Automating Laydown Yard Material Identification and Localization

1. Problem Statement

Industrial construction projects are challenged by the storage and handling of a large quantity of fabricated materials in laydown yards, such as steel pieces, pipe spools, valves, and fittings. Effective material tracking requires not only the knowledge of what materials are currently present in a laydown yard, but also the ability to identify exactly where they are located for quick retrieval. Excessive crew hours spent on locating and retrieving materials can have a significant impact on field installation productivity and overall project schedule performance. A CII (2008) study showed that the average time a crew spent manually locating fabricated items in a lay down yard was over 35 minutes. On the other hand, a past case study indicated that effective material management has a benefit/cost ratio of over 5 to 1 in medium sized commercial construction projects (Thomas et al. 1989).

Automated material identification and locating studies conducted in the last decade have shown that such automation can increase productivity, cost efficiency, while minimizing data entry and material tracking costs. Among these technologies are barcoding, global positioning systems (GPS), radio frequency identification (RFID), and ultra-wide band (UWB) locating. While these solutions provide material identification and locating capability, they are different in various aspects, e.g. accuracy, implementation and operating cost, instrument setup effort, level of automation, robustness, ruggedness, and practicality/scalability for projects of various sizes. Therefore, for everyday field applications, the key question is to tradeoff among these competing needs and finds the most practical technical solution.

2. Objective

The goal of this research is to design a balanced material tracking solution that provides adequate accuracy and robustness yet with low system cost and user-friendly setup. Such a solution is expected to improve the scalability of automated locating systems for projects of different sizes, while minimizing implementation efforts, thus resistance to changes. The intended application is for locating fabricated materials in material laydown yards in industrial construction projects. Sub-objectives of this study are:

- Design and implement a material tracking system based on cost effective, mature, and robust technologies;
- Measure the accuracy and efficiency of the proposed system in locating and retrieving materials.

3. Literature Review

3.1 Current Practice

This section describes the current practice in laydown yard material identification and localization process in a typical industrial construction project. As shown in Figure 1, fabricated materials are tracked manually in this process (Nasir et. al 2010). Once materials are delivered by a fabricator, they are inspected, unloaded, and shaked out in the laydown yard. To identify the location of a material item, the laydown yard is typically divided into a grid, and each grid section is identified by an alphanumeric location code. The material item identification code (e.g. piece mark or tag) along with the grid location code are recorded manually after unloading an item, and then later entered into the central material tracking database. If an item is moved during their storage in the laydown yard, the above process will be repeated to capture the item's latest location. When an item is needed for field erection, the laydown yard crew will look up the item in the material database for its identification and location codes. The crew will then arrive to the grid location, and manually search for the item for loading and hauling to the field installation area. Finally, the removed item's status is marked and later updated in the database. As can be seen, this process involves manual collection of material data which can be tedious and error prone. More importantly, although the grid location code helps to find the approximate item location, it fails to pinpoint the exact location and still requires the crew to take the extra time to search for a specific item in a large grid section area, which is typically about 5,000 square feet. As mentioned previously, the CII case study (2008) found that this manual searching procedure can take more than 35 minutes.

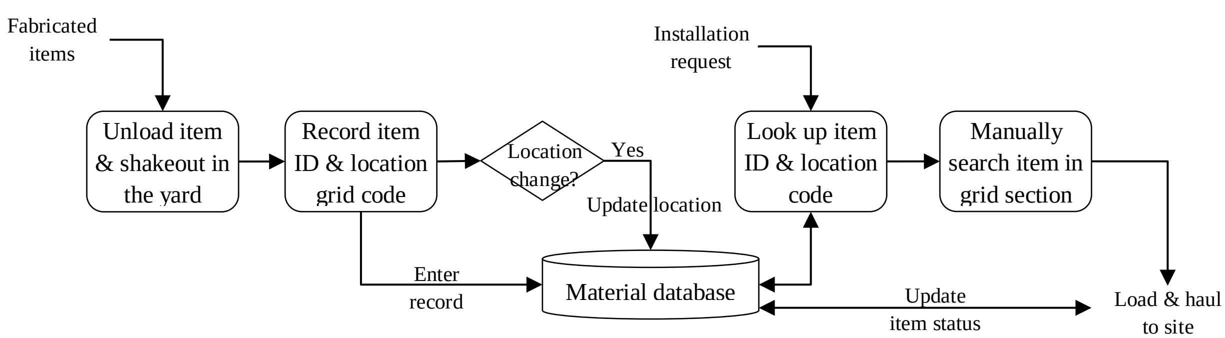

Figure 1: Current practice in identifying and locating materials in laydown yards

3.2 Literature Review of Available Technologies

Current available material identification and localization technologies are summarized in Table 1. The table compares the technologies in terms of functions, system setup, and availability (including approximate cost range and maturity). To improve the material tracking process described above, the selected solution must (1) enable both material identification and localization with reasonable accuracy; (2) have a flexible system setup for dynamic site environments; (3) be cost effective, reliable, and robust for outdoor use.

Table 1 Available technologies

Function	Technology				
	Barcode	**RFID**	**UWB**	**GPS Receiver**	**GPS Tagging**
1. Identification	X	X	X	-	X
2. Localization (accuracy)	-	-	X (0.5m)	X (2-5m)	X (2-5m)
System setup	Tag and mobile reader	Tag, mobile or fixed readers	Tag, fixed sensor and hub network	GPS receiver and satellite	GPS tag and satellite
Availability					
- Cost range	Label ~$0.1 Reader ~ $100-500	Tag ~ $1- 50 Reader ~ $1k-5k	Tag ~ $5 Sensor & hub ~ $10k (estimated)	Receiver ~$200 Satellite signal free	Tag ~ $200-500 Satellite signal free
- Maturity	Already widely used by fabricators/required by owners	Research & newly commercialized in construction	Research/testing	Widely used for surveying in construction	Research/testing

Barcoding has long been widely used by fabricators, and many owners require all fabricated items with bar-code label attached. Barcodes are machine-readable codes with a pattern of parallel lines of varying widths, and each unique code identifies one individual fabricated component. Bar code readers can easily scan codes in the field of view, thus avoid error-prone manual data entry (Thomas et. al 1989). Technology standardization, low cost barcode labels and reliable mobile readers contribute to its widespread use. However, barcode alone can only be used to identify whether an item is on site or not, and it cannot show where the item is actually located.

RFID replies on radio-frequency electromagnetic fields to transfer data (e.g. identity and location) between a tagged object and a reader. CII (2008) applied RFID tags, RFID readers, and a GPS receiver to locate fabricated materials. A RFID tag was attached to each fabricated item. A worker drove around the laydown yard on a daily basis with a mobile computing device with a RFID reader and a GPS receiver attached. On the fly, the RFID reader identified the presence of tagged components around a location, while the GPS receiver determined an item's rough location. Post data processing also allowed pinpointing an item's exact location within a radius of a few meters centered on the tag. To capture possible item relocation in the yard, RFID and GPS data are collected on a daily basis in order to record the latest location. Item-location maps were given to workers to search for a specific item. This approach automatically identifies and locates tagged items, but its implementation is limited by (1) the relative high cost of equipment (i.e. tags and receivers), (2) lack of equipment standardization, (3) interference of metal to RFID data sensing, and (4) risk of damage to tags during material handling.

GPS is a satellite-based navigation technology that has been widely used for determine outdoor point location in terms of latitude and longitude, such as surveying applications. For material tracking, a Canadian study (Pardasani et. al 2009) used a GPS tagged camera to collect item piece marks as well as item location to assist item localization. The newer GPS tagging technology integrates GPS receiver and cellular/satellite communications to allow uniquely identifying a tagged object globally and broadcast its location remotely. However, for relatively low-cost large-volume construction material tracking, the very high cost and the risk of tag damages make GPS tagging a less attractive option.

UWB is a short-range radio communication technology which has been recently studied for precise material locating application (Shahi et. al 2012). Unlike GPS-based locating technology, UWB can identify and locate items in both indoor and outdoor environments, and can reach sub-meter accuracy. However, since UWB radio signal only works in a short range, a fixed array of receivers must be set up and calibrated for a specific site layout. As a result, if the site layout is changed, the system must be re-established, which can be a very repetitive and time-consuming process. In addition, the technology is relatively new and equipment costs are too high for practical construction applications.

4. Proposed Approach

Based on the above discussion, in this study, we propose to use a combination of barcoding and GPS for material identification and localization for the following reasons: (1) for material identification, barcodes are already widely applied by the industry and require no or minimal change to the current practice; (2) GPS has also been widely used for surveying and locating applications in construction; (3) both technologies enjoy relatively low cost, high level standardization, and reliability for outdoor construction environments. It is expected to make material tracking solution more scalable for projects of varying sizes, while minimizing implementation efforts, and thus resistance to changes. Although, a commercial product, Track'em (2012), is based on similar technologies, its performance and actual usage is poorly documented and publicized. Our proposed solution will be based on the most recent advancement of mobile computing to increase efficiency while reducing costs. Also integrated into our project is a measurement and verification plan of system performance, which is detailed in the next section - "Work plan."

The proposed procedure of laydown yard material identification and localization process can be summarized below and as shown in Figure 2. When compared with Figure 1 current practice, areas of improvement in the proposed approach can be easily identified. These automated or semi-automated activities are expected to eliminate paper-based data collection, increase item localization accuracy, and substantially reduce item searching time.

- Contractor receives fabricated materials with barcodes applied to each item.
- Unload and shakeout items in the laydown yard. A worker uses a handheld device equipped with a barcode reader and a GPS receiver to record each item's identification barcode and its GPS location. A digital photo will also be taken to further assist future item retrieval.
- Item status data will be updated to the central material database through a Wi-Fi connection in real time or later in the office via a wired connection.
- If an item is relocated in the laydown yard, the above two steps will be repeated to capture the latest location. A CII study (2008) found that about 20% items were moved to a different location. This extra effort appears to be reasonable, especially comparing with the RFID and GPS solution (CII 2008) which requires daily data collection and updating.
- When an item is requested for field installation, the crew can search for the item in the database and retrieve its location information.
- An onboard GPS will guide the driver to the laydown yard location to retrieve and load the item. The item is scanned again and marked as "removed" in the central database.

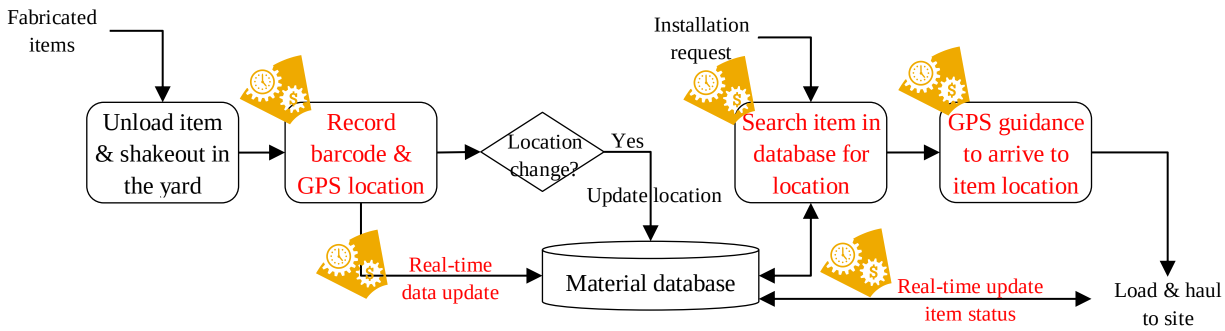

Figure 2: Proposed practice in identifying and locating materials in laydown yards

5. Work Plan

Table 2 shows the work plan and deliverables. The project will be completed in one year. The proposed prototype system includes hardware components (including barcode reader, GPS receiver, and handheld computer) and software components (including barcode and GPS data integration, database updating procedure, and location map visualization). At this stage, we plan to design the system on mobile computing devices, such as tablet computers and smart phone, which is readily available to the research team. They integrate barcode reading, GPS positioning, and database updating capabilities. This will help to design a compact, flexible, and low cost system. The system design will consider current material receiving and tracking procedure, and augment existing barcoding and database/spreadsheet tools with precise GPS-based item localization capability. Survey-grade GPS equipment (provided by Fluor) will only be used to verify the GPS positioning accuracy of the proposed mobile computing devices for laydown yard material tracking.

The system will be tested in an actual construction project (project access provided by Fluor). The system performance and crew productivity (e.g. location accuracy, processing time, and user feedback) will be measured and reported.

Table 2 Work plan

Tasks	**Deliverables**	**Weeks**											
		1	2	3	4	5	6	7	8	9	10	11	12
Design detail work process	Work process specification	X	X										
Define system structure	Hardware and software specifications		X	X									
Configure hardware components	Tested hardware solution			X	X	X							
Design software components	Tested prototype system				X	X	X	X	X				
Field case study and performance measurement	Test results									X	X	X	
Documentation	Final report											X	X

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