For the first problem, we consider the case of two agents in a planar space that measure relative range to known features in the environment. For a baseline case, both agents act and estimate independently. For a second case, the agents also measure and share relative range (and possibly bearing) as well.

## 2D system description

For the 2D system, agents are described by a position vector with two DoF and a heading angle . Range and bearing measurements to landmarks with known positions are assumed. IMU measurements of acceleration and angular rate are assumed for full state observability.

The system measurement model is as follows, where is the vector to landmark *j*, is the unit vector aligned with the vehicle body 1 axis:

Landmark *j* range:

Landmark *j* bearing:

Body-axis acceleration:

Body-axis angular rate:

Using the shorthand and , a first-order approximation to discrete-time system propagation equations can be written as:

The measurement equation

has gradient

A discrete-discrete Kalman filter is formulated as:

Update:

Propagate:

For landmarks the measurement gradient