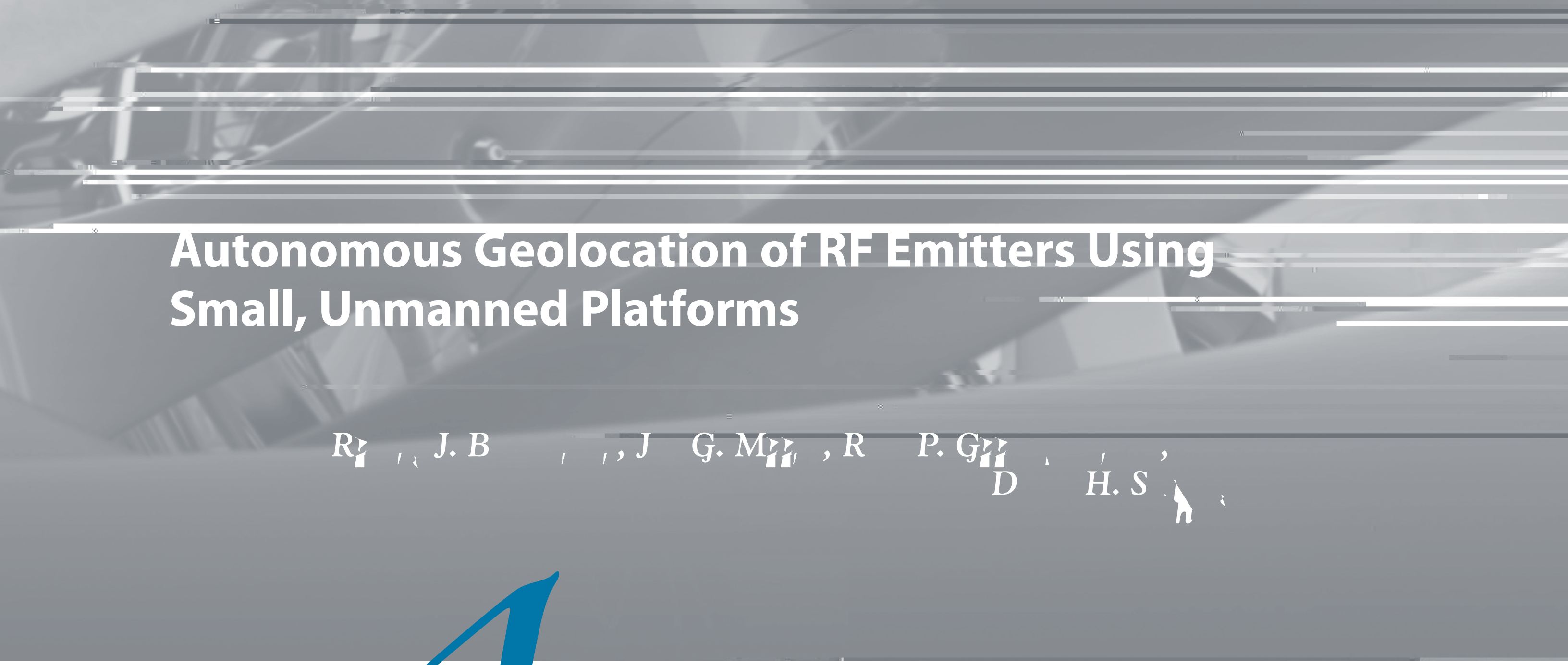

Autonomous Geolocation of RF Emitters Using Small, Unmanned Platforms

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Autonomous geolocation of RF emitters using small, unmanned systems is a game-changing technology for military, government, and commercial missions. This technique employs a novel application of a common RF direction-finding technique called pseudo-Doppler. Emergent autonomous control concepts are used to control the sensor platform and optimize flight trajectories for efficient and rapid geolocation of the target. The basic components of this concept, from sensor development to unmanned system autonomous behaviors, were tested in simulation and subsequently demonstrated in flight during the Tactical Network Topology experiment.

loop control and use sensor platforms from higher echelons that may be too expensive or difficult to schedule cles seem to be optimal for this application). This is especially true for moving RF emitters.

For this effort, two UAS vehicles were used as the sensor platforms (although not optimal, two were considered adequate for proof of concept, although one can also provide a solution). Each vehicle implemented an onboard Kalman filter for fusing LOB measurements into a geolocation solution. Each vehicle broadcast its measured LOB values, along with the time and location [illegible]

The Java-based software implementation of the UAS autonomy was developed from a system of related subsystems, including the agent system and the belief network interface.

At the center of the implementation is the agent system. This subsystem has interfaces to the sensor interface, the autopilot, the Kalman filer, and the belief network. It acts as a data conduit and processing system. The UAS behaviors are also implemented in this subsystem.

The agent system interfaces with a virtual blackboard known as the belief network. This blackboard is made up of all the belief managers spread across the network. The belief managers attempt to automatically and efficiently synchronize and update the beliefs held in the blackboard. For this effort, two sensor beliefs were added to the legacy belief network. They represent the LOB output from the onboard sensor package and the uncertain target geolocations. These are called “RangeBearingSensorBelief” and “UncertainTargetBelief,” respectively.

RangeBearingSensorBelief represents a time-indexed list of all sensor readings performed by any agent. For efficiency, the belief drops any sensor reading older than a certain decay time. This decay time is configurable at run-time. UncertainTargetBelief holds the results of the sensor data beliefs and geolocation uncertainties of each individual agent. The geolocation uncertainty is represented by an error ellipse about the derived geolocation solution. This belief is ucicienca7Thi [illegible]

the uncertainty shrinks, because the next sensor reading may be the last. At each iteration of the control law, the courses will be chosen so as to maximize the rate at which shrinks, that is, we wish to minimize $\dot{\ }$, the time rate of change of , with respect to ψ_1 and ψ_2. First we must derive an expression for $\dot{\ }$:

$$\begin{aligned}\dot{\ } &= \delta_1\delta_2\frac{\left({}_1\dot{\ }_2 + {}_2\dot{\ }_1\right)\sin|\Delta\beta| - {}_1\,{}_2\cos|\Delta\beta|\,|\Delta\dot{\beta}|}{\sin^2|\Delta\beta|}\\ &= \frac{\delta_1\delta_2}{\sin^2|\Delta\beta|}\left[\left({}_1\ \ {}_2\cos\theta_2 + {}_2\ \ {}_1\cos\theta_1\right)\sin|\Delta\beta| \mp {}_1\,{}_2\cos|\Delta\beta|\left(\dot{\beta}_1 - \dot{\beta}_2\right)\right]\\ &= \frac{\delta_1\delta_2}{\sin^2|\Delta\beta|}\left[\left({}_1\ \ {}_2\cos\theta_2 + {}_2\ \ {}_1\cos\theta_1\right)\sin|\Delta\beta| \mp {}_1\,{}_2\cos|\Delta\beta|\left(\frac{{}_1\sin\theta_1}{{}_1} - \frac{{}_2\sin\theta_2}{{}_2}\right)\right]\end{aligned} \qquad . \quad (2)$$

To choose ψ_1, we set $\partial\dot{\ }/\partial\theta_1 = 0$ and solve for θ_1:

$$\sin\theta\ \ |\Delta\beta| = \pm\ \ \cos|\Delta\beta|$$

The UAS platforms that were employed for this effort were Unicorns with 153-cm wingspans from Procerus Technologies (see Fig. 4). The small size, low power, and light weight of the sensor and control payload developed for these platforms demonstrate that this technique could be implemented on a fielded military or commercial UAS of similar, or even smaller, size. The UAS autopilot is a Kestrel Autopilot v.2.22, also from Procerus Technologies. These autopilots contain three-axis angular rate and acceleration sensors, a three-axis magnetometer, a

snapshots are roughly equally spaced throughout the data collection time period, so t_0 is the initial reading at 0 s, t_1 is at t_0 + 145 s, t_2 is at t_0 + 290 s, and t_3 is the final error ellipse at t_0 + 435 s.

The plot in Fig. 10 also shows convergence to a geolocation solution over time. At the end of the 435-s data collection period, the error between estimated target location and true target location was 60 m.

Because of the calibration issue, the data in Fig. 10 and the 60-m error vector were derived from data fused from only a single aircraft loitering 550 m from the target. The flight path provided little angular diversity (a maximum of 29° with respect to the target), and data collection was over a relatively short time period (435 s). On the basis of simulation, when this data set is extended to three airplanes circling the target at the 550 m distance

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