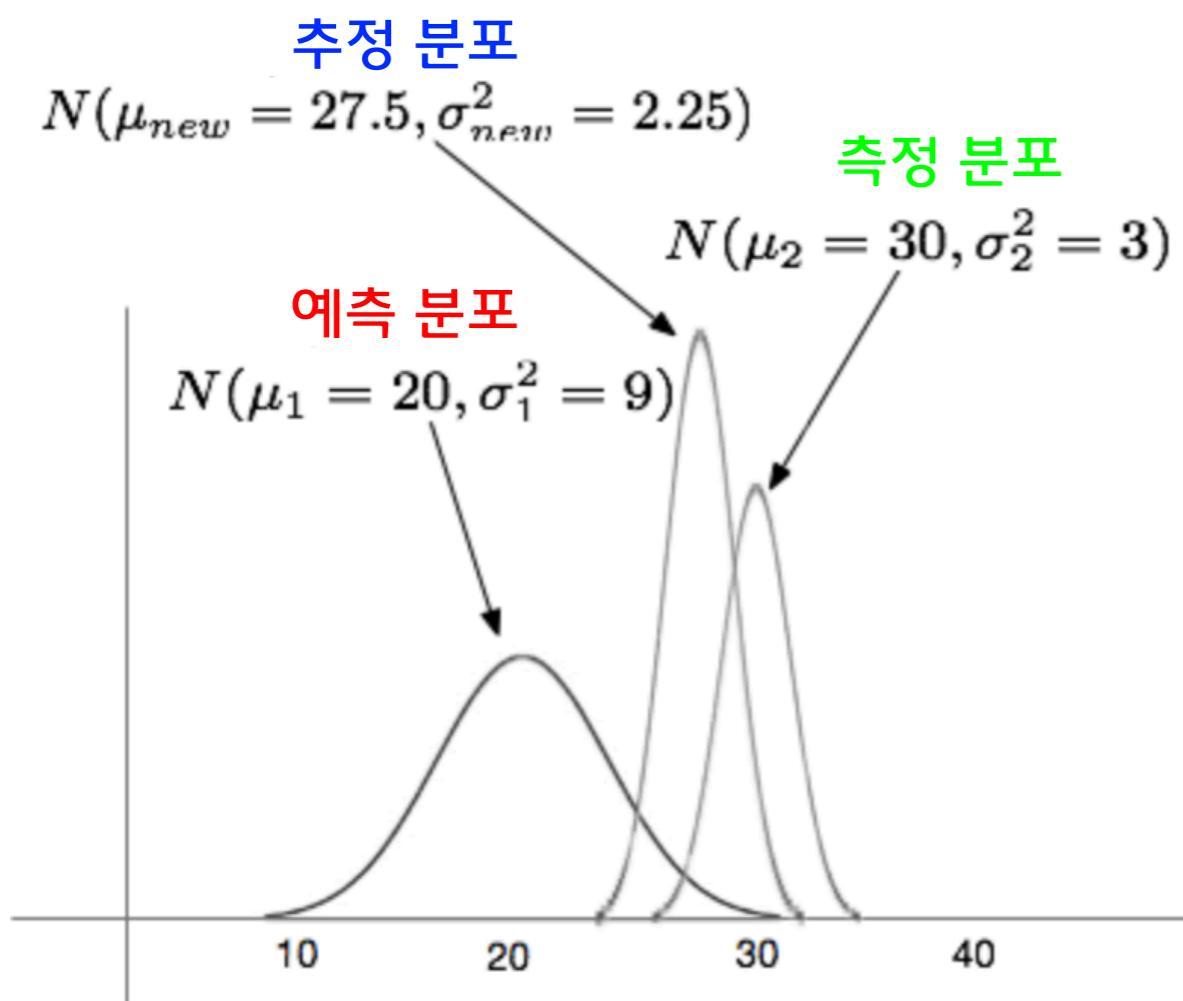


파이썬으로 구현하는 칼만 필터 (풀잎스쿨 10기)

경로 추정 과정



위치 추정값의 확률 분포

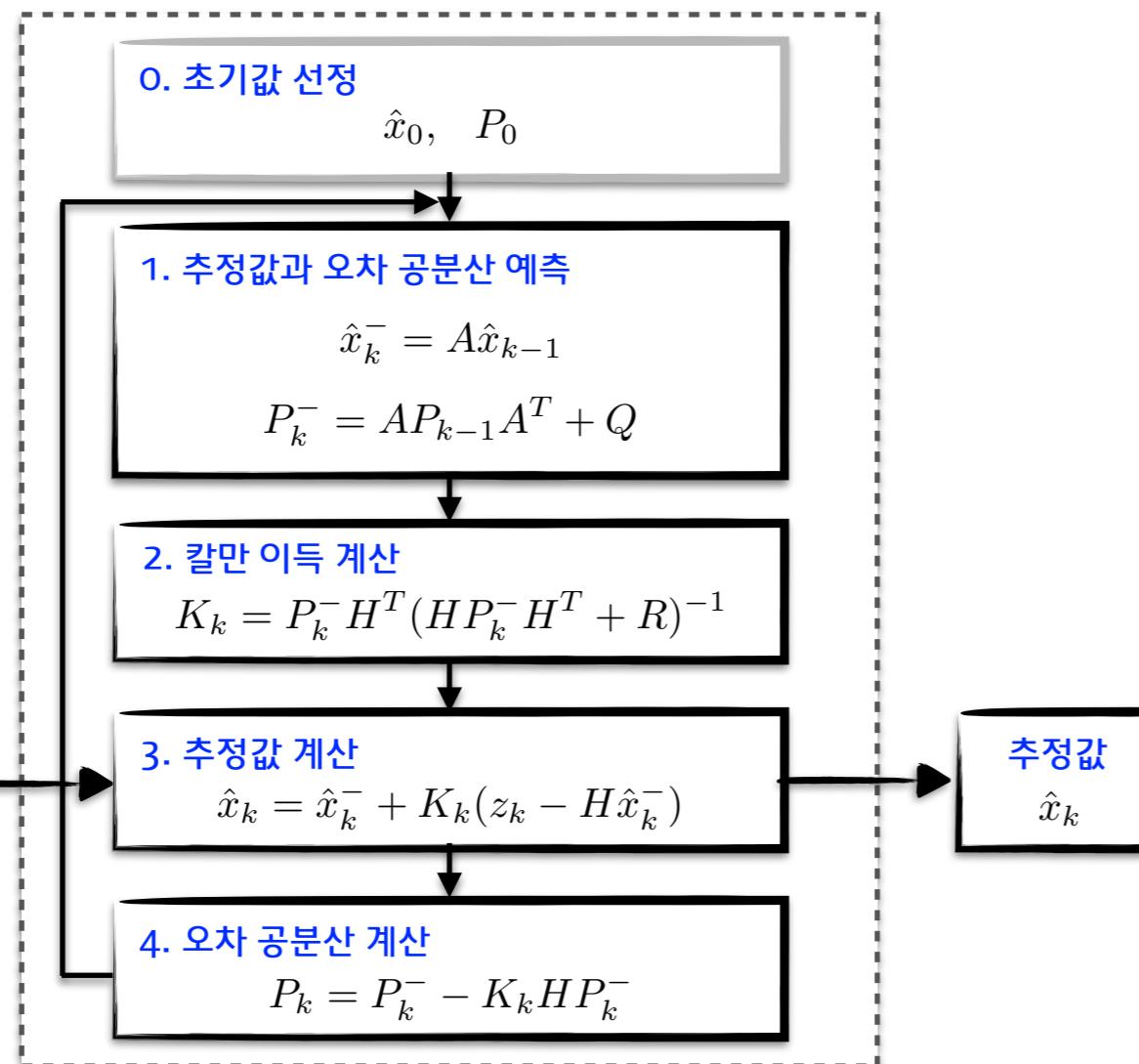


$$\mu_{new} = \frac{\mu_2 \sigma_1^2 + \mu_1 \sigma_2^2}{\sigma_1^2 + \sigma_2^2}$$

$$\sigma_{new}^2 = \frac{\sigma_1^2 \sigma_2^2}{\sigma_1^2 + \sigma_2^2}$$

참고자료: Kalman filter 소개 (신동원님)

칼만 필터 알고리즘 & 코드



```
def kalman_filter(z_meas, x_esti, P):
    """Kalman Filter Algorithm."""
    # (1) Prediction.
    x_pred = A @ x_esti
    P_pred = A @ P @ A.T + Q

    # (2) Kalman Gain.
    K = P_pred @ H.T @ inv(H @ P_pred @ H.T + R)

    # (3) Estimation.
    x_esti = x_pred + K @ (z_meas - H @ x_pred)

    # (4) Error Covariance.
    P = P_pred - K @ H @ P_pred

    return x_esti, P
```

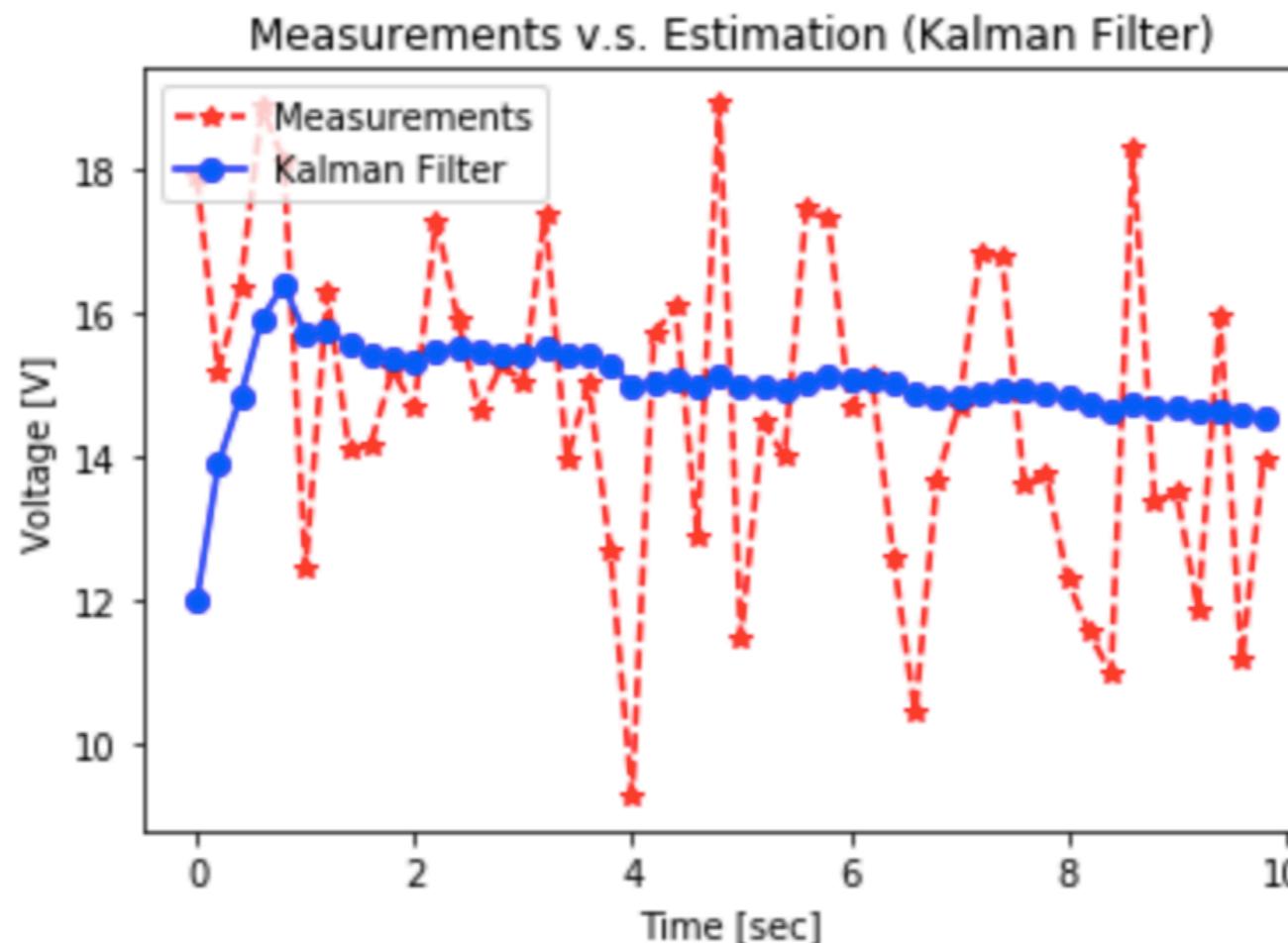
칼만 필터: 전압 측정 예제

- 10초 동안 0.2초 간격으로 배터리의 전압 측정
 - 배터리의 명목 전압 = 14.4 V
 - 측정 잡음 $\sim \text{Gauss}(0, 2^2)$
- 칼만 필터를 사용하여 배터리의 전압을 추정하자!

https://github.com/tbmoon/kalman_filter/blob/master/Ch08.SimpleKalmanFilter/simple_kalman_filter.ipynb

칼만 필터: 전압 측정 예제

- 10초 동안 0.2초 간격으로 배터리의 전압 측정
 - 배터리의 명목 전압 = 14.4 V
 - 측정 잡음 $\sim \text{Gauss}(0, 2^2)$
- 칼만 필터를 사용하여 배터리의 전압을 추정하자!



선형 상태 & 시스템 모델

선형 상태 모델

- $x_{k+1} = Ax_k + w_k$

$$w_k \sim Gauss(0, \sigma_w^2)$$

- $z_k = Hx_k + v_k$

$$v_k \sim Gauss(0, \sigma_v^2)$$

시스템 모델

- A : 시간에 따른 시스템 변화
- H : 측정값과 상태 변수 관계
- $Q = \sigma_w^2$
- $R = \sigma_v^2$

선형 상태 & 시스템 모델

선형 상태 모델

- $x_{k+1} = x_k$

$$w_k \sim 0$$

- $z_k = x_k + v_k$

$$v_k \sim Gauss(0, \sigma_v^2)$$

시스템 모델

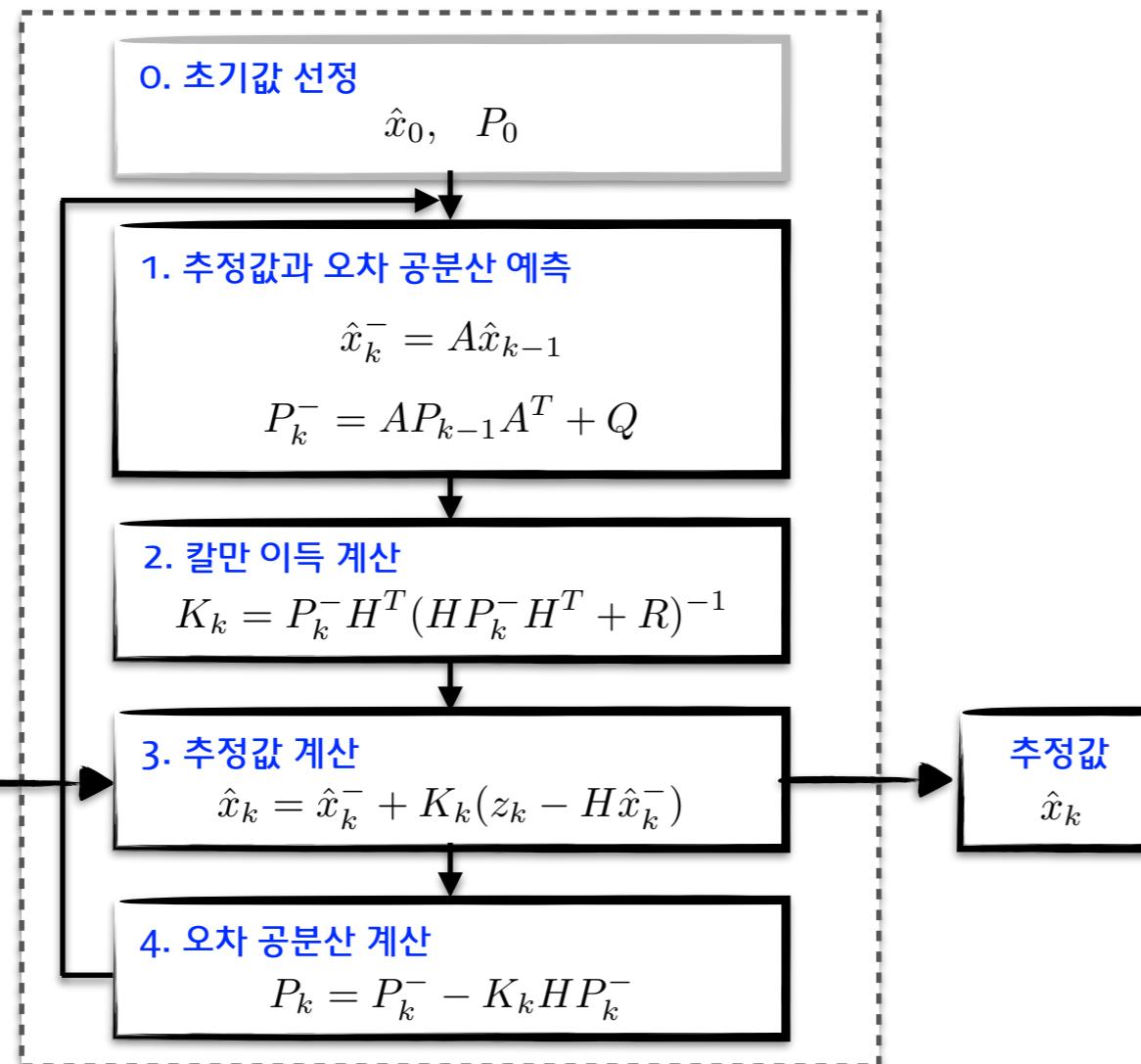
- $A = 1$

- $H = 1$

- $Q = 0$

- $R = 4[V^2]$

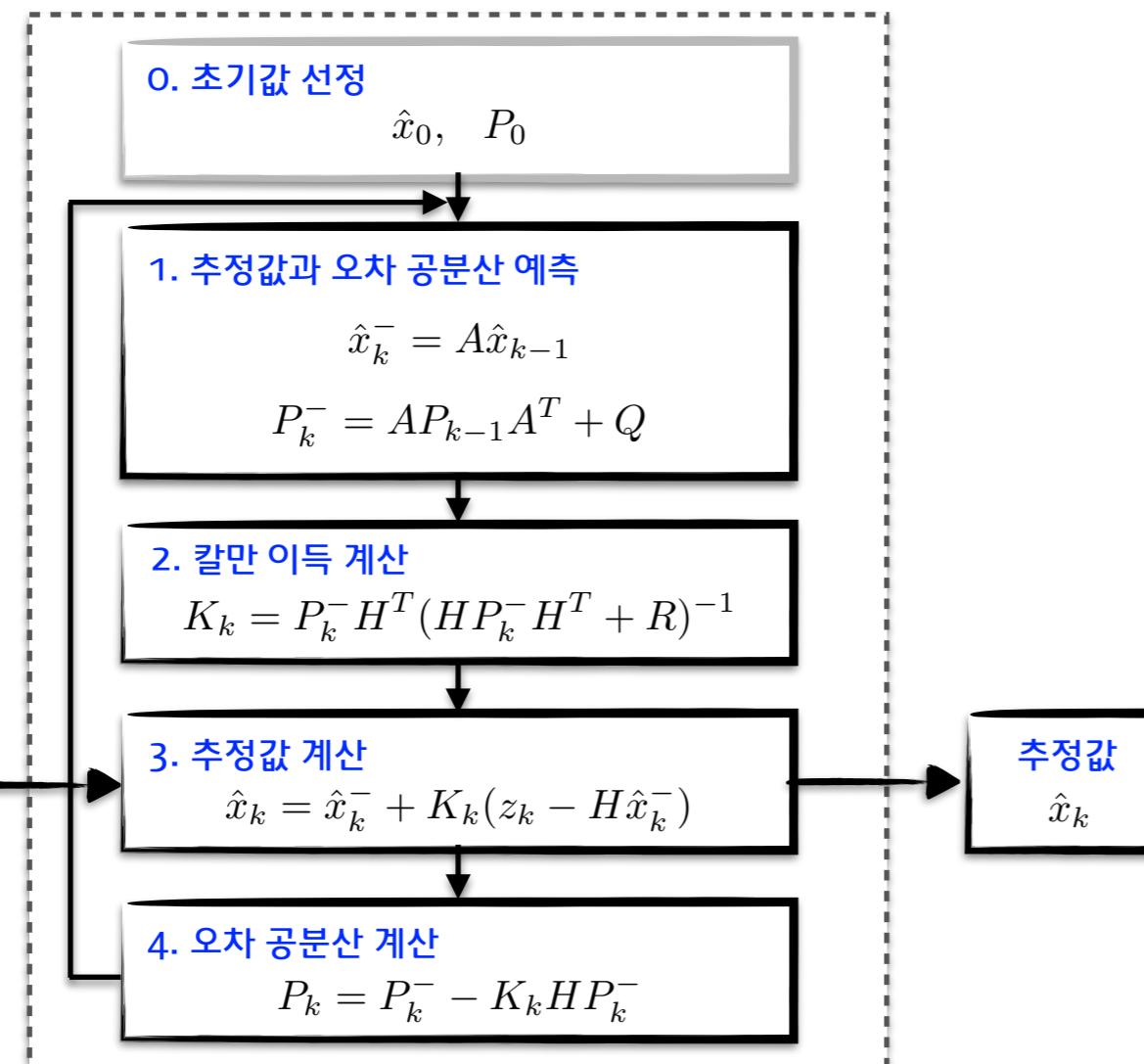
칼만 필터 알고리즘 & 코드



```
# Initialization for estimation.  
x_0 = 12 # 14 for book.  
P_0 = 6
```

```
def kalman_filter(z_meas, x_esti, P):  
    """Kalman Filter Algorithm for One Variable."""  
    # (1) Prediction.  
    x_pred = A * x_esti  
    P_pred = A * P * A + Q  
  
    # (2) Kalman Gain.  
    K = P_pred * H / (H * P_pred * H + R)  
  
    # (3) Estimation.  
    x_esti = x_pred + K * (z_meas - H * x_pred)  
  
    # (4) Error Covariance.  
    P = P_pred - K * H * P_pred  
  
    return x_esti, P
```

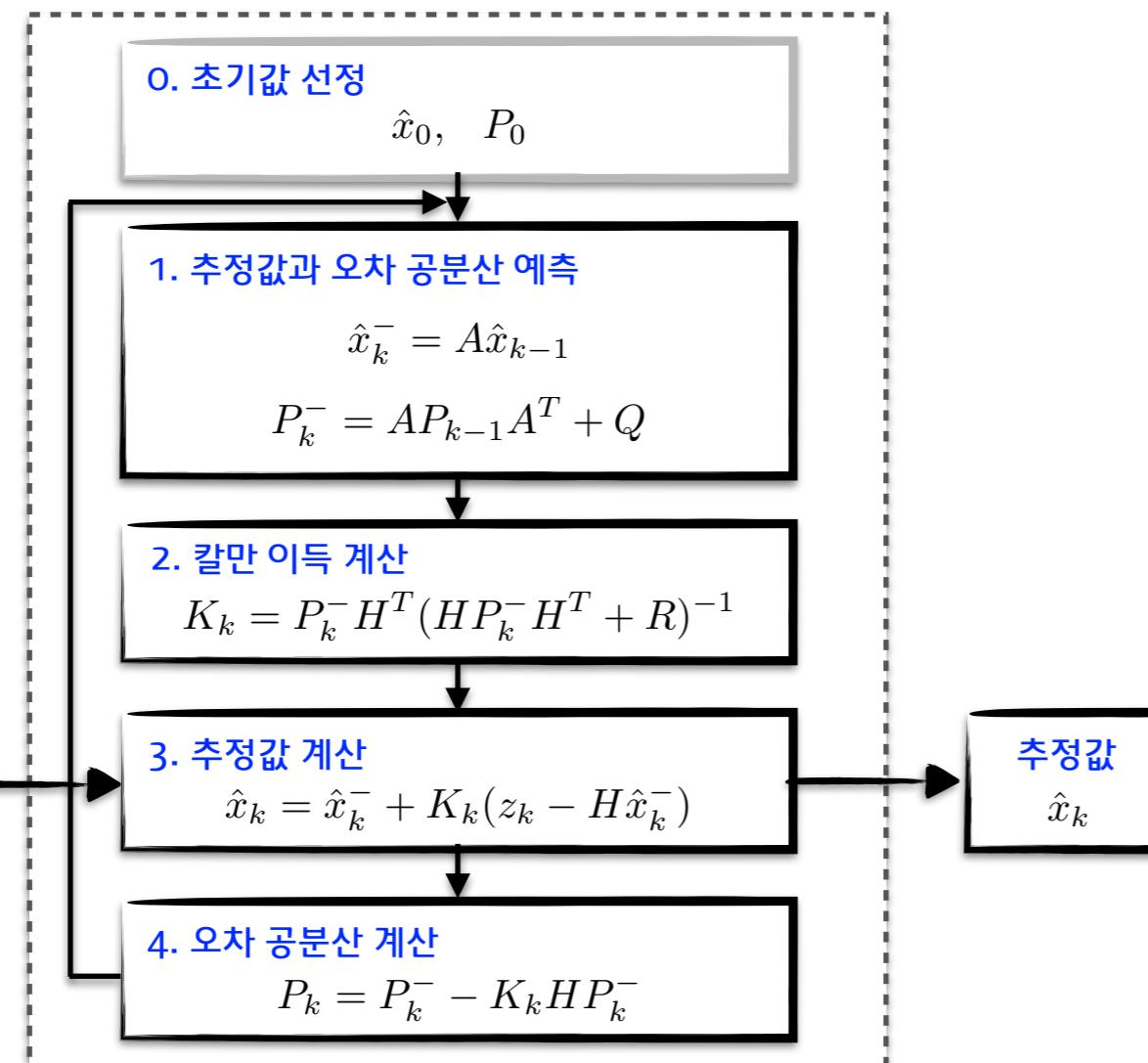
칼만 필터 알고리즘 & 코드



```
# Initialization for estimation.  
x_0 = 12 # 14 for book.  
P_0 = 6
```

```
def kalman_filter(z_meas, x_esti, P):  
    """Kalman Filter Algorithm for One Variable."""  
    # (1) Prediction.  
    x_pred = x_esti  
    P_pred = P  
  
    # (2) Kalman Gain.  
    K = P_pred / (P_pred + R)  
  
    # (3) Estimation.  
    x_esti = x_pred + K * (z_meas - x_pred)  
  
    # (4) Error Covariance.  
    P = P_pred - K * P_pred  
  
    return x_esti, P
```

칼만 필터 알고리즘 & 코드



```
# Initialization for estimation.
x_0 = 12 # 14 for book.
P_0 = 6

def kalman_filter(z_meas, x_esti, P):
    """Kalman Filter Algorithm for One Variable."""
    # (1) Prediction.
    x_pred = x_esti
    P_pred = P

    # (2) Kalman Gain.
    K = P_pred / (P_pred + R)

    # (3) Estimation.
    x_esti = (1 - K) * x_pred + K * z_meas

    # (4) Error Covariance.
    P = (1 - K) * P_pred

    return x_esti, P
```

칼만 필터 흐름 확인

```
# Initialization for system model.  
A = 1  
H = 1  
Q = 0  
R = 4  
# Initialization for estimation.  
x_0 = 12 # 14 for book.  
P_0 = 6
```

```
def kalman_filter(z_meas, x_esti, P):  
    """Kalman Filter Algorithm for One Variable."""  
    # (1) Prediction.  
    x_pred = x_esti  
    P_pred = P  
  
    # (2) Kalman Gain.  
    K = P_pred / (P_pred + R)  
  
    # (3) Estimation.  
    x_esti = (1 - K) * x_pred + K * z_meas  
  
    # (4) Error Covariance.  
    P = (1 - K) * P_pred  
  
    return x_esti, P
```

k	x 측정 [V]	x 추정 [V]	P 추정 [V^2]	x 예측 [V]	P 예측 [V^2]	칼만 이득
0		12	6			
1	15.20					
2	16.35			채워 보세요!		
3	18.88					
4	18.14					

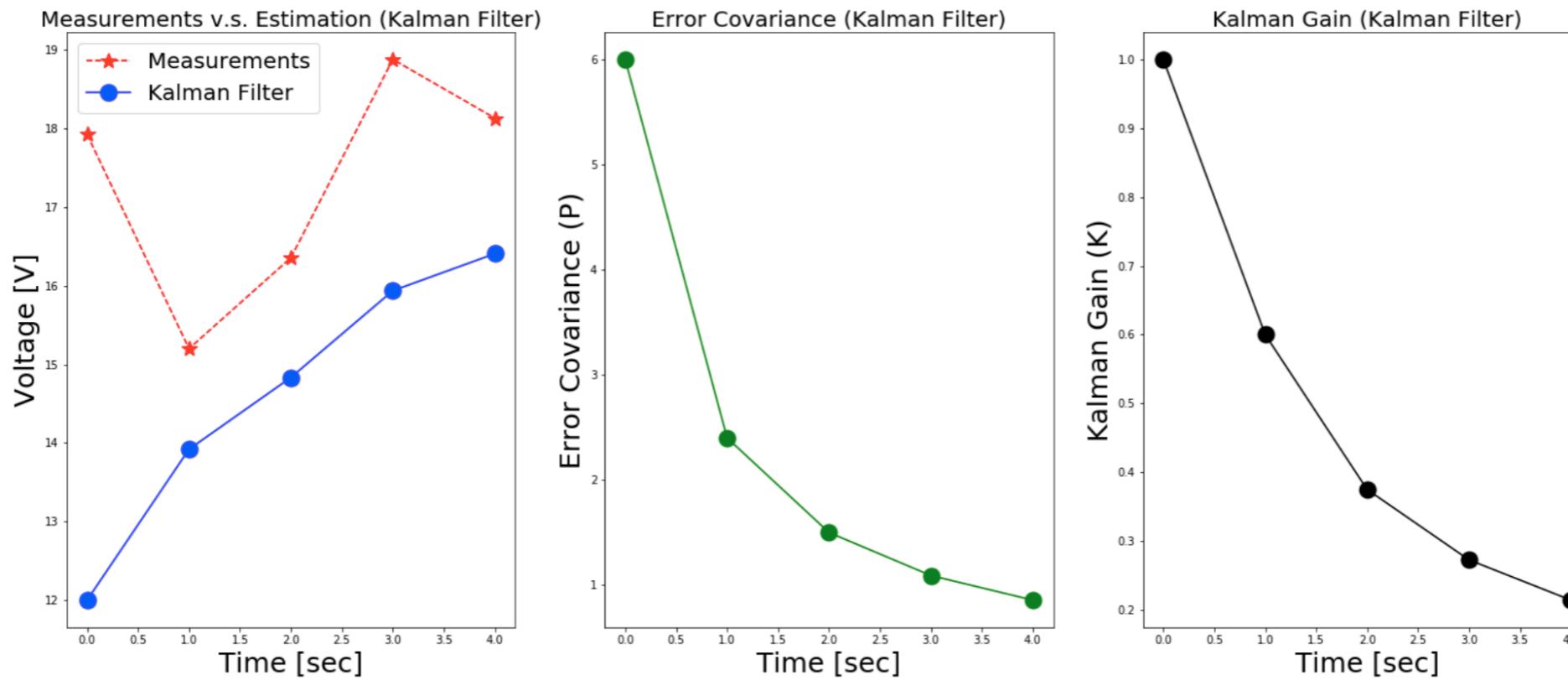
칼만 필터 흐름 확인

```
# Initialization for system model.  
A = 1  
H = 1  
Q = 0  
R = 4  
# Initialization for estimation.  
x_0 = 12 # 14 for book.  
P_0 = 6
```

```
def kalman_filter(z_meas, x_esti, P):  
    """Kalman Filter Algorithm for One Variable."""  
    # (1) Prediction.  
    x_pred = x_esti  
    P_pred = P  
  
    # (2) Kalman Gain.  
    K = P_pred / (P_pred + R)  
  
    # (3) Estimation.  
    x_esti = (1 - K) * x_pred + K * z_meas  
  
    # (4) Error Covariance.  
    P = (1 - K) * P_pred  
  
    return x_esti, P
```

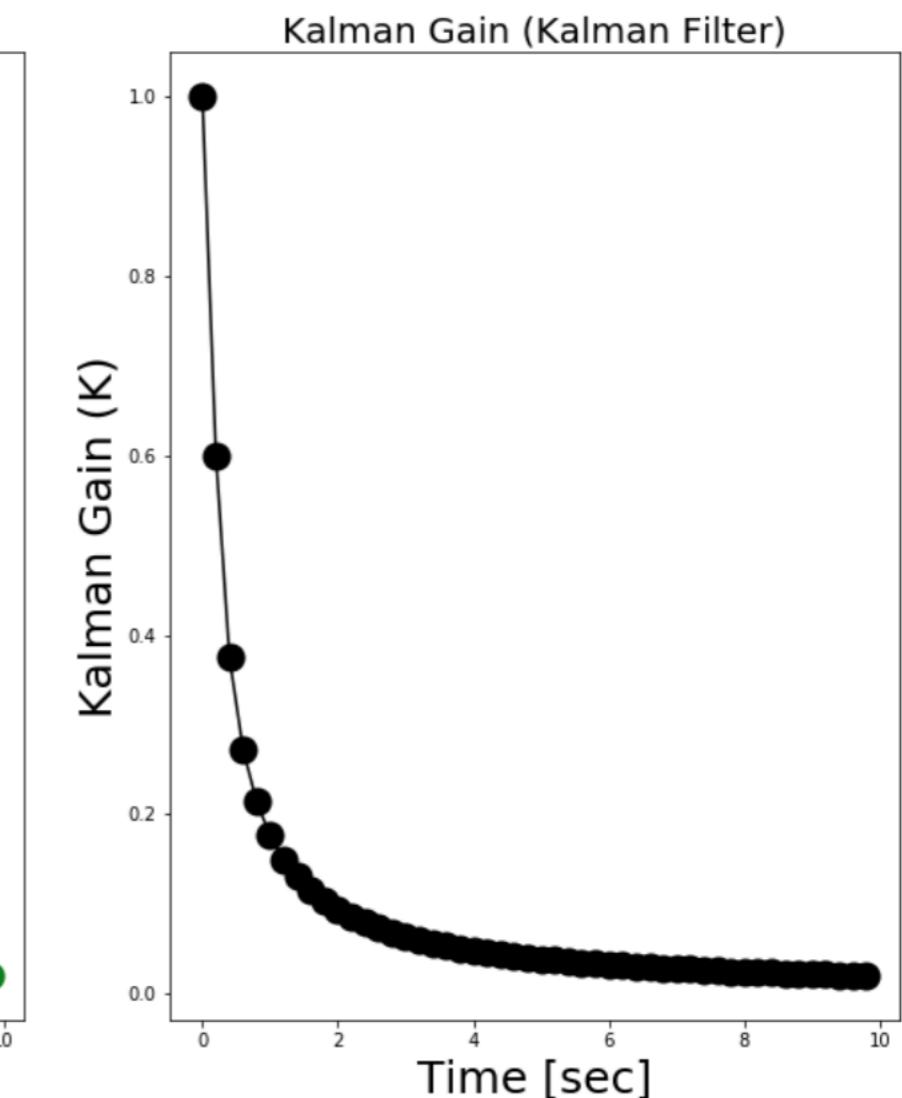
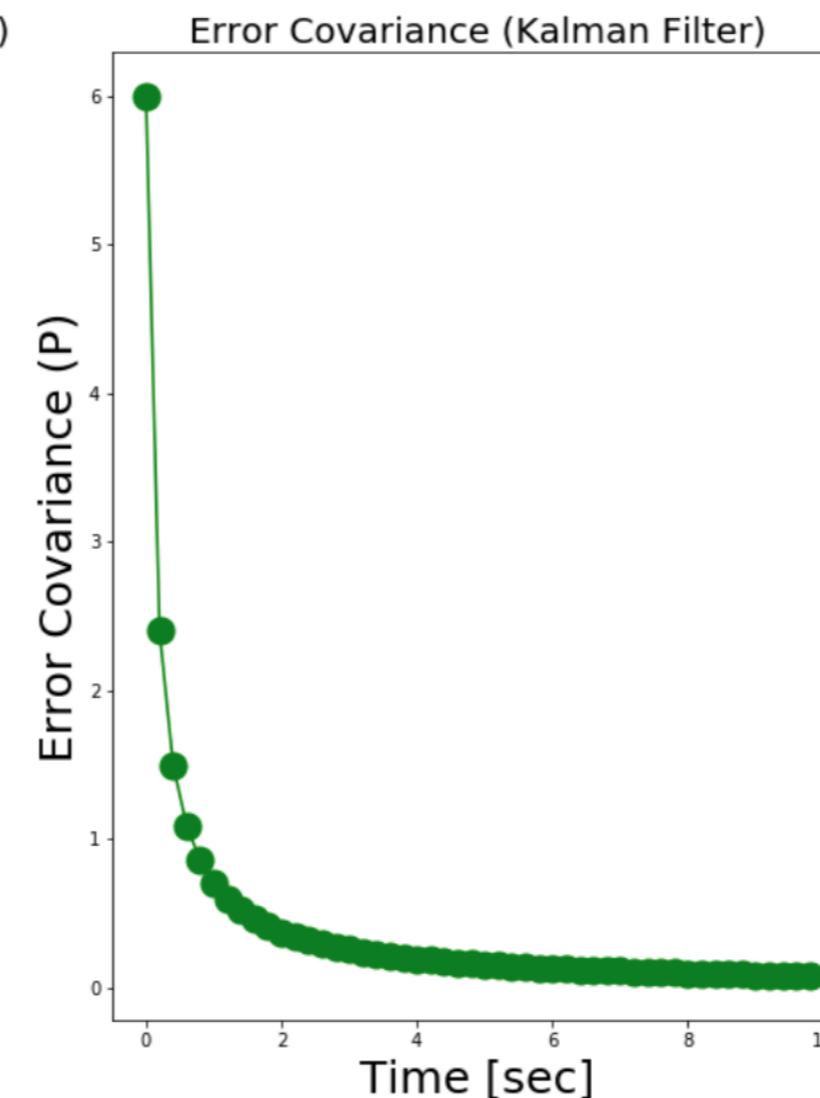
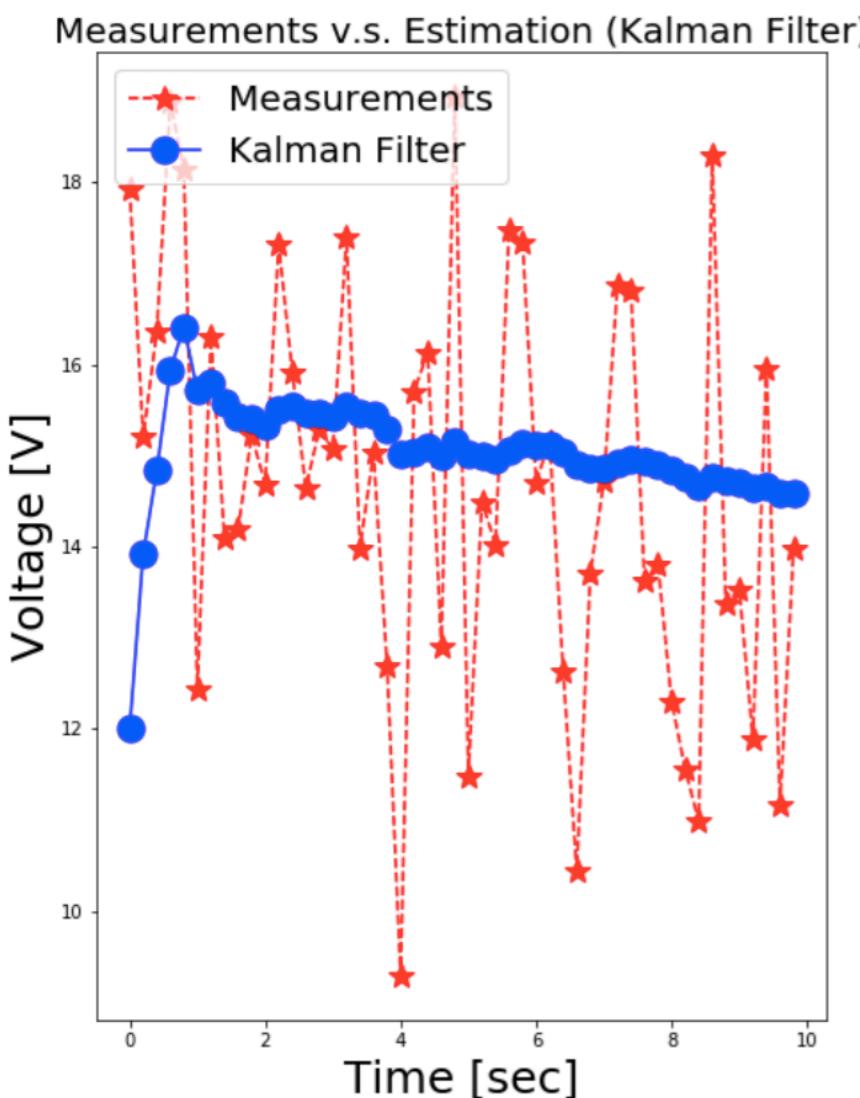
k	x 측정 [V]	x 추정 [V]	P 추정 [V^2]	x 예측 [V]	P 예측 [V^2]	칼만 이득
0		12	6			
1	15.20	13.92	2.40	12	6	0.60
2	16.35	14.83	1.50	13.92	2.40	0.38
3	18.88	15.94	1.09	14.83	1.50	0.27
4	18.14	16.41	0.86	15.94	1.09	0.21

칼만 필터 흐름 확인



k	x 측정 [V]	x 추정 [V]	P 추정 [V ²]	x 예측 [V]	P 예측 [V ²]	칼만 이득
0		12	6			
1	15.20	13.92	2.40	12	6	0.60
2	16.35	14.83	1.50	13.92	2.40	0.38
3	18.88	15.94	1.09	14.83	1.50	0.27
4	18.14	16.41	0.86	15.94	1.09	0.21

칼만 필터: 전압 측정 결과



칼만 필터 파라미터

- 초기 위치 추정량 (x_0)이 커지면 어떻게 될까?
- 오차 공분산 (P)이 커지면 어떻게 될까?
- 측정 잡음 공분산 (R)이 커지면 어떻게 될까?
- 칼만 이득 (K)이 커지면 어떻게 될까?

참고 자료

- 칼만 필터는 어렵지 않아 (저자: 김성필 님)
- 파이썬으로 구현하는 칼만 필터
- Kalman filter 소개 (신동원 님)
- SLAM: KF & EKF (정진용 님)
- Robot Mapping (Cyrill Stachniss)
- The Kalman Filter (Michel van Biezen)

풀잎 스쿨 11 주간 일정

- 01 주차 1월 08일 - 재귀 필터 (퍼실이)
- 02 주차 1월 15일 - 칼만 필터 기초 & 초간단 칼만 필터 예제 (퍼실이)
- 03 주차 1월 22일 - 칼만 필터 기초 & 위치로 속도 추정하기 (퍼실이)
- 04 주차 1월 29일 - 영상 속의 물체 추정하기
- 05 주차 2월 05일 - 기울기 자세 측정하기
- 06 주차 2월 12일 - 기울기 자세 측정하기
- 07 주차 2월 19일 - 확장 칼만 필터
- 08 주차 2월 26일 - 확장 칼만 필터

완료

-
- 09 주차 3월 04일 - 무향 칼만 필터
- 10 주차 3월 11일 - 무향 칼만 필터
- 11 주차 3월 18일 - 파텍클 필터 혹은 정리/쫑 파티

예정

감사합니다