

Observation Systems

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An observation system observes behavior of a person, objects, or a group of persons and objects in an environment. The goal of such a system is to observe activities performed in the environment and to keep a record of important events and activities. Such a system may prepare a database of all activities and events as well as store raw data and even intermediate processing to provide analysis environment to understand and gain insights in the environment by correlating all multifarious data collected from disparate sensors and other sources.

Observation systems have applications in many areas including but not limited to surveillance, traffic monitoring, ethnography, marketing, and healthcare. For example, a surveillance system observes behavior of a person or a group of persons in an environment. The goal of such a system is to study activities performed in the environment to monitor any suspicious or abnormal behavior with the goal to report any dangerous behavior. Surveillance data is usually used for reviewing past activities to find and explore important past events. Other observation systems may have entirely different roles, including immersive telepresence at a remote location where a meeting, sporting event, or family event may be taking place.

An observation system may utilize many disparate sensory sources to collect the data about the objects and the environment and analyze this data to obtain the information that it may consider important to perform its task. These sources may include maps, three dimensional models, information about objects, and live sensors of different types. Each sensor is just a data source and contributes towards building a complete observation of an environment. Many sensors of different types are employed in the environment to gather relevant partial information that is assimilated to build a holistic picture of the complete environment.

In most cases, an observation system is designed for a class of operations. This class is bounded, but is reasonably flexible. Thus, it is expected that the system uses sensors, analyzes data and stores information that is relevant to a certain class of operation, but the queries that users can ask are not just a few hardwired ones. We will make this more concrete by discussing this issue in more depth for at least one class of observation systems.

Such a system may be autonomous or may be interactive. In an interactive system, all the data may be stored with the goal of providing any information that a user may need. A user will be able to articulate his queries and the system should provide him answers to his query. The answers may be either at the symbolic level or may render (present) appropriate data sources. Automatic observation systems may provide alerts for the

events specified by users. These systems will provide an environment to define user requests for specific events.

Functionality

An Observation System has some general basic functionality. For specific applications these may be modified and refined. Some applications may require only a small subset of functionality discussed below. In general, the following are the functions that an Observation System should provide:

1. Store all raw data for review when required. There may be lossless compression of the data. Lossy compression should be avoided as it may make review of the data for extraction of specific information impossible or very difficult.
2. Provide a list of all important events and associated information for the domain of application. Obviously, a system designer will consider the events, activities, and attributes that must be included in the system at the time of the design.
3. The system may have many clients (users) with different devices, access rights, and facilities. It may be possible that a user has many devices (multiple desktops, mobile phones, ...) that are registered to receive and access information. The system should consider devices and access rights in formatting and presenting appropriate information.
4. The system may work in two distinct modes. It may monitor live events for 'standing requests' (continuous queries) or a user may access the system to inquire about specific information about past events.

(a mouse clicking and moving system)

(User typing recording system)

5. A user should be able to visualize the state of the observation system at any time and should be able to query about any past events. This should be done in terms of application level events, activities, and attributes.
6. Statistical characteristics of events, activities and attributes should be available to users in spatio-temporal formats.

(Statistics based pattern classification and machine learning)

7. The system should provide tools to address privacy issues as may be required. Since depending on different requirements, the privacy rules may be different, the system should allow defining those rules and implementing those as may be required.

8. A user should be able to specify 'standing queries' and the system should send alerts about specific events to specific clients as requested in the standing query.
9. Allow exploration of different types of past events that may have happened but not detected by the system. This may require an environment in which a new type of event could be defined and explored.
10. Event definition environment should be provided. Events could be defined in terms of primitive domain events or may be mapped into events into specific data sources. The mapping into specific sources may not be visible to a user.
11. A system designer should be able to define new data events both at primitive event level as well as at compound level.
12. A system designer should be able to update credibility rating for different information sources and should be able to develop information assimilation approaches.
13. Any new data device can be added to the observation system at any location in the environment. Similarly any existing device could be deleted from the environment. An information source registry (ISR) should keep this information for each information device.
14. Given a location in the environment under observation, the system should be able to identify the sensors and other sources that will help in observing that environment.
15. For each sensor, it should be able to relate sensor data to the real world information.
16. Data from different sensors should be analyzed and assimilated to develop observations in the application environment in terms of events, activities, and attributes of the application environment.

Prospecting Perspective

An observation system adopts a flexible prospecting perspective. This system is organized to store data, meta data, and derived information in such a way that a user could either search for any information unit in the system at any level – from data to application views – or could prospect all data sources for any specific information. In this sense, this system will behave as a database, as a search engine, and as a prospecting system that allows analyzing, reanalyzing, and exploring all sources to find presence of specific information nuggets.

This system maintains the observed data – commonly called raw data – in its original form. All analysis, intermediate results, annotations, detected events and activities are stored appropriately as derived data and results. This is important to provide multiple perspectives on the same set of data and ability for different analysts to maintain their analysis trails.

Technical Components

To realize the functionality discussed above, the system takes ideas from many existing applications and system components. Many novel concepts and techniques will be required to implement these systems. In this section we discuss major technical components in an observation system.

1. Each sensor or other data source is registered with the information source registry (ISR). This gives the location and viewpoint for the sensors and characteristics of other information sources. All the parameters that are relevant for the transformation of the sensory data to the real world environment are available. If exact parameters are not available, the uncertainty in parameters should be characterized and made available in ISR.
2. When a new sensor is added to the system, it is entered in the registry and its key parameters for the transformation are also entered. Each sensor captures some physical attributes of the environment being observed. The nature of sensor data and its mapping to the environment should be part of the information source transformer (IST) that is available to the system.
3. All data from each sensor is stored in the media storage. This data is available to view the details or to do prospecting for specific information nuggets. Data and information available from other sources should also be stored as it becomes available. All this data and information is stored in its original form.
4. Though each sensor stores its data in terms of the sensor coordinate system in the storage, each sensor's relative offset with respect to the physical environment are available and stored in the ISR. Thus it is possible to convert sensor coordinates into spatial coordinates of the environment. But these conversions are performed only on as needed basis.
5. System uses a global clock. Each information source may have its local clock whose relative position is available and stored in the ISR. Thus it is possible to convert sensor time stamps to global time stamps. These conversions are performed only on as needed basis.
6. Each data stream is processed independently only based on data characteristics. The result of the processing of each data stream may be stored in a database.
7. Application knowledge (also called domain knowledge) should guide processing when required. This guidance should be explicit and may be stored along with the results explicitly. Thus the results of the processing of a data stream in data driven and goal driven manner should be explicitly stored and characterized.
8. The interpretations of data could be made based on application tasks but such interpretations should be considered as interpretations and should be kept separate

- from the data. The interpretations of data should not be mixed with the data. Multiple interpretations of data are possible and should be each stored separately with the context used for interpretation. The context may include the application, analysts, and assumptions used in the interpretation.
9. Data from different sensors should be assimilated in environment model (EM). Each data stream is transformed to environment information. Environment information from different data sources, including but not exclusively from sensors, is assimilated into environment model. The environment model contains 3-dimensional information about objects, their activities, and attributes in the environment.
 10. All assimilated information from different sensors is in objective form and is in application independent manner – it should be as objective as possible.
 11. Application oriented views and functions could be defined on top of the objective system. These views could be computed and separate databases created for each application views. Thus, using the same data, one could have a surveillance view, or enjoying art gallery, or a video ethnography view. All these views could be computed from the objective database using different event models and related attributes.
 12. An end-user will interact with the system using application oriented interfaces. This user will articulate queries using application functionality.
 13. The application view will allow definition of application oriented queries that may not be available in the system. These queries will be propagated to the objective database and may even be propagated to individual data sources using environment model. A user may not be aware of the query transformations to objective and data levels, however.
 14. Source credibility can be assigned to each information source. It should be possible to specify which source has credibility in which area. This credibility rating could be used by the system to select information sources for specific tasks and could be used in information assimilation.
 15. Information display could be in geo-spatial-temporal form. Thus the system should be able to show types of information coming from specific spatial positions at specific times. This facility would be useful in analysis and understanding of activities and events.
 16. System designer can add different events and activity detectors to the system. These could be at any level from data stream to application. These should be added in the list of these detectors available to the system.

17. A system designer should be able to change privacy requirements in the system. Depending on the rules in an application environment, the designer should be able to change access to parts of data depending on the data characteristics as well as the access rights of a user.
18. An application view system will allow development of application specific event and activity detectors to populate the application-view-database.
19. An A-O transformation system will allow any application specific query to be translated to objective level.
20. An O-D transformation system will take an objective level event or activity and transform it into data stream level events and activities. This may require use of ISR to select appropriate combination of information sources and data streams.
21. A continuous query system will allow formulation of standing queries for generating real time alerts in the system. This system will monitor real time events specified at application level by transforming this using EM and other components to appropriate level and combining results to generate appropriate alerts and related information.
22. Information from different sources will be combined for presentation to a user using presentation system (PS) that will consider nature of data to be presented, client characteristics, and access rules.