MapNexus

Modelling Human Behavioral Patterns in Architectural Space to Enable Context-Aware Information Exchanges in a Wireless Intranet

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Abstract Architectural interior spaces provide a rich syntax for context-aware modeling. In a wireless wide area network (WAN), an urban environment can be geographically tessellated into a series of polygons reflecting the radio transmission range of each wireless access point (AP). By using these APs as spatial aggregation units in a relational database, logical assumptions about short-term behavioral patterns can be modelled; this paper describes a method to capture, encode, and interpret context-aware cues. These cues are then utilized by an intranet web server to produce context-aware output, information that fits the client's short-term activity landscape and intentions. The method does not require any special client-side software and preserves the user's anonymity as it derives the client's physical location implicitly. Such a framework permits a new type of context-aware web interaction based upon the logical "common sense" patterns that are specific to architectural interior spaces at a given time.

1 Mapping Human Behavior in Architectural Space

1.1 THE GOAL TO IMPROVE THE CONCEPT OF WEB "PAGE"

Since Mesopotamian times, the structure of the written "page" has not changed much. A paper page contains text (written, typed, or computer-generated) which has been created by an author in the past and which will be read by an individual in the future. Hence, the relationship between the author and the reader is one of estrangement as they are separated in both time and place: a text is always removed from its original context. Nowhere is this separation more acute than within the web. The web author's audience is largely unknowable – a reader of a web page could theoretically speak any language, live in any country, and be of any age. Since there is no defined simulacrum of “reader,” there is a paucity of common knowledge linking writer and reader as the very idea of “context” has been completely eroded from the author’s viewpoint. This “unknowability” has become problematic in information exchange. A web site that is cognizant of the client’s context can offer a shift in this reader-writer equation since “common sense” is implicitly understood by both parties before a conversation ensues.

This paper lays out a new and unobvious framework and related methods to model a client’s context and to produce a context-aware web site. This thesis project is concerned with web-based information exchanges that occur in a campus-like computing environment or a wide area network (WAN) using wireless access. More specifically, this project uses the MIT campus and its students as the intended environment for implementation of a prototype; the term, MapNexus, is used to indicate a future prototype set in MIT’s computing environment. However, this thesis project is limited to the presentation of a conceptual framework – the project has not yet been put into practice, but efforts are ongoing to build a prototype at present.

1.2 THE PROBLEM OF CONTEXT IN ARCHITECTURAL SPACE

“Contextere” is a Latin verb meaning “to weave together.” When people speak to one another in person, the communication exchange is rich in implicit messages: body language and eye contact. Moreover, the physical environment – a crowded subway car or a private office – has innate characteristics that implicitly guide the thoughts and conversations that occur within that particular architectural space. Likewise information seeking starts with an internal conversation – talking with oneself. By looking carefully at the architectural space, one can gain cues about which conversations would be appropriate in a given space and which conversations would be unusual. MIT as a physical environment is rich in its contrasting architectural syntax – most buildings have a specialized function. There are clearly land-use patterns within the 152-acre campus that can be modelled on a building-by-building basis. Context-aware applications try to ascertain an individual’s intent as it relates to architectural space and the behavioral patterns expected within in a given space at a given time. There is a definite relationship between architectural space and the range of human behavior expected within the walls of a particular building. The “potential energy” of an architectural space consists of things, people, and ensuing possibilities.

1.3 A BRIEF VISION OF A FUTURE PROTOTYPE

As indicated in Figure 1, MapNexus is a framework to capture, encode, and interpret context-aware cues about people’s anticipated behavior as a function

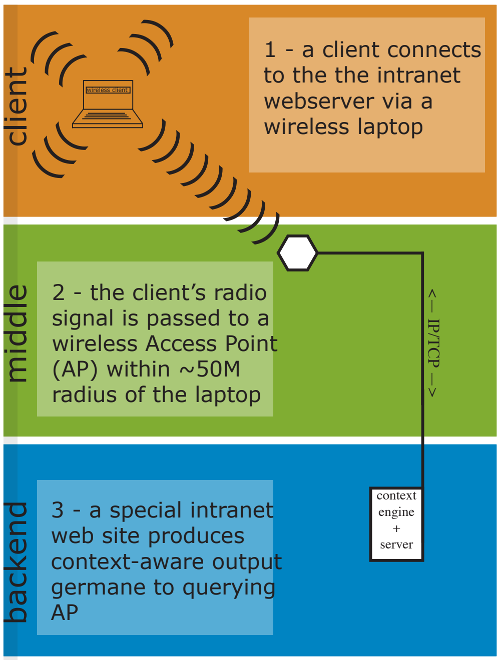


Figure 1. MapNexus Structure: Front-End, Middle-Ware, and a Back-End server/database.

of site-specific architectural space. When human-computer information exchanges reflect the behavioral context of a particular setting, a client saves time and is better able to make decisions in the field. Cues from a particular architectural space are utilized by an intranet web server to establish a behavioral context and a physical setting to gage one's short-term intent. A framework for the operation of a context-aware web server focuses upon defining the client's short-term possibilities. Finally, a five dimension attribute model is presented to track the context of each wireless access point's environmental attributes in a WAN. This 5-D model is also used to represent corresponding events in order to match them with a particular context akin to a jigsaw puzzle. MapNexus is a framework that consists of three separate parts:

Front-End

1. Information germane to the client's logical frame of behavior in a certain place and time.

Middle-Ware

2. A method to implicitly sense the client's AP and to create a computer-generated context model in real-time.

Back-End

3. Web content offered by the intranet server and database.

1.4 THEORETICAL ORIGINS, THREE STRANDS

MapNexus draws together three separate methods to represent knowledge about architectural interior space and expected behavioral patterns:

from geographic information systems (GIS) ≈ the "spatial aggregation unit"
from artificial intelligence (AI) ≈ the "context-aware engine"
from natural language processing (NLP) ≈ multi-dimensional context markup

The "spatial aggregation unit," a concept utilized in GIS modeling, is a polygon of physical space in 3-D; this tesselation of space is designed to create a spatial database in the entity/attribute model. MapNexus seeks to borrow some of the concepts AI and its context-aware applications: creating sensors and aggregates to gain cues about a particular physical environment. Finally, MapNexus draws from the Natural Language Processing (NLP) theories to create a grammar to represent common sense knowledge propositions.

Seeking and making sense of the vast amount of information on the web requires a cognitive ability to place the pieces of the puzzle together in order to complete the task. The time barrier to the retrieval of useful information is one of the most important determinates in a web site's long-term success, fractions of a second count. The utility of a web site often has an inverse relationship to the amount of explicit input (i.e., clicks and text) required to gather data; less is more (Huberman, 2001).

1.5 TECHNICAL DESCRIPTION OF MIT'S WIRELESS FRAMEWORK

MIT has approximately 4,000 people using wireless laptops on a given day; the Institute has one of the largest wireless wide area networks (WAN) of any university, with over 450 Avaya transmission APs in its 152 acre campus. The wireless WAN runs on the IEEE 802.11 protocol which is able to achieve a high rate of data transfer by the use of direct signaling spread spectrum (DSSS) – a physical layer technology involving ~40 separate transfer streams simultaneously spread over a number of frequencies (processed at ~2.0 GHz). The range of coverage of a given AP varies due to physical obstructions; by default the client communicates to the AP with the strongest signal. Most APs are within a 50M radius of the client. The AP placement is designed to maximize the coverage in a particular architectural space. Thus the particular AP that is receiving the client's transmission is an excellent cue to location. Each AP has a unique internet protocol (IP) address in a network to facilitate IP packet routing to a server.

1.6 EXAMPLES OF CONTEXT-AWARE WEB INTERACTION

MapNexus provides utility to the client's field-based decision-making by delivering information quickly in a given context so that the client may make better short term decisions. The larger issue is to refrain from using the web as a means to disseminate paper based information (static schedules) and to offer context aware information as transparently as possible (sorted according to the client's place/time) to permit greater personal productivity and more informed decision-making. The set of algorithms guiding human behavioral patterns will closely mirror that changing "event landscape" over time. For example, a person who was selecting a lunch option at the Media Lab at 10:32 am on Monday, would, as a default, find the following set of assumptions: there would be a time frame for the length of the episode as well as a secondary frame to travel back and forth to the lunch. As a default, it would be assumed that one would travel to lunch as a pedestrian or would utilize the proximity of public transportation. Because the context-aware web server would be able to closely coordinate the transportation schedule with the lunch options, a client could better make decisions that were based upon a combination of pedestrian travel and public transport to facilitate decision making.

One of the central dilemmas of the web in terms of information seeking is the explosive amount of data that is being added constantly. Such a large library of data makes it difficult to find information relevant to a particular context and time frame. MapNexus is designed with attention to the power of suggestion regarding "what is going on" in one's environment. For example, a Saturday afternoon is generally unscheduled for most students. MapNexus is aware of such time-activity patterns and is therefore in a position to suggest "things to do" that make common sense. In "Negative Expertise," Minsky (1994) argues:

> Negative knowledge is involved in many of the forms of thinking that we term 'emotional', notably those involved with humor, shame, fearful, and aesthetic appreciation. This machinery includes a variety of suppressors, critics, and inhibitors, some of which can inhibit not merely actions but entire strategies of thought. Thus, once one begins to look for it, one finds examples of negative knowledge in many activities that we usually see as positive.

MapNexus aims at filtering events – a method of suppression – to allow for a client's preference. By filtering out information, the client is left with a more manageable set of options.

Drawing from the theories of urban form by Kevin Lynch (1960), we know that residents of a city have a spatial index of symbols embedded into memory. Directions to new sites are best conveyed to an individual if they build upon this previously existing spatial knowledge – if the new journey is related to those recollections of previous journeys. Furthermore an individual will have a better chance to memorize new directions and thus is less apt to require a printed map – if the new path is presented as a modification of previous experiences in spatial reference. The client of MapNexus, MIT's academic community, is assumed to have a default set of spatial icons in memory — thus the questions becomes, "How do we structure a computer system to recognize these common sense rules?"

2 Structuring Human Behavior in Architectural Spaces

2.1 MICRO-SCALED LAND-USE PATTERNS

Consider for example a zoning map (Figure 2) in which certain areas of a city's ordinance allows for residential, commercial, or industrial land uses.

This map is an example of parcel-specific data that has been simplified into a visual representation. MapNexus draws from the idea of the zoning

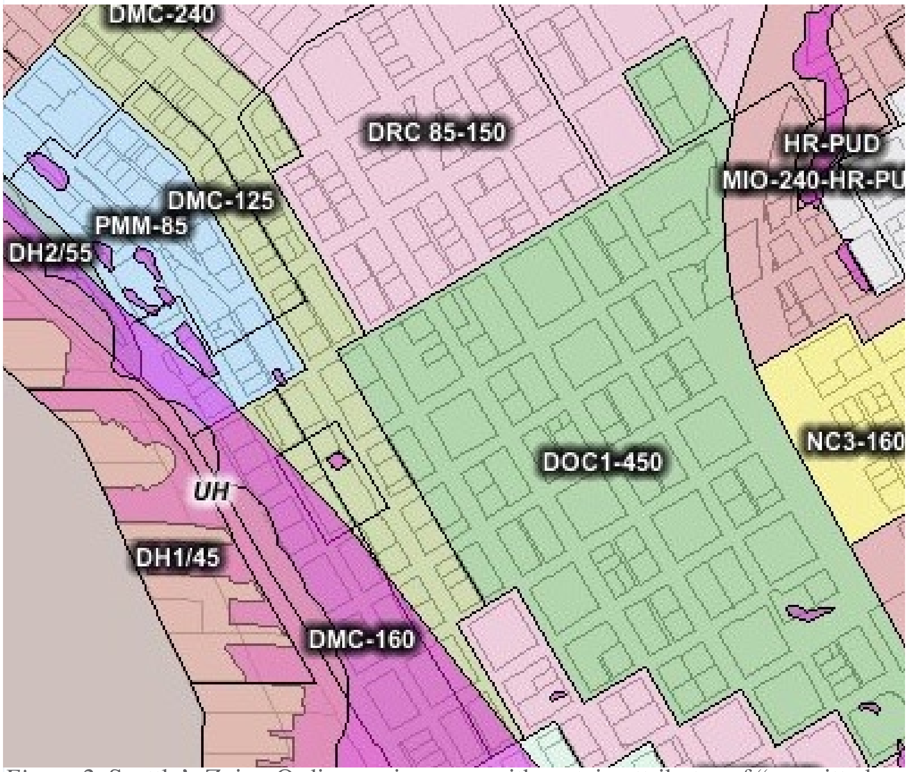


Figure 2. Seattle's Zoing Ordinance is a map with certain attributes of "permitted uses" for each zone. Interior architecural space could be modelled in a micro-scale.

ordinance map: a legal statement of permitted human activities in a given polygon. Zoning maps show a fairly accurate representation of the long term habitation activities. MapNexus seeks to use the concept of a zoning map with its table of "permitted uses" to represent human behaviors in the short term as a function of interior architecture – the land use of buildings and rooms. In zoning maps, each land-use has a table of permitted uses – activities that people may or may not engage in on this particular premise. Likewise each building has rooms with different functions. MapNexus uses a coherent scheme of visual representation of the MIT campus based on color and also makes logical deductions about a building's use to create context profiles from the various clues that can be gained from looking at a building's macro and micro scaled use patterns. There are no buildings at MIT that could be considered truly mixed-use (i.e., to combine chemistry labs and living space). While there are often many activities occurring within the ~50M range of a given wireless AP, rudimentary deductions can be made – tagging a space as recreational, work, or living.

2.2 WITTGENSTEIN'S LANGUAGE GAMES

The communication between a client and the web often breaks down because of the failure of the latter to recognize context. Often the problem in mining place/time data is that there are no clear formulas of how variables fit together: just pieces of isolated data such as an address, hours of operation, and events. It takes time and skill to make a quick analysis of the information, especially when information is often displayed in separate sites which force the client to rely upon short term memory or shorthand notes. MapNexus creates a way to impose logic upon a vertical tree of multivariate data that is germane to a particular event. The idea of MapNexus is not so much to define what is possible but rather to define what is not possible. What are the rules of the community in a particular context?

If one views the ecology of information in the Internet as an infinite extension of our own mental capacity for recollection of data, the problem quickly shifts to what Wittgenstein calls "private languages," the phenomena of thinking and reasoning in language outside the realm of the community of language speakers. The vast data available on the Internet allows the client a large amount of new information; yet one's ability to understand patterns and connect information to one's environment is not augmented in tandem. MapNexus thus aims at providing the client information germane to a given spatial/temporal context to allow immediate interpretation with minimum ambiguity. The goal is not to utilize the web to look for obscure data but rather to utilize the web to provide data that could be used in one's immediate context to help make every-day decisions. Hence, there is an overall view to offer data in logical groupings so that decisions that require comparison or multiple variables can quickly be made.

2.3 MINSKY'S "SOCIETY OF THE MIND" APPROACH

MapNexus draws from two approaches to establish the 'common sense meaning' of our environment. First, what is common sense? To Minsky (1986), "Common sense is not a simple thing. Instead it is an immense society of hard-earned practical ideas — of multitudes of life-learned rules and exceptions, dispositions and tendencies, balances and checks." MapNexus aims to be an "intelligent" application and seeks to produce web content that reflects the common sense of a given physical environment at a particular time. One key approach to elucidate "common sense" is the *Society of the Mind* theory by Minsky that manifests itself as the OpenMind project by his student, Push Singh, at MIT (http://commonsense.media.mit.edu). The OpenMind project collects and organizes large data sets of simple propositions such as, “the sky is blue during the day.” MapNexus could mimic this type of proposition, “Students have more free time on the weekend than during the week.” By drawing from the work of Minsky and Singh, it becomes possible to envision a number of propositions that are related to place and time at the AP spatial granularity. In many ways MapNexus aims not to gather together but to caste away information on the web that is extraneous to the client’s situation.

Once assumptions about the client’s disposition and point of view can be made, MapNexus can then filter event information passing through a net in which the meshes are dependent upon the client’s place and time of inquiry. The net allows all the extraneous events to be cast away and then structures the remaining events into the framework of common sense possibilities. Thereby MapNexus should help us make short term decisions in a hour-to-hour time frame by offering key bits of data to help one get going: “the big feature of human-level intelligence is not what it does when it works but what it does when it’s stuck.” (Minksy, 2003). MapNexus’s goals are not lofty, but more mundane – helping us get to public transport schedules or suggesting fun things to do on a Friday night. Yet the goals are achievable and represent the sort of “connectionist” approach to application design by applying Minsky’s theories to the wireless technologies.

2.4 NATURAL LANGUAGE PROCESSING AND VERBAL CONTEXT

The most successful efforts to structure our spoken language is Lenant and Guha’s Cyc (pronounced “pysche”) markup language that provides a grammar for the unspoken cognitive context that underpins spoken exchanges. Cyc, which according to its website is “the leading supplier of formalized common sense,” is funded in part by the Pentagon’s Defense Advanced Research Projects Agency. Lenant’s work originated from his desire to create a processing system to enable common sense knowledge related to NLP to be represented. Cycorp determined that there are roughly 12 separate dimensions to spoken conversations. By describing the context of a conversation in such a matrix, it becomes possible to “virtually lift” assertions from one context to another. Once a context can be adequately described, it becomes possible to reason based upon assumptions.

While Cycorp’s “ontological engineering” has resulted in a sophisticated calculus to represent spoken exchanges (figure 3), the problem of the shared context of physical space is more elementary – there are less dimensions in MapNexus. I have taken as required from OpenCyc: I have omitted from Lenant’s 12-dimensions several attributes that would not be possible to model based on the AP’s location and time. What is desired in a context packet is a description akin to the artist’s quick sketch of a landscape, taking in both the

CyCorp's 12-Dimensions of Context in a Natural Language Exchange

1 Time *temporal projection, relative order, endpoints, granules*
2 Type of Time *operating with human actors, day vs. night, closing time*
3 GeoLocation *containment, relative assertions, nearness, everywhere vs. somewhere*
4 TypeOfPlace *granules of descriptions, cultural uses*
5 Culture (Restrictions on Type) *actors' subcultures: religion, gender, and regional characteristics*
6 Sophistication/Security *authority, educational level, permissions*
7 Topic *subject, preparation, events, primary focus*
8 Granularity *size of events germane to context, matrix of relationships based upon size*
9 Modality/Disposition/Epistemology *default memory status, expected knowledge*
10 Argument-Preference *what is the order of items in terms importance?*
11 Justification *quality of modelling context and the residual utility*
12 Let's (Domain Assumptions) *a specific case has been set, special conditions*

5 Dimensions of Every Wireless WAN's Access Point – the Attributes of Architectural Space

0 - AbsoluteTime
This metric contains data about the UTC time and makes relationships between intervals; this metric is used by all the other dimensions. *Example= September 3, 2003 19:35:12*

1 - RelativeTime
This metric handles fuzzy units of time – winter, lunch, a museum visit – that are derived from AbsoluteTime and the user's spatial context. *Example= Fall Term, rush hour*

2 - Frame
The perceived connections between one space and its surrounding environment as a function of both Absolute and RelativeTime as well as the client's mobility. *Example= Walking from 77 Mass. Ave. to the ICA in pleasant weather.*

3 - GeoLocation
This metric contains information on location – geospatial units and boundaries. Also contains a variety of cognitive representations. *Example= lat/lon, "the Great Dome"*

4 - Disposition
This metric contains data regarding the intended use of the space as a function of time – the behavioral frame of mind expected within this particular architectural unit. Also this dimension will capture ambiguities in use patterns. *Example= research activity, recreational space*

5 - Hierarchy
This is dimension that ranks the above metrics for a particular information-seeking case. The Hierarchy is akin to a tuning instrument for the other five metrics; it represents an assessment of the truth value of the description in its entirety. *Example= late at night, behavioral pattern predictions for short term activities are less accurate.*

Figure 3. The 5-dimensional model for context markup are derrived from the OpenCyc Markup Schema.

visual reality of a space (its appearance and purpose) and the psychological character. Again the emphasis is on impressions – trying to represent the essence of a physical place in a few quick marks.

In selecting the above 5-dimensional model to markup interior architectural context propositions, I have created a three tiered schema. First, there is the "atomic" data that has a fixed (1:1) relationship with the AP. The GeoLocation attribute along with the UTC time (AbsoluteTime) form the basis of the context-aware packet. It is this first order "atomic data" that is passed of to a database on the server-side for rule based propositions. These database driven attributes could be bifurcated into "objective" and "subjective" metrics. The objective propositions are related to the atomic data as well as cyclical time patterns. The subjective propositions represent "fuzzy" patterns involving site-specific behavioral expectations and preference associations.

3 Capturing Context in Real Time Information Exchange

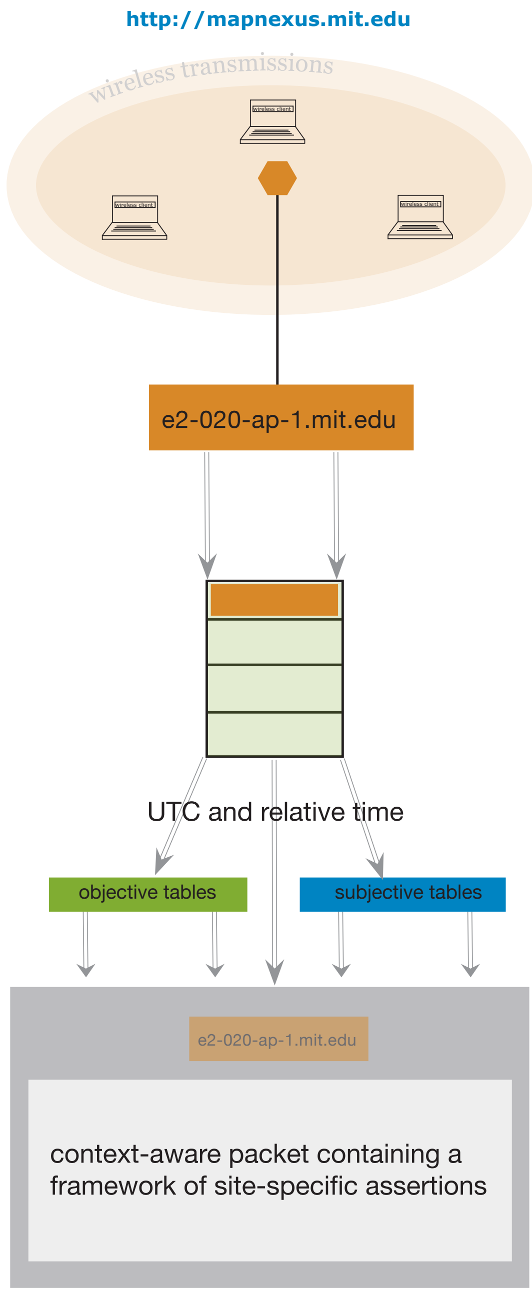
3.1 PRESENTING THE ROLE OF MIDDLE-WARE

In human-computer interaction (HCI) on the web, the computer is rarely tasked with elucidating "cloudy and indistinct" inquiries because open-ended questions depend upon common sense reasoning. Without cues to the client's context, an unspecific request on the internet results in too much information which is laborious and confusing to analyze. The technology and structure of the web — viewed as a living ecology of information — controls our ability to harvest useful data related to a particular time and place. The laws of economics are useful to consider in HCI, for the vast amount of information available online makes the opportunity costs too high to search the internet for anything that is of a "cloudy and indistinct" nature. Each click and keystroke is a spent currency of sorts – with MapNexus I am trying to lower the cost barrier to quickly find useful local information.

Considering the following inquiry: "What fun things are going on this Friday night?" The answer requires some common-sense reasoning ability. One could check a number of websites (yahoo movies, MIT arts calender, etc); each will require the client enter data relating to the date of inquiry as well as the venue. Since there is no clear method of implicitly modeling context on a broad scale across many web sites at once, narrowing down such a question by location and personal preferences is impossible, and the client quickly learns never to make such inquiries in the first place. Yet such a query could indeed be answered by an intranet server that was designed to provide local information in the short term to a specific set of individuals.

The overall question in this chapter is, "What role can a network's nodes play in a wireless WAN to assist in detecting site-specific behavioral patterns inside building? How can a network infrastructure itself 'add value' to the architecture it is affixed onto?" The bifurcation between the client and the server – the front-end and the back end – appears iconic in computer science. In an wireless intranet, data packets journey to and from a server via a number of hops through the physical transmission media: air and wires. MapNexus sketches the context of the client by looking carefully at the location of the nodes of physical transmission (figure 4). The AP lies in close proximity to the client in a wireless WAN as the radio frequency transmission range is roughly 50M; there is a definite pattern of geographic uniformity in the granularity of the AP cells.

Capturing the Context of Architectural Space



Step 1:
The client connects to a wireless AP on campus and pulls up the Map-Nexus URL.

Step 2:
The request is received by the server, and the AP node's unique IP address is detected and passed along to a server-side RDBMS.

Step 3:
The RDBMS makes a 1:1 match with using the AP's IP address as a primary key to index an atomic table of fixed data.

Step 4:
The RDBMS uses the atomic data to link to several tables containing rules about enviromental variables as a function of time.

Step 5:
The RDBMS creates a "context-packet" that contains many assertions; this packet is used to create a context-aware web site.

Figure 4 A specific architectural space's characteristics can be woeven together with the internet in a wireless WAN utilizing a middle-ware RDBMS to aggregate data to gain cues as to the client's short-term activity frame.

The barrier to the flow of site-specific information from the client's perspective is not connected with the speed of the network, but rather the time it takes for the user to cognitively process the large quantity of data and then to sift until only the desired data remains. This threshold of effort is high enough to render some data-seeking activities worthless as its capture has a higher opportunity cost than its utility. A "middle-ware bucket" of context cues can be used both to save the client time and to provide utility by reducing the need for explicit input (clicking and typing) in repetitive information-seeking tasks that one finds in one's day-to-day life: a pre-determined urban environment in which the client already has considerable "common sense" knowledge.

In the MapNexus framework, the Middle-Ware (or "Context-Engine") produces within a fraction of a second a computer generated representation — a snapshot of the client's present context — by combining objective data (place and time attributes) with subjective data (behavioral assumptions, preference patterns, and pre-existing cognitive knowledge) to produce with the aid of a pre-existing RDBMS of common-sense rules a "context-aware packet" that is designed to provide a grammar for MapNexus server to interpret. The intranet server is specially designed for information-seeking regarding the clients' environmental character within a specific WAN, and with certain modifications can be made to produce web content germane to the client's situational decision-making.

3.2 AP POLYGON AS A NEW UNIT OF SPATIAL AGGREGATION

The engineering feat of the 802.11 wireless protocol has a side effect of creating new geographical units of space – the AP cell or geographic area surrounding the AP – that can be modelled in a database as an entity with an array of attributes to establish context-aware cues. This entity-attribute model and geometric tesselation recall the organizational structure of the Zoning Improvement Code (a ZIP code was conceived as a routing shorthand for parcel delivery) which became the de facto unit of demographic modelling in the USA. While the MapNexus wi-fi tesselation is not as accurate as that position promised by 3G mobile communications (E-911), MapNexus will at least place the client within a particular building on MIT's campus — a unique parcel of real estate with a particular function. Conversely, triangulation approaches are akin to pin-pointing or a vector representation; MapNexus follows a hybrid raster model in that it is not a simple grid overlay (as many places on campus have no wi-fi access), but rather the grid of varying granularity that changes with the architectural landscape.

When a client makes a request for an intranet site, an upstream HTTP "get" command can be parsed to determine which AP node is crossed as the packets move upstream in the first hop from the client's laptop to the physical media or transmission cables. At MIT, the tradition is to name the Internet protocol (IP) address of the AP for its physical location which makes it very easy to create an index of the ~450 APs in the Athena system (Figure 5). The atomic unit for the context-gathering is the AP which is in MIT's WAN is conveniently given an IP address that is synonymous with the AP's physical location:

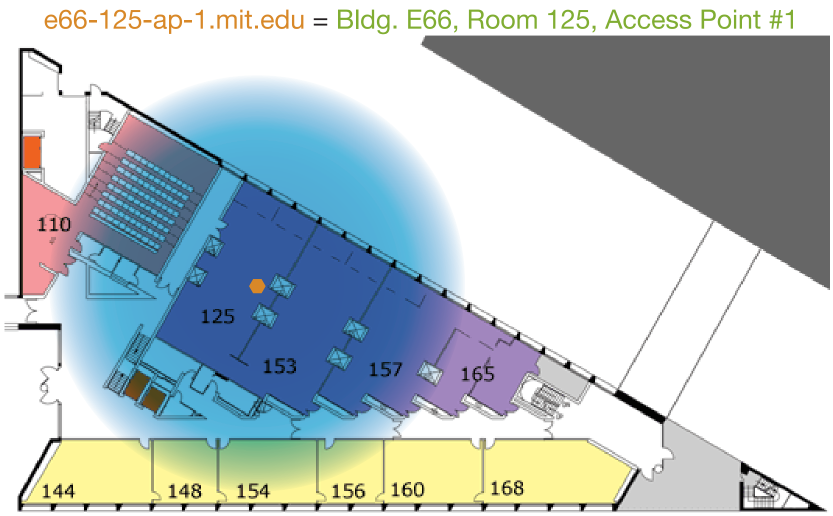


Figure 5. This AP is located in a chemistry laboratory (rm 125).

There are several applications that are based on the UNIX "traceroute" command that are specifically designed to identify the route of a specific IP transmission from the server side. Therefore it is within the network administrator's capability to make available the AP's IP address to the MapNexus server when an incoming HTTP request occurs. By identifying the AP, the client's position is determined *implicitly*.

A question that begs to be answered: "If the location of the client is fairly easy to establish, why are there not already context-aware websites?" First, there is often little correlation between the physical location of the client's nearest network node (a fixed physical piece of hardware) and client's actual location in a sub-net or local area network (LAN). Historically, MIT has been organized into LANs that are structured by departmental administration — thus it is possible to have a LAN that is unusually shaped. Second, a large amount of Internet traffic is handled by dial-up connections (ISP), and this arrangement offers few cues to be placed in the upstream IP/TCP packet envelope to establish a consistent spacial relationship between the client's location and the nearest network node.

MapNexus is only designed to provide web content within a predetermined wireless WAN — MapNexus cannot make assertions about clients who make inquiries without preexisting data that correlates to an architectural space. For a MapNexus type system to exist, there first has to be a "context-rich" geography of the physical intranet — the wires and APs — within an urban fabric. Moreover, this urban fabric has to be modelled in a pre-existing database of site-specific "common sense" propositions and data sets (such as schedules). Today one's user experience of the web is completely estranged from one's physical context. Wi-fi could provide a means joining these two separate realms – the client's physical surroundings and the client's web content — to gain a more conversational approach that is based on Minsky's notion of "common sense" knowledge.

3.3 DERIVING OBJECTIVE ATTRIBUTES OF ARCHITECTURAL SPACE

From the 5-dimensions of context I have re-adapted from the NLP markup techniques by Lenant, there are three categories: atomic, objective, and subjective descriptive data. While the atomic data has a 1:1 relationship with the AP (it is unchanging), the objective data changes either as function of time or as a function of the geography. Subjective data is derived from pre-existing assumptions about the client's expected behavioral patterns as a function of place and time. The two dimensions of objective data that are produced on the server-side RDBMS are RelativeTime and Frame. Each of these dimensions can be modelled in a straight-forward blackboard approach using tables linked to the atomic context data and the UTC time. This intermediate step in the middle-ware "context engine" is akin to present day LBS and calender algorithms. In summary, the objective attributes of the context-packet relate to relatively simple variables (time and geometry) that can easily be represented. The RDBMS will be able to implicitly create a snapshot of the client revealing not only cyclical occurrences such as bus schedules and academic time patterns, but also cognitive landmarks in the surrounding physical environment as well as frames of physical mobility (defining what is close and what is far away). Much of the attributes of the objective tables in the RDBMS will be linked to the more complex, multi-variable dimensions concerning logic: the subjective variables.

3.4 DERIVING SUBJECTIVE ATTRIBUTES FROM ARCHITECTURAL SPACE

MapNexus's context-aware engine (or set of algorithms) is utilized only to select a starting point for information exchange. The question at hand, "How can 'common sense' reasoning be modelled from the objective data derived from the AP?" The answer shall depend upon the skill and artistry of the information architect — the task at hand is similar to that of narrative description of a physical environment. Unlike a mental recollection, the context-engine requires a preexisting database of assumptions about future behavioral patterns: an ability to predict. Context-awareness is concerned with being cognizant of the past, present, and future forces that exist in a certain space. The task before the designer is to provide a platform for common sense reasoning to define some logical inferences about site-spefic spaces over time. The descriptions — and the algorithms that result — should not be considered either "right" or "wrong," but rather "context-rich" or "context-poor."

Drawing from the established patterns of choice theory and its computerized progeny — JITIR agents and DSS — I sought to create a set of conditions for each architectural environment by linking tables in a server-side RDBMS that would both act negtively filter out extraneous data but to draw the client's attention to particularly useful information. The goal is to fill the MapNexus web page with useful information germane to the client's situational frame of activities. In terms of the field of artificial intelligence (AI), the approach regarding the subjective elements of the context-aware packet could be considered a logic-based effort to represent common sense knowledge and reasoning ability.

Some of these logical assertions are represented below when I considered the buildings in MIT's East Campus that surround the Media Lab; such brainstorming is very useful as a starting point to begin an investigation into making logical rule-based inferences:

1 If one is located in an academic building on a Sunday, one is likely to be working.
2 If one is located in a dorm room on a Monday morning, one is likely to be preparing to travel to the main campus to engage in a new activity.
3 Since MIT is a 24 hour environment, there should always be options to eat — even if the pickings are slim at 4AM — nearby vending machines and the nearest off campus dinner that is open should be suggested.
4 Directions should be based on cognitive landmarks and match the client's preexisting knowledge every student should already know.
5 Students should be encouraged to take a break from their work on the weekend when their schedule is likely to be free thus social events take precedent.

From the above common sense statements I have created a series of "if then" statements that are represented in the server-side RDBMS that are linked to the context-aware packet.

4 Designing a Context-Aware Web Server

4.1 STRUCTURE OF A CONTEXT AWARE WEB SERVER

A context-aware web server must have a predetermined scope and scale of functionality that is required, in order to identify a viable decomposition of the operations into modular tasks and to design an elegant aesthetic interactive approach (GUI). An "event landscape" represents all possible activities the clients might choose to engage in the short-term (Kirsh, 2001). MapNexus is a web site that acts to assist the client in switching contexts – to begin a new task that requires additional information. The process of matching the client's intent with a set of possible events.

The structure of the MapNexus web site differs substantially from a static hypertext markup-language (HTML) web page (Figure 6). The MapNexus site will have a set uniform resource locator (URL) which the client enters into a browser. The web site produces database driven web page using some combination of a dynamic content mechanism (PHP, XML, JDBC, and the like) to generate output based on SQL queries that match and rank events based upon the user's context-packet (derived from the AP). Nothing more than javascript and XML capabilities are required at the client side. An XML approach for the client/server dialogue would allow style sheets and similar mechanisms to further custom tailor the interface via RDBMS lookups. A crucial question related to MapNexus's modelling is, "Will the 5-dimensional model of context present an unmangable amount of variables?" Since many of the variables are so closely related (like the concept of "season" and an academic "term"), a consolidated matrix of the context variables would indeed be possible to produce having the context-engine (a RDBMS) continually producing a context-packet for each of the 400 APs and then storing this representation in a register time slot in advance much like the technique used in search engines which despite the illusion of "searching" the web at the time of inquiry, actually due most all the labor in advance.

4.2 THE MAPNEXUS FRAMEWORK'S ADVANTAGES

The three primary advantages of MapNexus are (1) its ability to implicitly capture context, (2) its focus on the user's short-term intent, and (3) its straightforward blackboard approach. The framework is based on the ability to identify accurately the location and function of spatial aggregation units on the MIT campus, as well as behavioral patterns of the intended audience – the MIT undergraduate population. As MapNexus draws directly from the

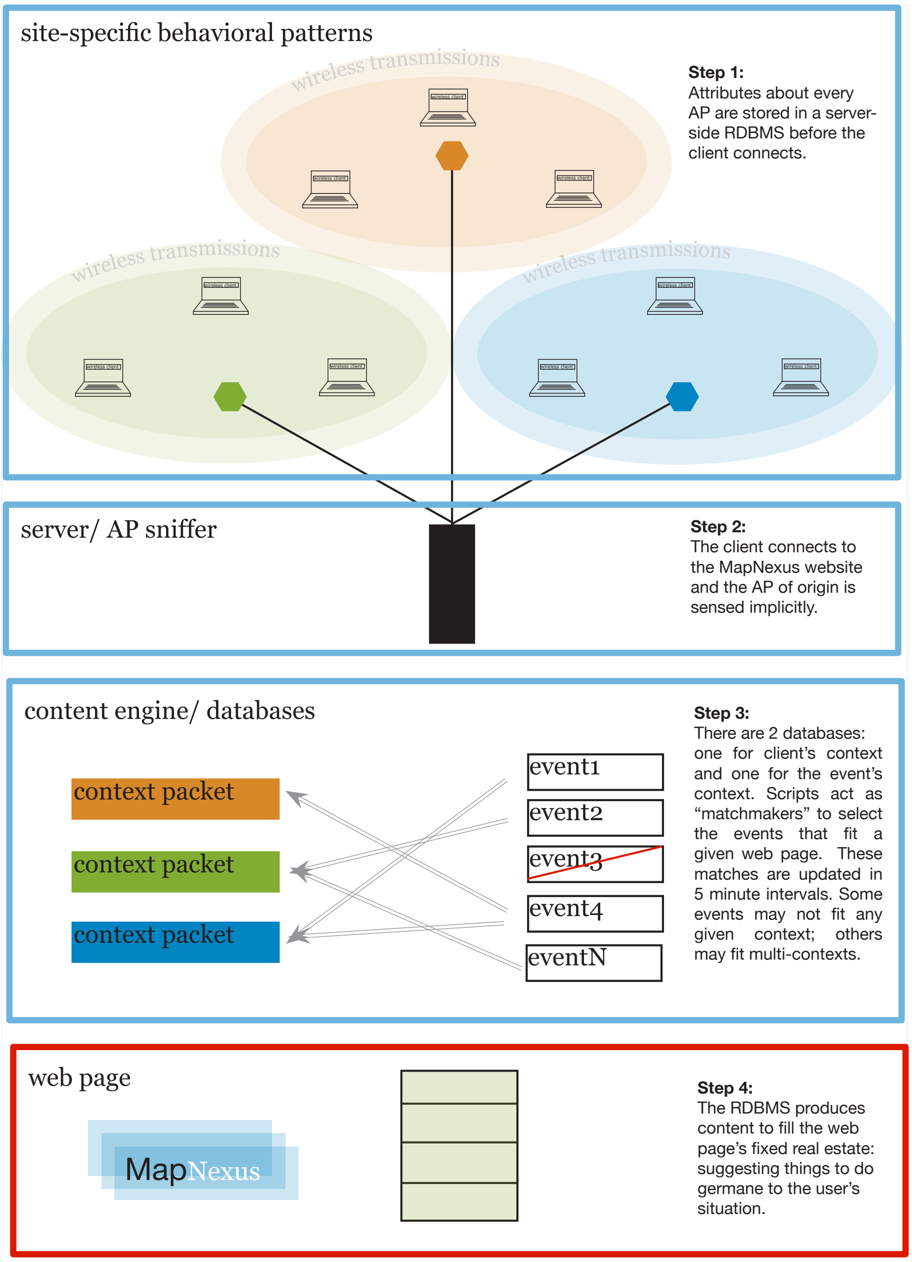


Figure 6. The MapNexus web page is based upon common sense knowledge about both the client's behavioral patterns and shifting environmental possibilities.

structure of the wireless WAN, it requires no cookies, login sequences, or downloads. With MapNexus the client is always anonymous; it is the AP that is tracked preserving clients privacy.

4.3 THE MAPNEXUS FRAMEWORK'S DISADVANTAGES

The principle disadvantage of the MapNexus framework is that it is not easily transferable to other locations where context-aware applications are readily sought, such as a heterogeneous urban environment. Much of MapNexus's "intelligence" derives from the fact that MIT is a closed community, and the undergarduate population (the target audience) has many common attributes. Thus the people being modelled are a sub-set of the larger population, and they are moving over a space rich in architectural cues. MapNexus depends upon the context-master to determine the client's intent by modelling. Therefore any criticism of functionality is bound to be tied to a single person's "view" of the campus. While the MapNexus framework is a 'one size fits all' approach, based on a precise knowledge of the physical environment and a homogeneous audience, this very framework would not be as cognizant of a client's intent in a less predictable, fluid environment. The framework might, however, work in other similar contexts such as the European Union governmental complex in Brussels, which like MIT, is a 'campus' of buildings within a larger urban fabric having a homogenous clientele (Eurocrats) and an architectural context-rich structure (each Directorate General having it's own building).

4.4 CONCLUSIONS

Like an evolutionary process, the web is a constantly changing ecology of information. Wireless connectivity can provide a window into a client's location and frame of mind. MapNexus is a framework for improving web-based information exchange by gathering cues from the user's physical environment. The client's "event landscape" can be derived from the particular place and time of inquiry (a spatial aggregation unit). This unit will allow modelling in five dimensions: the time (absolute and cyclical), the cognitive aspects of an environment, the location, the behavioral disposition of the individual likely to be in the space, and the hierarchy of an attribute's relative truth value. Since wi-fi is increasingly popular, it would follow that a client's increasing mobility would lead to a shift in how one approaches information seeking. In one's day-to-day life, much of the short term decisions we make are made in an arbitrary fashion. MapNexus will offer the client utility by organizing information about one's immediate surroundings and delivering this information in tandem with a modicum of common sense.

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The paper is a condensed version of a master's thesis at MIT that is supervised by Professors Joseph Ferreira (Urban Information Systems) and Ted Selker (Media Lab).