2011 IEEE International Conference on Technologies for Practical Robot Applications[1]

Paper Title: "Using Geographic Information Systems (GIS) for UAV Landings and UGV Navigation"
Authors: Nathan Rackliffe, Dr. Holly Yanco, Jennifer Casper

Abstract: Unmanned air and ground platforms are not currently designed to process contextual information to aid in landing and navigation. For unmanned aerial vehicles (UAVs) operating in the national airspace (NAS), it is very important to find safe emergency landing zones that avoid people, houses, and populated areas. For unmanned ground vehicles (UGVs), sensors and processing provide information on physical objects, terrain and mapping but not contextual information about the area (i.e. school, hospital, shopping mall, etc.).

The objective of this effort is to explore the integration of geographic information system (GIS) data with sensor data to enable (a) UAVs to locate safe emergency landing locations without operator intervention, and (b) UGVs to incorporate contextual GIS information for navigation. The use of GIS data as an additional sensor stream for UAVs and UGVs is a new area of research. Preliminary evaluation of the designed system, integrating GIS and sensor data, reveals potential impact through more efficient navigation and locating safe landing zones.

This effort builds the foundation for employing GIS data streams in UAV landing and UGV navigation. The platform agnostic nature of this effort not only impacts the UAV and UGV fields, but also applies to other fields such as data analysis interfaces.

A wide variety of GIS data, covering many different types of features, is publicly available. The level of detail, age of the data, and accuracy varies for each data set. Despite the potential imperfections in the GIS data, the information provides an additional level of detail to inform autonomous systems.

This paper describes an approach to incorporating GIS that revolves around building probability and cost surface maps. An architecture, including the use of Environmental Systems Research Institute (ESRI) ArcGIS components, was designed to take in the GIS data, process it according to mission parameters, and output probability maps which can either indicate where to land or navigate. We have taken a platform-agnostic approach as the maps produced may be used to feed many types of existing systems beyond the two covered here. Three phases are needed to create the maps: (1) data collection, (2) data conversion, and (3) geo-processing. In our current system, steps one and two are manual; the architecture executes step three.

Phase I - Data Collection: Different types of GIS data may be manually obtained: global, federal, state, county/city, and organization. *Global data* is usually very coarse grained and generally only able to resolve to features larger than 1 square kilometer. This resolution provides little benefit for UGV operations, although UASs may exploit the data for course-grained maps. *Federal agency data* provides more detail about the features within the agency's boundaries, including such features as terrain information and land use. *State data* is often available through a state's GIS office. The data resolution is higher than federal data due to the smaller area covered. *County/city data* is typically the finest grain data available, used for tracking tax parcels and planning purposes. *Organization data*, where available, has a resolution better than county/city data, generally with the addition of permanent structure within their boundaries. The Texas A&M University (TAMU) data set and the National Institute of Standards and Technology (NIST) data set were used for the effort described in this paper. The data sets are specific to the respective campuses and contain a resolution suitable for informing both navigation and landing operations.

Phase II – Data Conversion: The formats of the GIS data obtained in phase I may vary. For instance, the TAMU data is in the State Plane Coordinate System (SPCS) 83, Zone 4302, Texas Central projection. Given that the probability maps are needed in near real-time operating environments, it is beneficial, in terms of processing time, to convert all data sources to the same

---

[1] Approved for Public Release: 10-3788. Distribution Unlimited.

projection prior to geo-processing. For this effort, because the scenario takes place fully within zone 4302, the data was left in this projection.

Phase III – Geo-Processing: Using the data prepared in phase II and mission profile settings, the system geo-processes the data into components for calculating the probability surface, then outputs a probability map. Each layer of interest is converted into a binary raster with positive and negative areas marked; the markings are based on ease of navigation or landing. For example, the structures layer includes all of the buildings in the area. The buildings are marked as non-traversable while everything else is marked as traversable. Once all of the layers are thresholded, a weighted sum is calculated from each of the components. The weights are selected based on the mission profile such as stealthy UGV navigation or size of UAV landing. The final composite layer is constructed from the summed components and cropped to the area of influence designated by the robot type, size, speed, etc. In the UGV case, sensor information indicating the platform location and the desired destination are used to dynamically calculate a least-cost surface from the current location. This surface is the probability map representing the traversability for UGVs or the probability of minimized impact for UAVs. Examples of resulting maps are shown in Figure 1 for UAVs and Figure 2 for UGVs.

Treating these computed maps as another source of sensor information, they may be used by other systems and fused with live sensor data. The probability maps derived from GIS data provide an extended view of the world beyond what can be directly sensed by unmanned platforms. Informal evaluation of the implemented approach and probability maps revealed how the probability and cost-surface maps have the potential to inform UGV navigation and UAV landing systems.

Figure 1. Minimized impact probability maps for an emergency UAV landing at TAMU based on current location and possible trajectories: (a) small UAV during the weekday, (b) small UAV during the weekend.

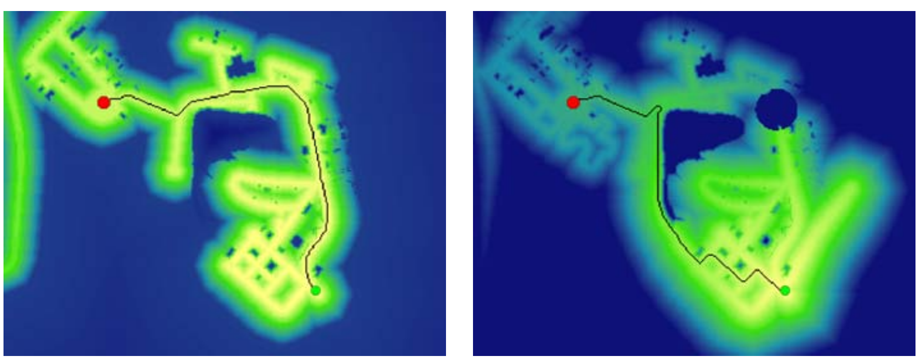

Figure 2. Cost-surface maps for UGV navigation at TAMU based on the current location and intended destination: (a) least-cost path for the UGV, (b) least-cost path adjusted when hazard is marked.

Author Contact Information:

Nathan Rackliffe
The MITRE Corporation
202 Burlington Rd M/S K320
Bedford, MA 01730
Phone: 781-271-8392
Fax: 781-271-2352
nrackliffe@mitre.org

Holly Yanco, Ph.D.
The MITRE Corporation
202 Burlington Rd M/S K320
Bedford, MA 01730
Phone: 781-271-2257
Fax: 781-271-2352
hyanco@mitre.org

Jennifer Casper
The MITRE Corporation
202 Burlington Rd M/S M325
Bedford, MA 01730
Phone: 781-271-2510
Fax: 781-271-8500
jcasper@mitre.org