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.

## Check on observability

Before considering the 2D case, we verify that the system with landmark measurements only has observability. Considering a 1D case with otherwise similar dynamics, we can compose the system model for a single agent with landmark measurements. Taking to be the vector of vehicle position and speed and assuming an acceleration-level control , the linear dynamics are:

The measurement model for the *j*th landmark writes the measured range in terms of a known landmark position and Gaussian measurement noise .

The constant term does not affect error computations that involve since it is assumed exactly known. For a single landmark measurement, the system observability matrix is

This is clearly full rank so observability is satisfied for the reduced system. By analogy, we assume observability can be extrapolated to the 2D framework.

## 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.