High-Accuracy Multisensor Geolocation Technology to Support Geophysical Data Collection at MEC Sites

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Reliable and accurate geolocation is essential to robust detection, discrimination and remediation of unexploded ordnance (UXO) and other munitions and explosives-of-concern (MEC). The MEC characterization and remediation activities using the currently available detection and geolocation technologies often yield unsatisfactory results, and are extremely expensive, due mainly to the inability of the current technology to detect all MEC present at a site, and their failure to discriminate between MEC and non-hazardous items. This is a consequence of insufficiently accurate relative geolocation information of the electromagnetic (EM) sensors, since multiple EM images are combined together to produce a 3D images of the buried objects, which are often blurred due to the poor sensor geolocation. As a result, most of the cost (90%) of MEC remediation is on excavating targets that pose no threat. Thus, the goal of this research is to design and implement a high-accuracy device that can address the stringent navigation/geolocation requirements of a man-portable EM system in open and impeded environments, to lower the cost of remediation by improving the geolocation accuracy of MEC that will result in better discrimination, by practically eliminating excavation of non-hazardous objects.

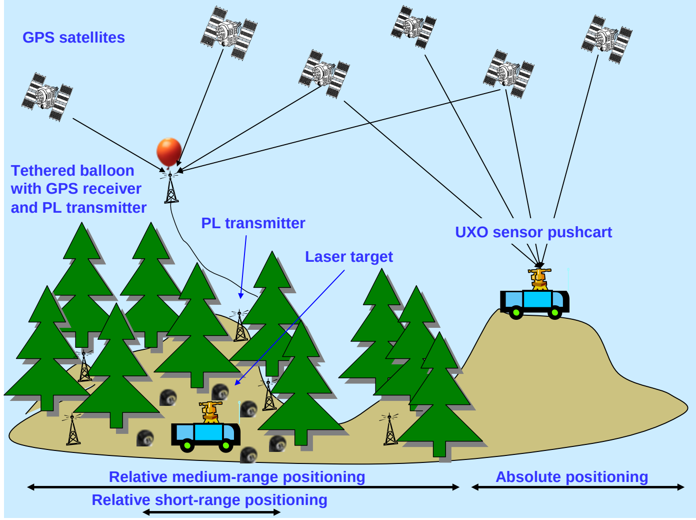

Figure 1. MEC site survey concept

The system design is based on the tight quadruple integration of the Global Positioning System (GPS), inertial measurement unit system (IMU), terrestrial RF system – pseudolite (PL), and terrestrial laser scanning (TLS) to support high-accuracy navigation for a non-contact mapping system in various environments. The key novel component of the proposed multi-sensor system is the integration of TLS that can provide very high positioning accuracy in a local frame, and thus can support a GPS/INS/PL-based navigation system in achieving both absolute and relative high positioning accuracy in impeded environments, see Figure 1.

TLS in the mapping mode is normally placed at a site with known coordinates, or GPS/IMU can be used for direct geolocation if the system is located on a moving platform. However, an inverse problem can be defined, that is, if the TLS's location is unknown, it can be triangulated from the scanned objects with known locations, or, if the absolute coordinates of the scanned objects are not identified, the objects' coordinates defined in some local frame (or TLS frame) can be used to determine a change in the TLS location coordinates. This is possible by matching the multi-site scans that allows for the determination of the coordinate transformation parameters between the sites. For example, a 6-parameter similarity transformation can be established between two point clouds of the same scene (here: spherical targets) collected at locations T_1 and T_2, as shown in Figure 2. These transformation parameters describe the change in TLS location and orientation between T_1 and T_2 that can facilitate measurement update in the integrated EKF. Thus, TLS, which is collocated with the EM sensor via known (calibrated) boresight parameters, can be used as a navigation/geolocation device for the EM sensor. The simulations and field tests to date demonstrated that cm-level accuracy can be maintained by TLS under GPS/PL blockage.

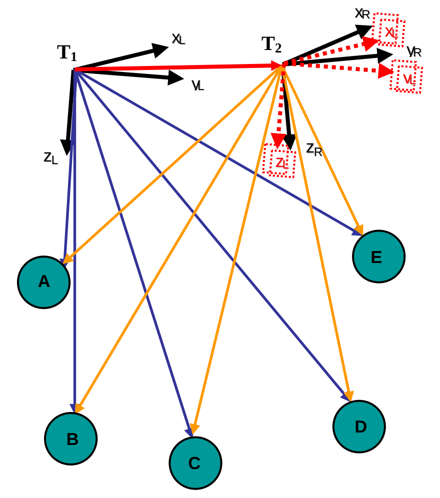

Figure 2a. TLS-based navigation concept based on spherical target matching at two locations of the TLS/EM, T_1 and T_2. Targets are denoted as A-E, the TLS coordinate system is centered at TLS and changes its location and orientation between the consecutive locations of TLS; $X_L Y_L Z_L$ and $X_R Y_R Z_R$ represent two consecutive locations/orientations of the TLS coordinate system.

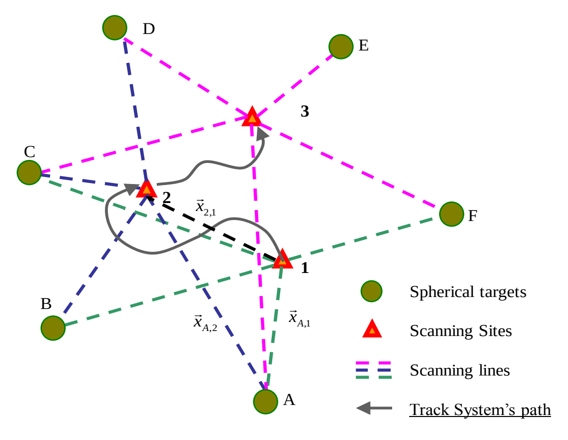

Figure 2b. The spatial (3D) or partial resection (2D) concept using TLS ranges and spherical targets

Figure 3 shows the TLS point cloud of a spherical target in two views (top and side). The points on the target are covering only a relatively small part of the surface, yet, the coordinates of the sphere center can be estimated with a standard deviation less than one cm, which has been verified by several test data sets. Obviously, the number and the distribution of the points on the spherical surface have a strong influence on the coordinate accuracy of the sphere center and the computational efficiency (i.e., the resulting number of iterations). Table 1 shows sample results from one data set. Note the center point positioning accuracy and the influence the number of reflected laser points from targets.

Figure 3. The field test: TLS data collection and the deployment of spherical targets (basketballs).

Table 1. The derived center coordinates of the spherical targets from the example data set

Sphere	**X (m)**	**Y (m)**	**Z (m)**	**Point Precision (mm)**	**Sphere Points**	**Iterations**
1	17.932	-15.111	-1.972	0.6	181	2
2	21.109	-11.503	-1.832	0.7	152	3
3	19.263	-15.479	-1.851	0.5	148	3
4	14.546	-20.353	-2.009	0.7	147	3
5	19.066	-14.224	-1.869	0.8	124	3
6	16.181	-18.127	-1.916	0.8	119	3
7	24.561	-8.683	-1.759	1.0	84	3
8	22.920	-16.328	-1.709	0.9	82	3
9	25.422	-12.524	-1.657	1.0	66	3
10	21.313	-18.230	-1.790	1.5	49	3