Introduction to SLAM

Known maps make localization easy, known poses make mapping easy. The joint estimation is more tricky.
SLAM is the task of estimating a map of the environment and at the same time localizing your sensor(robot) in the map that you are currently building.

. Frontend: takes the raw sensor data and turns it into an immediate representation. such as constraints in optimization problem or probability distributions about landmarks derived from sensor data.

. Backend: Takes this intermediate representation and solve the underlying state estimation or optimization problem.
Three different categories: EKF, particle filter, least squares "graph based SLAM" which is the most popular.

Graph based SLAM: uses a graph to represent the variables and relations between those variables.
Most popular: pose graph, factor graph.

Pose graph: every node represents the pose of the sensor at a certain point of time. Edges represent spatial relations that extracted from sensor data. Optimization system tries to find the best node configuration.

Bundle adjustment: a special form of visual SLAM which has a special form of constraint that is basically the reproduction error of pixel coordinates.

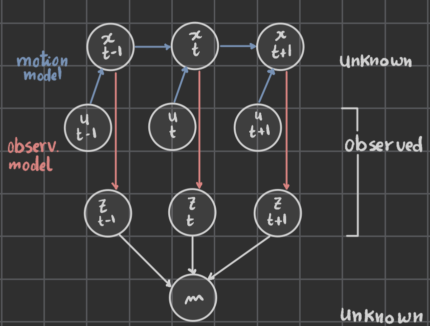
What is SLAM ?
Localization: estimating the robot's location, mapping: building a map.
SLAM: building a map and localizing the robot simultaneously.

Localization example: given landmarks "map" help to correct robot's pose.
Mapping example: estimates the landmarks given the robot's poses.
SLAM example: estimates the robot's poses & the landmarks at the same time.
- SLAM is an online variant of the bundle adjustment problem for arbitrary sensors.
- considered a fundamental problem for truly autonomous robots.
- SLAM is the basis for most navigation systems.

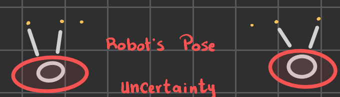
Definition of SLAM problem: given the robot's controls $U_{1:t} = \{ U_1, U_2, \dots, u_t\}$ and observations $Z_{1:t}=\{z_1, Z_2, \dots, z_t\}$
Required: map of environment "m", path of the robot $x_{0:t} = \{x_1, x_2, \dots, x_t\}$

Probabilistic approach: use the probability theory to explicitly represent the uncertainty.

Graphical model: $P(x_{0:t}, m \mid z_{1:t}, u_{1:t})$



Why SLAM is a hard problem:
- Robot path and map both are unknown: map & pose estimates correlated.
- Known vs. Unknown correspondence "data association" : the mapping between observations and the map is unknown, picking wrong data association can have catastrophic consequences (divergence).



Full SLAM: estimates the entire path
Online SLAM: seeks to recover the most recent path, marginalizing out the previous poses.