A Survey and Taxonomy of Location Systems for Ubiquitous Computing

**Abstract** In this paper, we present the basic **techniques** used for **location-sensing**, describe a **taxonomy** of **location system** that define the field, show how the taxonomy can be used to **evaluate location-sensing systems**, and offer suggestions for future research.

1. **Introduction**

Many systems over the year have addressed the problem of automatic location-sensing, and they vary in many parameters. To make sense of this domain , we have developed a taxonomy to help devel- opers of location-aware applications better evaluate their options when choosing a location-sensing system

**Section2:** We present the basic techniques, such as triangulation, used for location-sensing.

**Section3:** Defines a taxonomy by examining issues in location system implementation

**Section4:** Then surveys several important commercial and research location systems and places them in the taxonomy

**Section5:** We give an example of applying the taxonomy to choose a location-sensing system for an application

**Section6&7:** Describes future research directions

**2 Location Sensing Techniques**

**Triangulation, scene analysis, and proximity** are the three principal techniques for automatic location-sensing.

**2.1 Triangulation**

The triangulation location-sensing technique uses the **geometric properties of triangles** to compute object locations. There are three general approaches to measuring the distances required by the lateration technique.

**2.1.1 Lateration**

We define the term lateration to mean for distance measurements what angulation means for angles.

1. Direct. Direct measurement of distance uses a physical action or movement
2. Time of Flight. Measuring distance from an object to some point P us- ing time-of-flight means measuring the time it takes to travel between the object and point P at a known velocity
3. Attenuation. The intensity of an emitted signal decreases as the distance from the emission source increases

**2.1.2 Angulation**

Angulation is similar to lateration except, instead of distances, **angles are used** for determining the position of an object.

**2.2 Scene Analysis**

The scene analysis location-sensing technique uses features of a scene observed from a **particular vantage point** to draw conclusions about the location of the observer or of objects in the scene.

**Advantage**: the location of objects can be inferred using passive observation and features that do not correspond to geometric angles or distances As we have seen, measuring geometric quantities often requires motion or the emission of signals, both of which can compromise privacy and can require more power.

**Disadvantage**: The observer needs to have access to the features of the environment against which it will compare its observed scenes.

**2.3 Proximity**

A proximity location-sensing technique entails determining when an object is “near” a known location. The object’s presence is sensed using a physical phenomenon with limited range. There are three general approaches to sensing proximity:

1. **Detecting physical contact**. Detecting physical contact with an object is the most basic sort of proximity sensing.
2. **Monitoring wireless cellular access points**. Monitoring when a mo-bile device is in range of one or more access points in a wireless cellular network is another implementation of the proximity location technique
3. **Observing automatic ID systems.** A third implementation of the proximity location-sensing technique uses automatic identification systems

**3.Location System**

A broad set of issues arises when we discuss and classify location system implementations. These issues are generally independent of the technologies or techniques a system uses.

The Global Positioning System is perhaps the most widely publicized location sensing system.

**3.1Physical Position**

A location system can provide two kinds of information: **physical and symbolic.** GPS provides physical position. In contrast, symbolic location encompasses abstract ideas of where something is: in the kitchen, in Kalamazoo, next to a mailbox, on a train approaching Denver.

**3.2 Absolute versus relative**

An absolute location system uses a shared reference grid for all located objects. In a relative system, each object can have its own frame of reference. An absolute location can be transformed into a relative location – relative to a second reference point, but the second point not always available.

**3.3 Localized Location Computation**

Some systems provide a location capability and insist that the object being located actually computes its own position. This model ensures privacy by mandating that no other entity may know where the located object is unless the object specifically takes action to publish that information.

**3.4 Accuracy and Precision**

A location system should report locations accurately and consistently from mea- surement to measurement.

**3.5 Scale**

A location-sensing system may be able to locate objects worldwide, within a metropolitan area, throughout a campus, in a particular building, or within a single room.

**3.6 Recognition**

For applications that need to recognize or classify located objects to take a specific action based on their location, an automatic identification mechanism is needed.

**3.7 Cost**

We can assess the cost of a location-sensing system in several ways. Time costs include factors such as the installation process’s length and the system’s administration needs. Space costs involve the amount of installed infrastructure and the hardware’s size and form factor.

**3.8 Limitations**

Some systems will not function in certain environments. One difficulty with GPS is that receivers usually cannot detect the satellites’ transmissions indoors. This limitation has implications for the kind of applications we can build using GPS.

**4. A Survey of Location Systems**

The open circles indicate that the systems can be classified as either absolute or relative, and the checkmarks indicate that localized location computation (LLC) or recognition applies to the system. Physical-symbolic and absolute-relative are paired alternatives, and a system is usually one or the other in each category.

**5.Applying the Taxonomy**

In addition to simply reasoning about a location-sensing system, our taxonomy can be applied to evaluate the characteristics of a location system needed by a particular application or the suitability of an existing location system for the application.

1. **Physical versus Symbolic**. The jukebox requires symbolic locations.

2. **Absolute or Relative**. Because the application uses fixed speakers driven by the infrastructure, absolute locations are needed.

3. **Localized Local Computatio**n. The infrastructure is already managing and keeping private each user’s repository of digital audio files

4. **Recognition**. The jukebox requires the capability to recognize and distinguish individual people in order to pipe users’ audio streams to the correct speakers.

5. **Accuracy and Precision**. Accuracy must be sufficient to distinguish the regions in which various speakers may be heard.

6. **Cost**. A low cost location-sensing system is always desirable.

7. **Limitations**. The location-sensing system must function in the indoor environment.

**6 Research Directions**

Location sensing is a mature enough field to define a space within a taxonomy that is generally populated by existing systems.

Future work should generally focus on lowering cost, reducing the amount of infrastructure, improving scalability, and creating systems that are more flexible within the taxonomy

**6.1 Sensor fusion**

Defined as the use of multiple technologies or location systems simultaneously to form hierarchical and overlapping levels of sensing, sensor fusion can provide aggregate properties unavailable when using location systems individually.

An example of current sensor fusion research, multisensor collaborative robot localization and map building presents a problem usually divided into two sub- problems:

• tracking location as the environment changes or the robot moves, and

• determining robot location from a zero-knowledge start state.

**6.2 Ad Hoc Location Sensing**

This approach to locating objects without drawing on the infrastructure or central control borrows ideas from the ad hoc networking research community.

**6.3 Location-Sensing-System Accuracy: A Challenge**

Comparing the accuracy and precision of different location-sensing systems can be an arduous task because many system descriptions lack a concise summary of these parameters.

**7 Conclusion**

In this paper, we have presented the basic techniques used for location sensing, taxonomized location system properties, and surveyed research and commercial location systems that define the field.