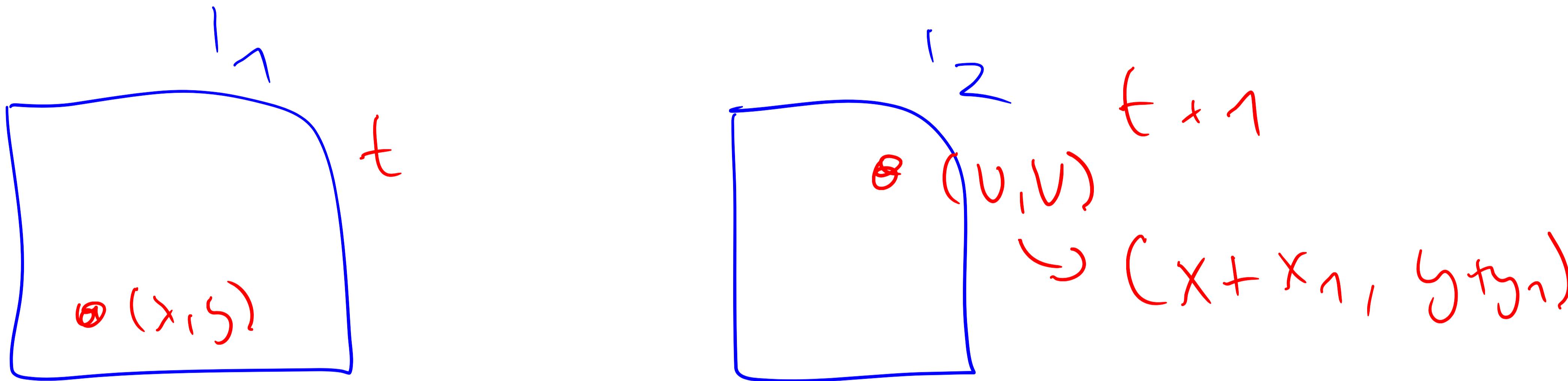


SLAM

Optical Flow

- Magnitude
- Angle

Brightness Constancy Assumption



$$I(x, y, t) = I(x + u, y + v, t + 1)$$

Brightness Constancy Assumption

Taylor Series

$$I(x, y, t) = \frac{\delta I}{\delta x} u + \frac{\delta I}{\delta y} v + \frac{\delta I}{\delta t} 1 + I(x, y, t)$$

$$0 = \frac{\delta I}{\delta x} u + \frac{\delta I}{\delta y} v + \frac{\delta I}{\delta t} 1 + I(x, y, t)$$

$$\frac{\delta I}{\delta x} u + \frac{\delta I}{\delta y} v = -\frac{\delta I}{\delta t}$$

Tracking

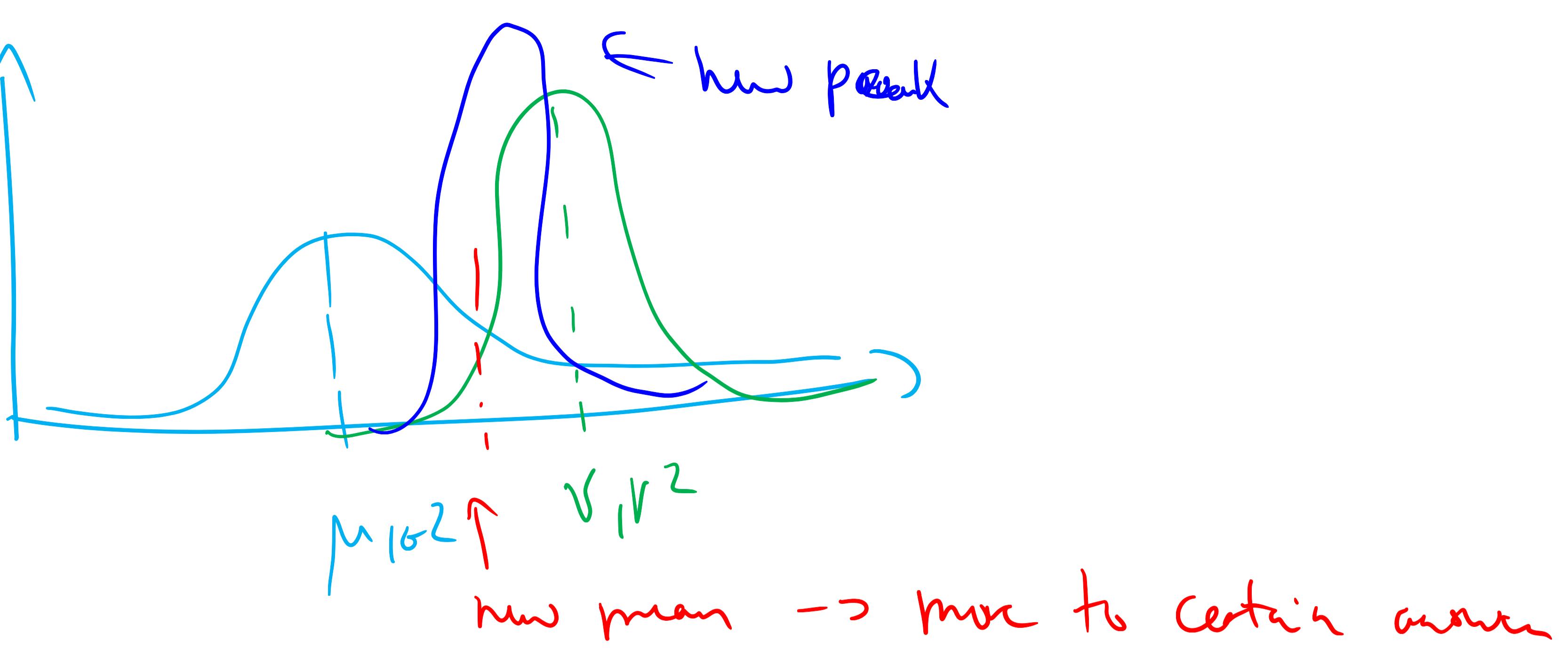
KF

Continuous

uni-modal

→ Gaussian

MC
discrete → Histogram
multi-modal



$$\mu' = \frac{r^2 \mu + \sigma^2 v}{r^2 + \sigma^2}$$

$$\sigma'^2 = \frac{1}{\frac{1}{r^2} + \frac{1}{\sigma^2}}$$

Kalman Filter

Measurement Update
Bayes Rule
Multiplication

Motion Update → $\mu' \leftarrow \mu + u$
Total Probability
Addition $\sigma'^2 \leftarrow \sigma^2 + r^2$

1. Initial Prediction, where am I?
2. Measurement Update
3. Prediction, where will it move?
4. Repeat

State: • Pose
• Movement

KF Design

$$\begin{pmatrix} \dot{x} \\ \ddot{x} \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ \dot{x} \end{pmatrix}$$

$$z = (10) \begin{pmatrix} x \\ \dot{x} \end{pmatrix}$$

↑ velocity

Graph SLAM

- Define probabilities w/ constraints
- collects constraints over time (poses, landmarks)
 - ↳ Sum = # of constraints

Constraints

$$\text{Example: } x_1 = x_2 + 4$$

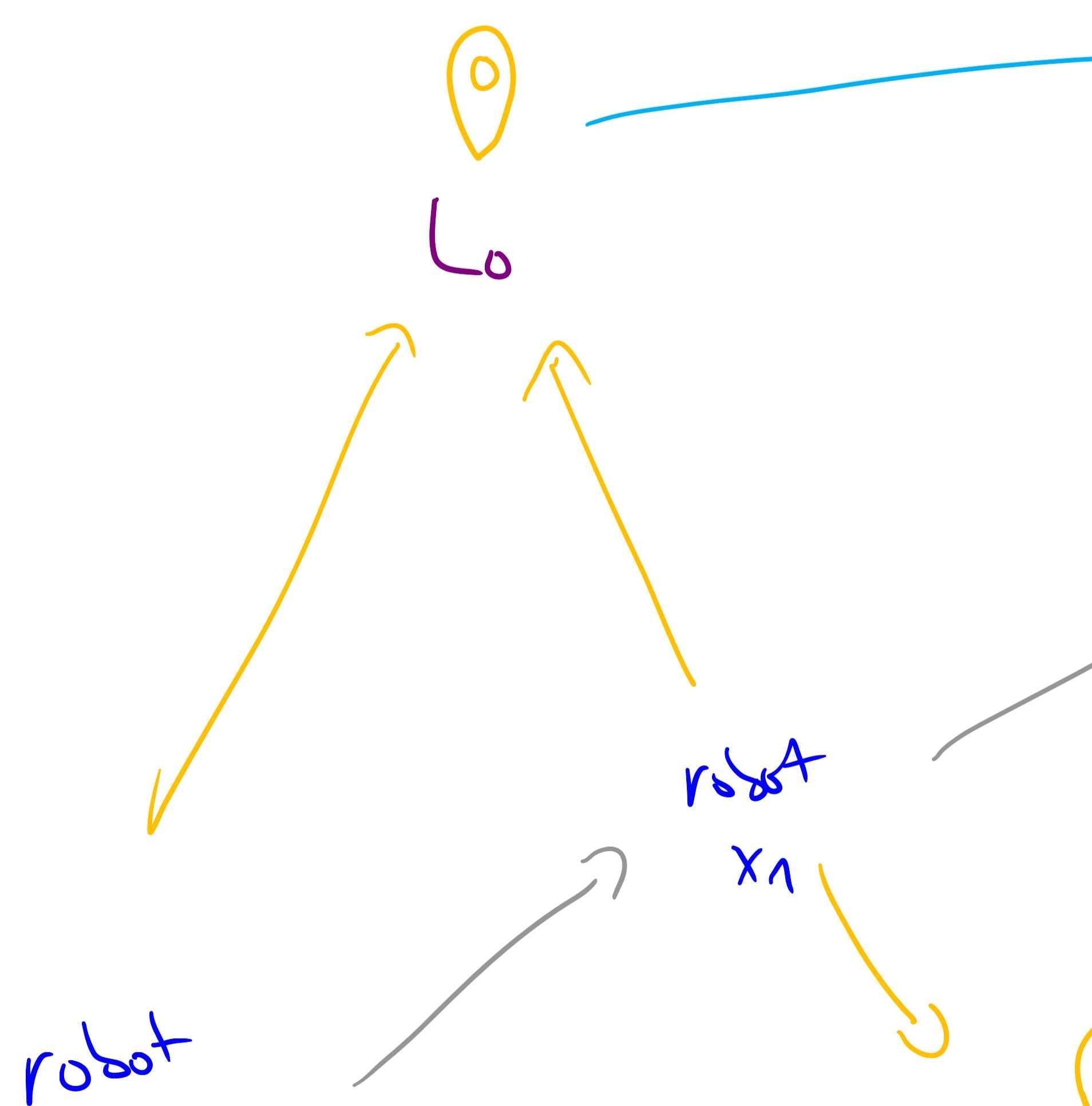
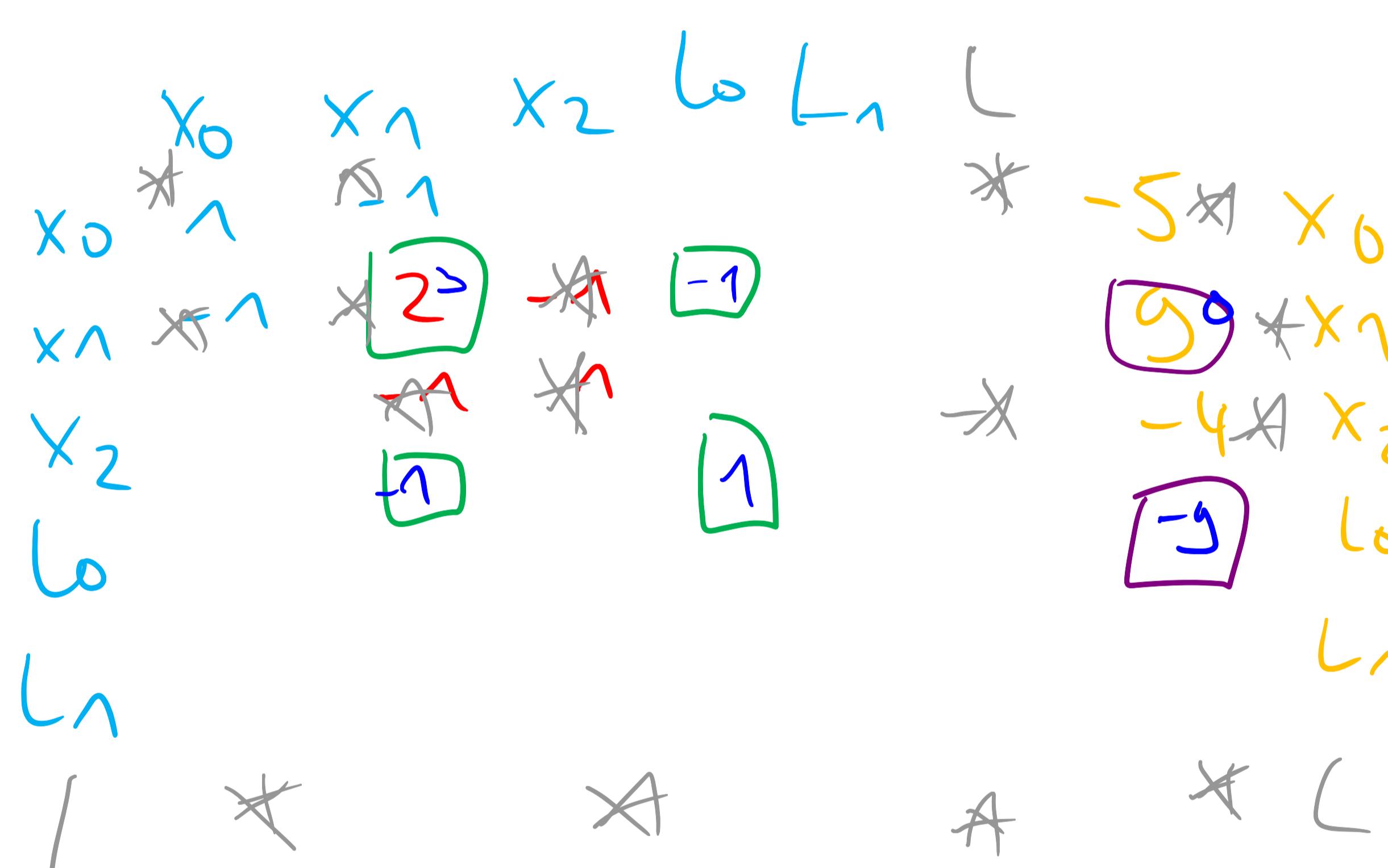
$$x_1 - x_2 = 4$$

$$\begin{matrix} x_1 & x_2 \\ +1 & -1 \\ x_1 & -1 \\ & 1 \end{matrix}$$

$$x_1 = l_0 - 5$$

$$x_1 - l_0 = -g$$

$$l_0 - x_1 = g$$



	x_0	x_1	x_2	l_0	l_1	x_0	x_1	x_2	l_0	l_1	x_0	x_1	x_2	l_0	l_1
x_0	•	•	0	•	0	•	•	0	•	0	x_0	x_1	x_2	l_0	l_1
x_1	•	•	•	•	•	•	•	•	•	•	x_0	x_1	x_2	l_0	l_1
x_2	0	•	•	0	•	0	•	0	0	•	x_0	x_1	x_2	l_0	l_1
l_0	•	•	0	•	0	0	0	0	0	0	x_0	x_1	x_2	l_0	l_1
l_1	0	•	•	0	0	0	0	0	0	0	x_0	x_1	x_2	l_0	l_1

Graph SLAM

$$\mu = Q^{-1} \xi$$

$$\begin{matrix} x_0 & x_1 & x_2 \\ -3 & 5 & 3 \end{matrix}$$

$$l = x_0 + 70$$

$$l = 7$$

Linear Graph SLAM

Constraints

$$\begin{matrix} \text{Initial Pose} \\ \text{Motion} \\ \text{Measurement} \end{matrix} \quad \left. \right\} \quad \xrightarrow{\text{add}} \quad R, \xi \quad \text{Strength} = \frac{1}{\sigma}$$

$$\mu = R^{-1} \xi$$

\rightarrow Path + Map