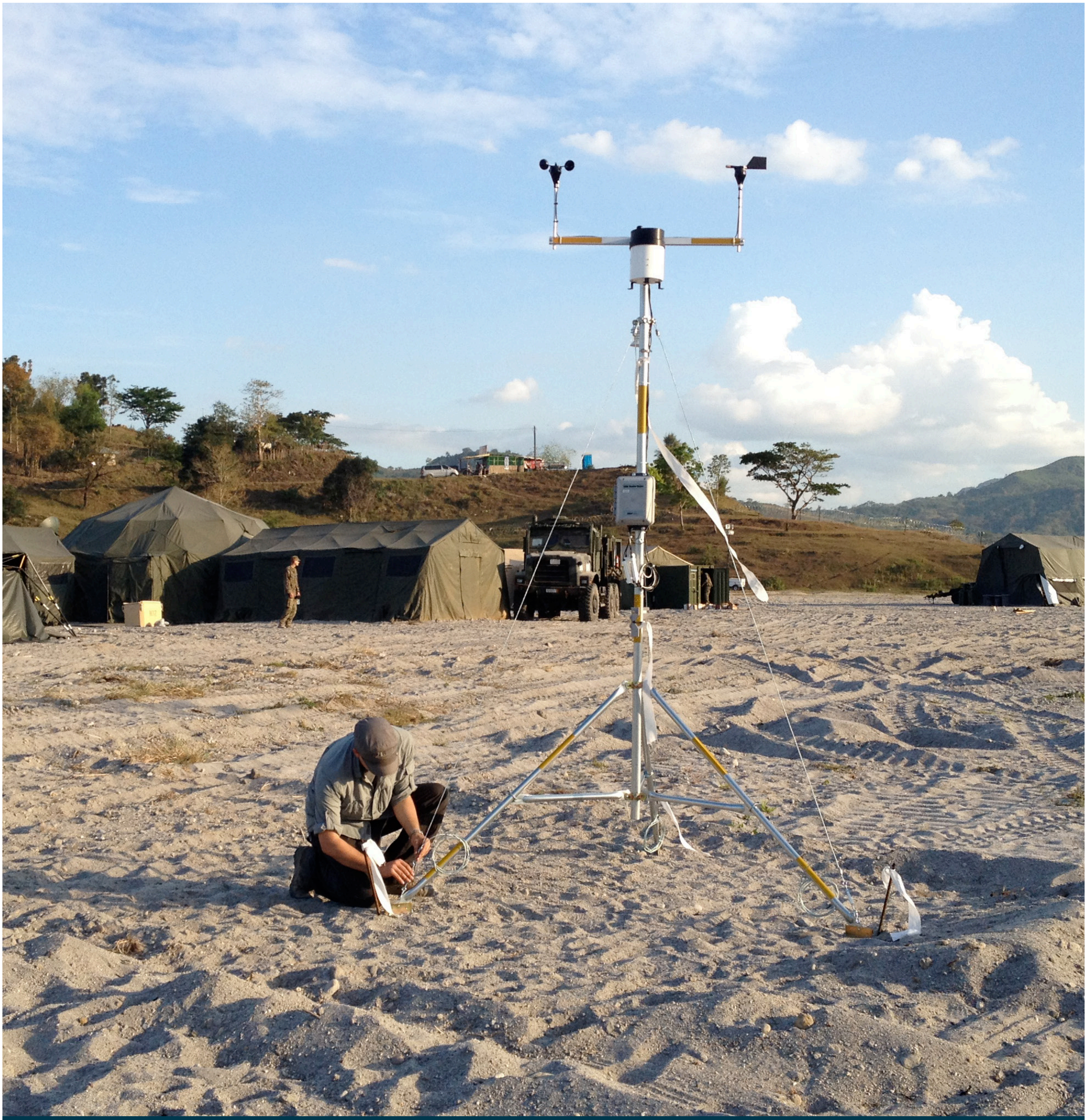


REACHE

A History Report

Prepared by
MKTHINK

THiNK

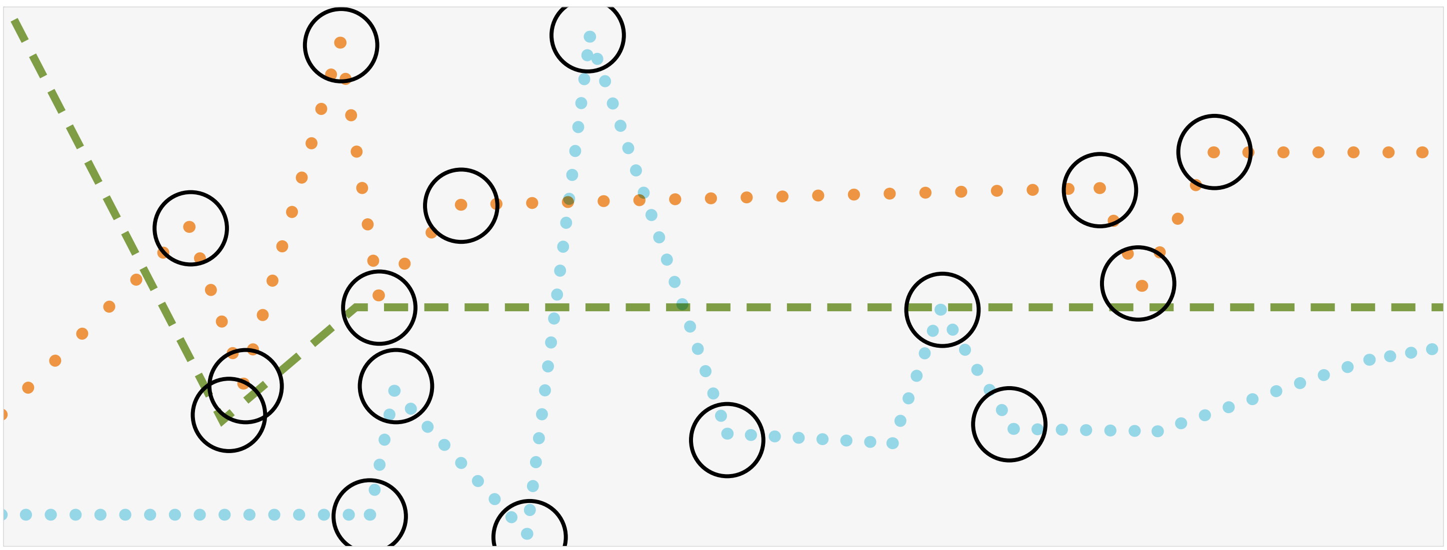
4

REACHE 4

ADV. DBMS RD&T PART 1

REACHE 4: ADV. DBMS RD&T PART 1

REACHE 4: Adv. DBMS RD&T P1 established the capability to capture unstructured cultural and architectural data. The intent of this phase was to augment data acquisition capabilities and thereby, provide more meaningful solutions to questions of space and energy use.



THE PROBLEM

Up to this point, REACHE projects succeeded in collecting environmental data. REACHE 4 Adv. DBMS Part 1 populated the remaining two REACHE spheres – Architecture and Culture – with data. A more robust REACHE dataset leads to more impactful solutions.

REACHE 4: Advanced Database Management System Research, Development & Testing (DBMS RD&T) Part 1 expanded the types of data that could be collected by leveraging natural language processing (NLP) and other software techniques and programs to form the Advanced Database Management System (Adv. DBMS).

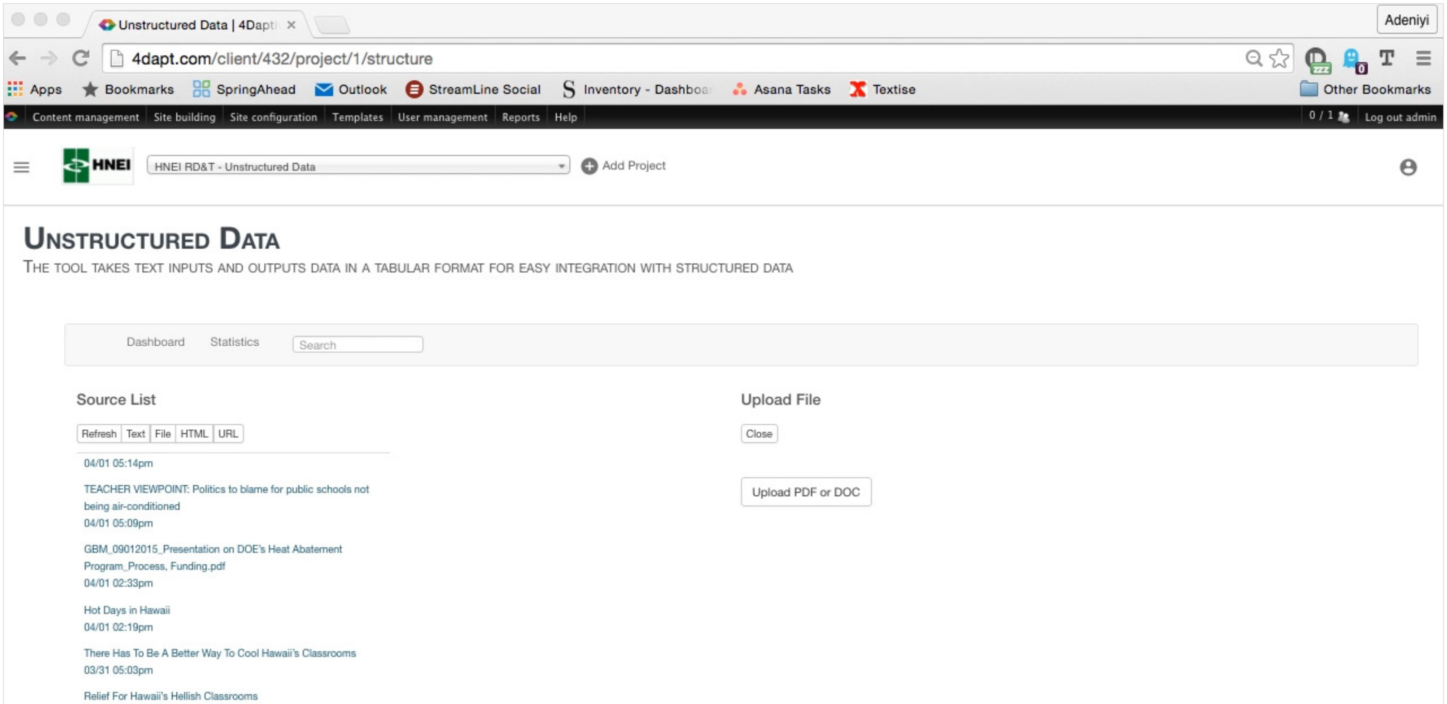
In REACHE 2 and 3, MKThink identified that architectural and cultural data was mostly inaccessible because it existed in unstructured formats, such as in visual, symbolic, textual and other non-numeric formats. 80-85% of an organization's data exists in unstructured formats, but many organizations do not have access to it because it is complex to acquire and synthesize.

MKThink determined that unstructured could enhance an analyst's understanding of the subjective factors contributing to energy use, such as organizational culture. REACHE 4 set out to develop systems to effectively collect and manage unstructured information.

In support of the University of Hawaii's Project "Hawaii Energy and Environmental Technologies Initiative," the Hawaii Natural Energy Institute (HNEI) partnered with MKThink to improve decisions related to sustainable energy solutions

STATEMENT OF WORK

REACHE 4 Adv. DBMS Part 1 addressed the lack of usable cultural and architectural data. MKThink leveraged NLP to develop software that could capture and integrate unstructured video, text, image, audio and handwriting data into 4Daptive.



LOGIC

This research effort hinges on the REACHE logic, that a heightened understanding for the Architectural and Cultural assets within an organization can refine planning strategies.

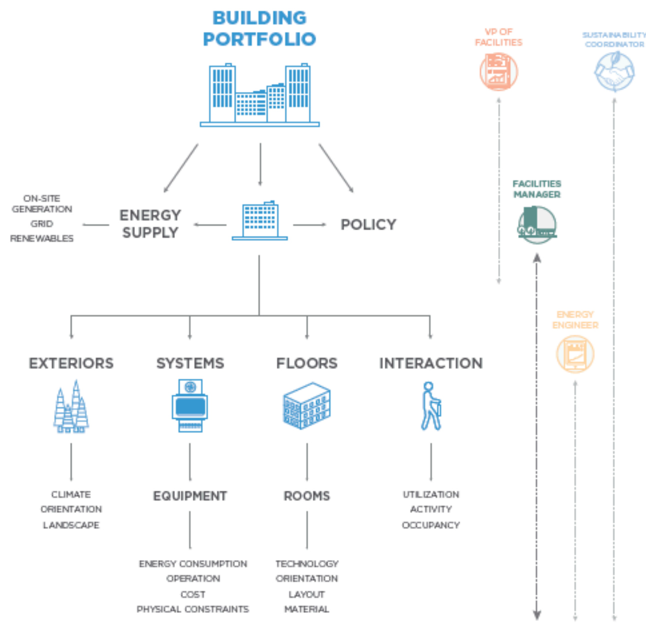
For instance, by capturing the cultural and architectural data, an organization can better understand space and employee usage patterns. Findings might cause the organization to consider vacating and selling an underutilized building and optimizing space elsewhere. Buildings intentionally designed for how they will be used, waste less energy.

With cultural data, data analysts can also get a better idea of employee satisfaction and their opinions about certain facilities by synthesizing survey results. Findings can inform design decisions, tailored to human wellness.

COMPLETED WORK

CONDUCT MARKET RESEARCH

MKThink conducted market research to narrow down the software tools and unstructured data types that would be most beneficial to those involved in making energy decisions, such as Sustainability Coordinators, Energy Engineers and Facilities Managers.



DEVELOP 4DAPTIVE SOFTWARE

MKThink developed a cloud-based Advanced Database Management System (Adv. DBMS). At the core of the Adv. DBMS is an analytic engine, which searches for relationships between Architecture, Environment, and Culture, and presents them to the user to help them make decisions.

Functional and non-functional requirements were developed to define the tool's capabilities. Functional requirements are elements of the tool that directly affect an external user's ability to effectively navigate the tool. These include interface design and system navigation. Non-functional requirements, on the other hand, are the components of the tool that are necessary for internal mechanisms of the tool to follow certain standards and guidelines when processing and transforming raw data. These include database management systems and data cleaning, backup and storage.

More specifically, the functional requirements are:

- Client Creation
- Project Creation
- Manual Data Import
- Automatic Data Import
- Unstructured Data
- Data Grid
- Chart Configuration
- Axis Settings
- Series Type
- Data Settings
- Visual Settings
- Chart Interaction
- Chart Saving
- Exploratory Research
- Statistical View
- Description

DEVELOP 4DAPTIVE SOFTWARE CONTINUED

And the non-functional requirements are:

- Database Management System
- Database Management Tools and Data Organization
- Data Backup, Recovery and Performance Monitoring
- ETL, CDC and Other Integration Tools
- Data Migration and Conversations
- Data Purging
- Data Visualization and Analysis
- Data Control
- Data Cleaning Support
- Quality Improvement
- User Admin
- Unauthorized Access Security
- Metadata Content
- Metadata Access
- Metadata Reporting
- Global and Local Reference Data Management
- Reference Data Application
- Storage and Access

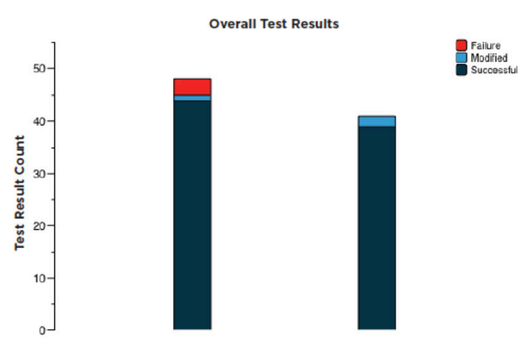
These requirements informed the analytical engine, which leverages existing NLP software, MonkeyLearn, to sift through content in Tweets, webpages and PDF files to extract key words and relevance. MKThink also demonstrated the ability to structure video footage using PrismSkylabs, a Computer Vision (CV) program.

MKThink could analyze utilization rates of spaces by determining occupancy and dwell times through dwell analysis, heat and path mapping in unstructured video analysis. MKThink could also produce reports using the processed structured and unstructured data.

On the 4Daptive platform, structured data, such as interior air quality, could be visualized alongside previously unstructured data, such as Twitter posts. This comparative analysis might inform how an environmental factor, such as interior air quality, affects attitudes and cognitive ability, cultural measures.

TEST 4DAPTIVE SOFTWARE

MKThink tested the 4Daptive software prototype to ensure it met functional and non-functional requirements. Specifically, MKThink was looking to see if previously unstructured data could be processed and visualized in combination with structured data, such as data on environmental conditions. Test results confirmed the tool's capabilities and provided insight into how the database management system could be further improved. The features of the tool that were identified as in need of further development were the project database set-up, the visualizer and the event detection capability. Enhancing the tool's set-up, interface and analytical engine were marked as key next steps.



	Functional Requirements	Nonfunctional Requirements
Failed	4	-
Modified	1	2
Successful	43	39
Total	48	41

CONCLUSIONS

In REACHE 4, MKThink established the capability to acquire, process, manage and analyze structured and unstructured data. MKThink developed an analytic engine within the Adv. DBMS to acquire, synthesize and analyze cultural and architectural data.

With these new capabilities, users could understand how Architectural, Environmental, and Cultural factors were impacting environmental conditions, facility operations and human wellness.

As a result, users were able to make decisions to optimize their facilities and increase energy efficiency.

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REACHE 4

ADV. DBMS RD&T PART 2

REACHE 4: ADV. DBMS RD&T PART 2

REACHE 4: Adv. DBMS RD&T P2 refined the sensor kit and the 4Daptive Analytical tool developed in earlier phases to expand the types of data that could be gathered and analyzed. In leveraging computer vision to capture activity patterns and equipping 4Daptive with cognitive computing capabilities, REACHE 4 refined decisions to space, facility and energy use.

THE PROBLEM

REACHE 4: Adv. Advanced Database Management System Research, Development & Testing (DBMS RD&T) Part 1 established the capacity to acquire unstructured test and video data, primarily to capture architectural and cultural data. As a continuation of this work, REACHE 4 Adv. DBMS RD&T Part 2 sought to connect data sets to decisions.

STATEMENT OF WORK

REACHE 4 – Adv. DBMS RD&T Part 2 intended to enhance both the REACHE logic and tools by connecting structured and unstructured data sets to culturally-sensitive design solutions for optimal performance and energy efficiency. MKThink refined the Adv. DBMS to perform the following analytic capabilities:

ADVANCED ANALYTICS (AA):	The application of data to problem-solving
COGNITIVE COMPUTING (CC):	The use of computer-driven intelligence to suggest decisions and refine analytic algorithms with limited or without the aid of human intelligence

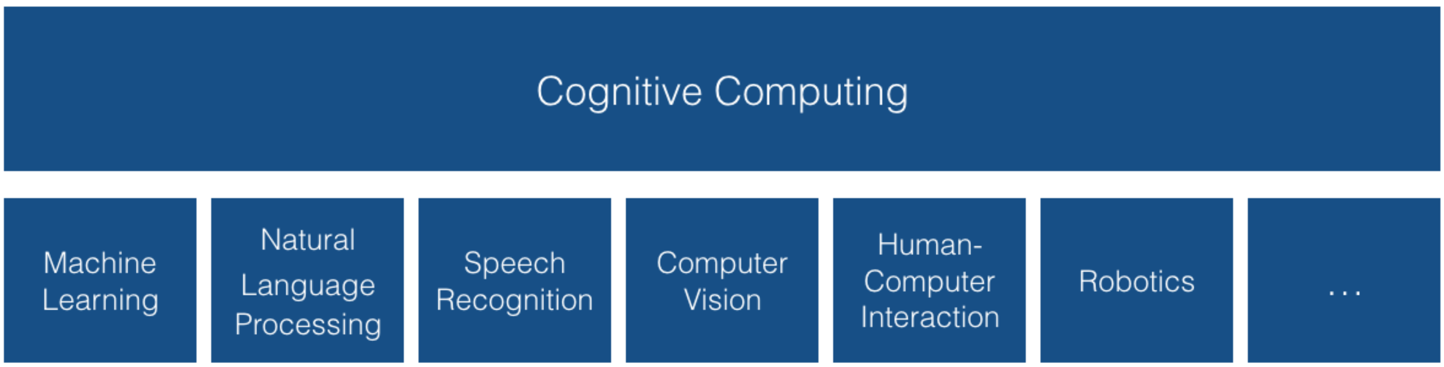
LOGIC

REACHE 4 – Adv. DBMS RD&T Part 2 employed the REACHE logic, examining how Culture, Assets and Resources interact for the purpose of optimizing facility performance. The Adv. DBMS receives data about the Cultural, Architectural, and Environmental factors at play in the user's organization and runs its algorithms to suggest changes in the organization's culture, built environment, and/or resource consumption patterns to optimize performance.

IDENTIFY THE KEY DRIVERS OF ENERGY CONSUMPTION

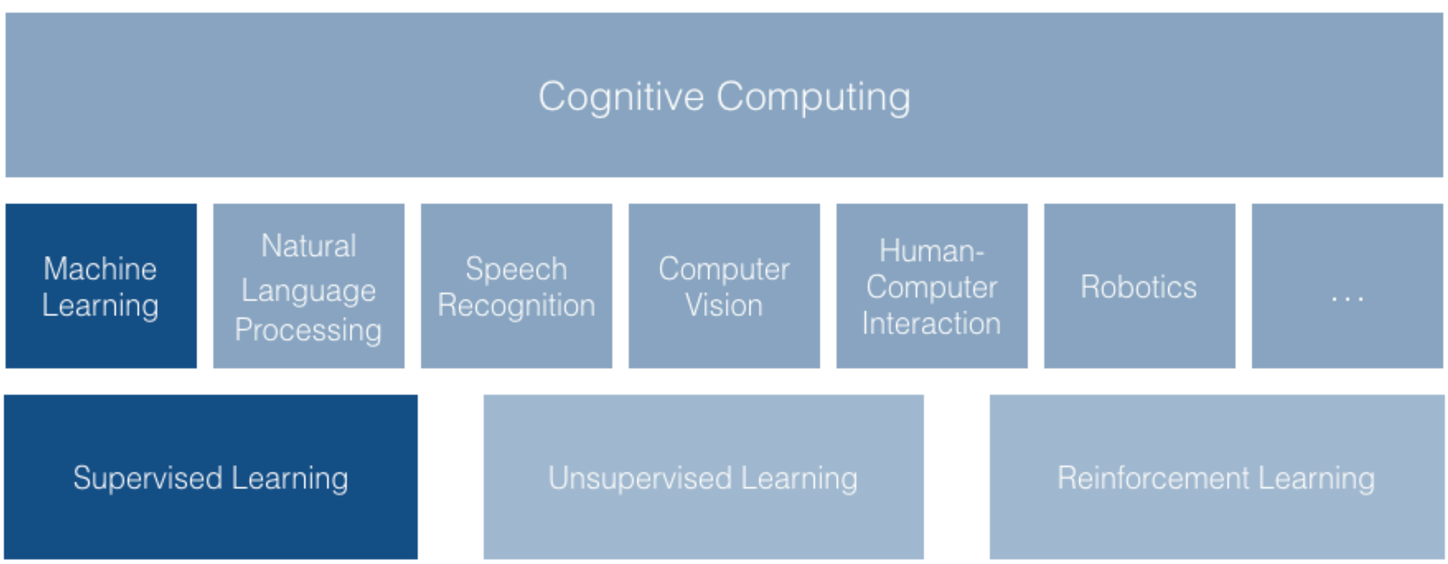
The MKThink research team extensively reviewed literature on the practice of Advanced Analytics (AA) and Cognitive Computing (CC).

Cognitive Computing is a branch of artificial intelligence with various technological capabilities, including machine learning, natural language processing, speech recognition, computer vision, human-computer interaction, and robotics.



After evaluating the various applications of Cognitive Computing, MKThink decided to pursue developing a machine learning capability within the Adv. DBMS. Machine learning is the ability of computer systems to improve their performance by exposure to data without the need to follow explicitly programmed instructions.

Machine learning can be supervised, unsupervised, or reinforced. Supervised learning programs label and train input to known outputs and integrate new data to verify the outputs. Unsupervised learning programs do not label input data and do not have known outputs; the model groups the data by similarities or other data-implicit attributes. Reinforcement learning learns actions to maximize reward in a training environment. Based on MKThink's space-based problem sets, mostly with labeled data, the team deemed supervised learning most relevant.



DEVELOP REQUIREMENTS

The MKThink team decided that the analytical tool within the Adv. DBMS needed to be:

ADAPTIVE:	The system must learn as information changes and resolve ambiguity, particularly through the use of a feedback loop
INTERACTIVE:	The use of computer-driven intelligence to suggest decisions and refine analytic algorithms with limited or without the aid of human intelligence
ITERATIVE & STATEFUL	The system must aid in defining a problem by asking questions or finding additional source input if a problem statement is ambiguous or incomplete
CONTEXTUAL:	The system must understand, identify, and extract contextual elements such as meaning, syntax, time, location, appropriate domain, regulations, user's profile, process, task, and goal

DEVELOP STRATEGY TOOL

MKThink has long used a strategy tool to uncover operational inefficiencies and opportunities for improvement with its clients. In REACHE 4 Adv. DBMS RD&T Part 2, the team decided to automate the strategy tool and incorporate it into the Adv. DBMS user interface as a way to test cognitive computing capabilities.

The strategy tool was originally developed by MKThink to provide a simple graphic image that allows people to perceive relative quantitative differences between of ideal and 'goal' states on a 4-axis graph.

Quantities on the 4 axes equal a central unit, represented by the area of the shape that forms on the axes. Most commonly, MKThink has measured for Effective Use Hours (EUH), but strategists have also experimented with central units that measure Annual Kilowatt-Hours (AkWh) and a Cultural Satisfaction Index.

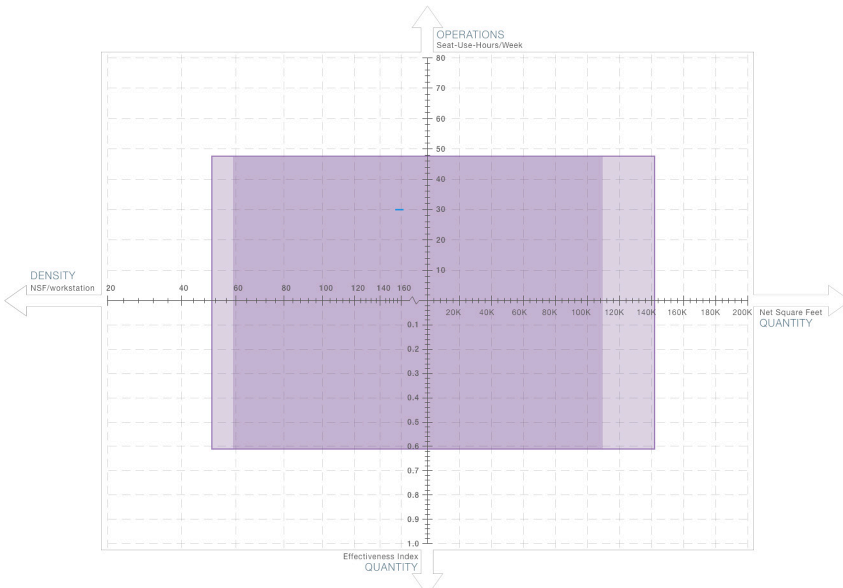
MKThink identified an array of problem typologies, which could be solved with the strategy tool:

- Holistic
- Resource
- Asset
- Human Factors

Holistic problems solve for revenue in dollars or another metric representing a holistic challenge within the organization. Resource problems solve for AkWh or another metric having to do with resource use. Asset problems are measured with EUH, a measure of how effectively a space is being used. A human factor problem is solved for by measuring user satisfaction.

The horizontal axes represent a certain asset that is involved in the production of the central unit. The right axis represents the Quantity of the asset and the axes extending to the left represents the Efficiency with which said asset is being used. In many cases, the horizontal axis has represented space, with gross square feet (GSF) as the metric for Quantity and GSF / full time employee (FTE), a metric of density, on the left to represent how efficiently the space is being used. However, the horizontal axes could also represent the number of full-time employees (FTE) or energy consumption, depending on the problem type.

The vertical axis always represents time. The top axis can represent Operating Time at any scale (hours / day, hours / week, hours / year, etc...). The bottom axis represents the Quality or effectiveness of said time. The Quality axis tries to quantify how improvements in the built environment (e.g. higher technology) affect performance output or human productivity.



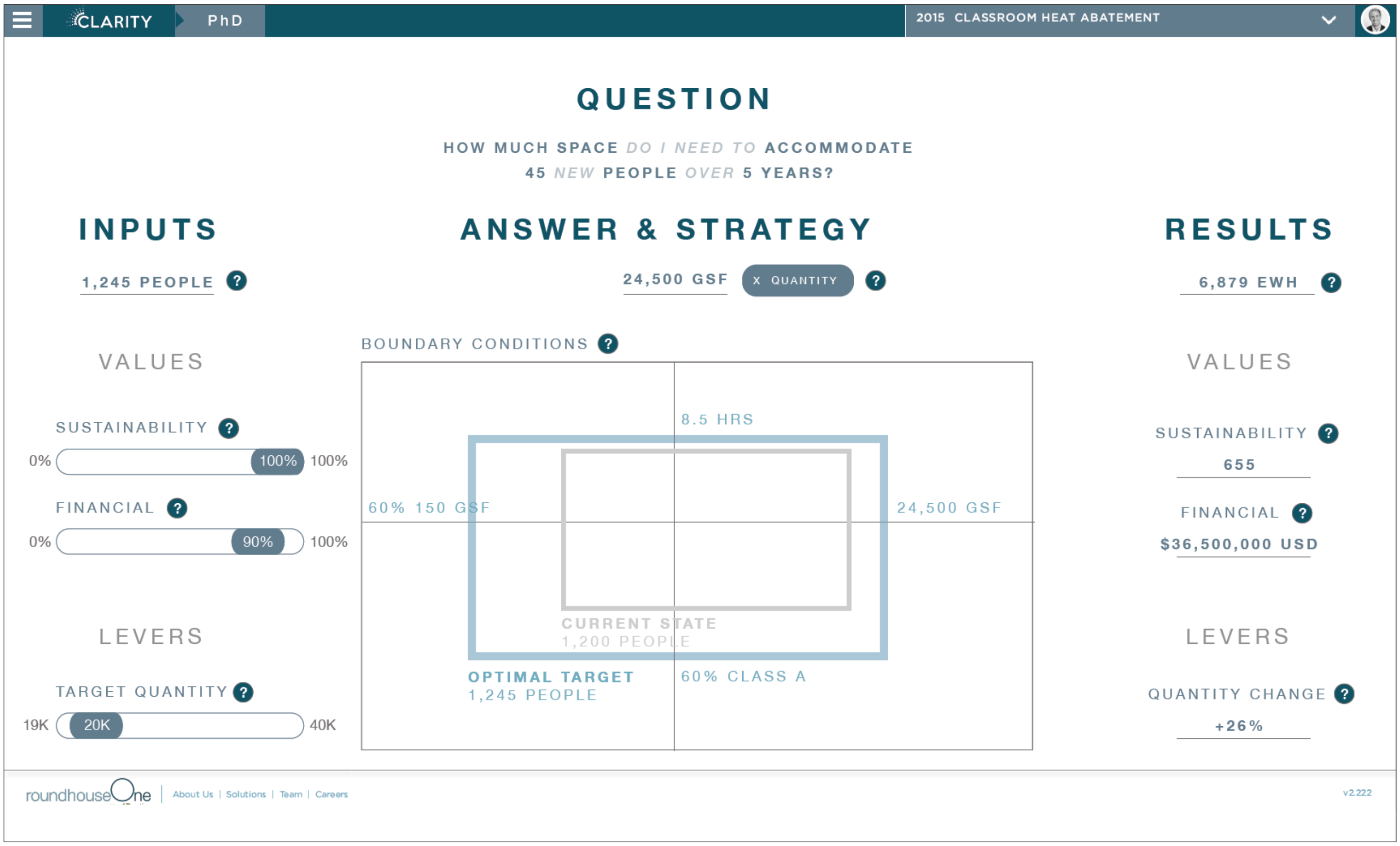
In the automated iteration of the strategy tool, the user logs on to the 4Daptive website interface and is prompted to input a problem statement by filling in a series of blanks, in the form of a Mad Lib sentence. The blanks are prepopulated with drop down menus as well as the option to enter custom values.

I need to _________ [increase/decrease] ____________ [object target] **by** _________ [amount/%]
while ___________ [increasing/decreasing/same] __________ [object boundary] **by** ____________ [amount/%] [+ More Boundaries]
and prioritizing ________ [object priority] [+ More Priorities]

Once the system has gathered sufficient information about the user's problem, it categorizes it as either a holistic, resource, asset, or human factors problem. The system then asks the user to set a target value for the central unit they aspire to achieve. Based on the problem type, the system recommends axes metrics to calculate the central unit. However, the user also has the opportunity to create custom axes metrics to adhere more closely with how they are capable of or prefer to solve the problem.

In this iteration of the strategy tool the user also has the opportunity to set priorities they would like to maximize for in their solution, such as cost, energy, health, and satisfaction. These settings will inform the system to generate an optimized solution based on the user's priorities.

The strategy tool generates shape visualizations of the user's current state, the target shape, which the user set, and recommended shape, based on the user's priorities.



The user can compare their shape to a benchmark, their peers, or themselves over time and constantly add more data to refine the computer's modeled predictions.

CONCLUSION + NEXT STEPS

In this second phase of REACHE 4, MKThink equipped the Adv. DBMS with analytic capabilities to not only organize data and reveal patterns, but to suggest decisions based on the user's goals and values.

MKThink is equipping the strategy tool with cognitive computing capabilities, notably a feedback loop, that will learn from patterns in user input and tool output. This will help refine the tool's algorithms to suggest more accurate and viable solutions. MKThink is continuing to define this feedback loop and its technical implications.

6

REACHE 4
SENSOR KIT

REACHE 4: SENSOR KIT

THE PROBLEM

The REACHE 3 Sensor Kit effectively evaluated environmental quality, but inadequately collected occupancy data due to limitations in sensor technology. Human factors have been traditionally difficult, if not impossible, to measure and understand, but have significant impact on actual performance.

The REACHE 4 contract recognizes the importance of filling this gap in the data. The REACHE 4 Sensor Kit focuses on the relationship between Culture and Architecture by collecting data on room dimensions, utilization, occupancy, and user activity. Based on the REACHE 3 field testing and post-field testing analysis, MKThink determined that the REACHE 4 Sensor Kit needed to be smaller, more durable, and simpler to deploy

STATEMENT OF WORK

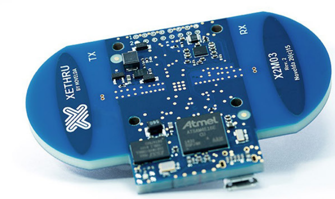
The mission of this section of work is to develop Sensor Kits for field deployment and for use in testing the Advanced Database Management System (Adv. DMS).

LOGIC

The REACHE 4 Sensor Kit seeks to make the REACHE dataset more robust by adding Architectural and Cultural data.

CONDUCT MARKET RESEARCH

MKThink researched state-of-the-art sensors and housing units for sensor packages in order to identify gaps in the sensor market. The team reviewed eight different occupancy and utilization sensor technologies across nineteen companies. The findings combined with MKThink's prior knowledge, acquired during the REACHE 2 and 3 projects as well as its experience using sensors with clientele, informed the design and functional requirements for the REACHE 4 Sensor Kit.



Technology Name	Video Tracking	Beacons	Infrared Depth Sensors	Passive Infared (PIR)	Infrared Break Beams	Pressure Activation	LIDAR	RADAR
Description	Video Tracking uses Machine Learning Algorithms to analyze pixels in a video feed to determine objects and movement within space	Beacons use mobile devices unique MAC address detected by WiFi or Bluetooth beacons to track occupants movement in space	By projecting a pattern of infrared dots the Infrared Depth Sensors can identify depth, size, and movement of occupants by the distortion of the original pattern when objects are captured by the sensor	Passive Infrared Sensors measure infrared (IR) light radiating from objects in its field of view; detects the energy given off by other objects	Infrared Break Beam emitter sends a beam of IR light to a receiver across the way; when something passes through the IR beam, the system counts; simplest way to detect motion	Pressure Activation Sensors count foot traffic with floor mats that can detect pressure when walked over	LIDAR (Light Detection and Ranging) is a surveying method that measures the distance to a target with lasers	RADAR (Radio Detection and Ranging) measures distance by emitting radio waves, which deflect off of objects, back to the position where they were originally emitted
Companies	• Prism Skylabs • Camlytics	• Walkbase • Aruba • Insoft • Estimote	• Density • Orbecc Persse • Occipital Structure • Intel • Blueview	• OccupEye • FLIR • VergeSense	• Walkbase • OccupEye	• Ecocounter	• Scanse • Velodyne	• XeThru
Metrics	• Utilization • Occupancy • Average Occupancy • Movement (Average Dwell Time) • Heat Mapping • Path Mapping	• Utilization • Occupancy (Unique) • Movement (Rate, Dwell Time) • Heat Mapping	• Dimensions • Utilization • Occupancy • Movement (Dwell Time)	• Utilization • Occupancy • Movement • Proximity • Location	• Utilization • Occupancy	• Utilization • Occupancy • Movement (Direction)	• Dimensions • Utilization • Occupancy	• Dimensions • Utilization • Occupancy • Movement (Direction)

DEVELOP REQUIREMENTS

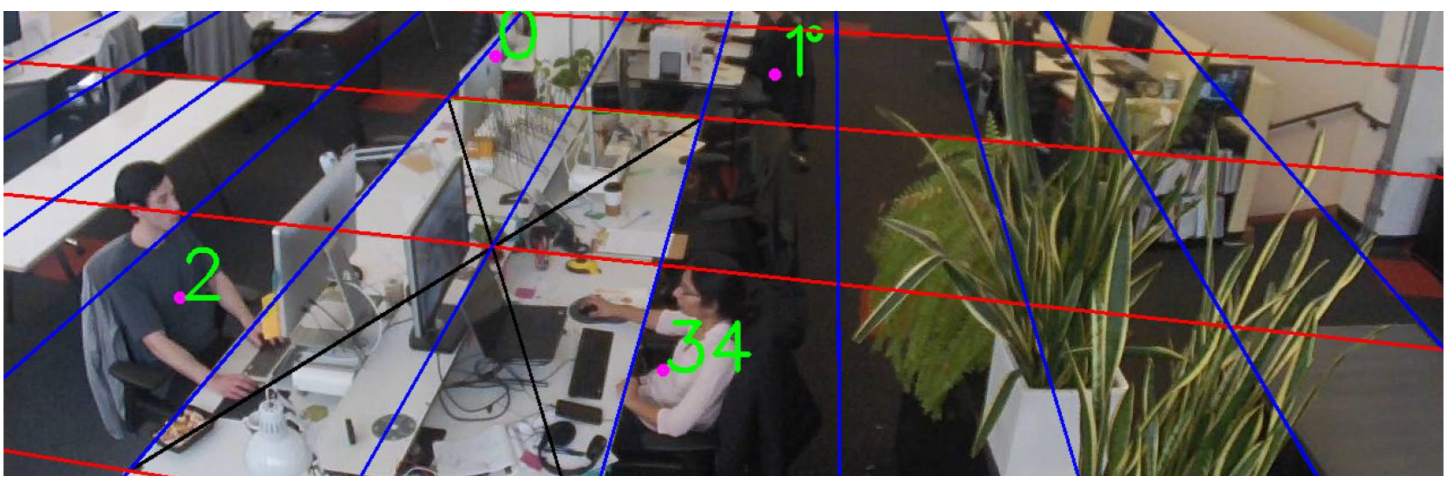
At the onset of REACHE 4, MKThink established the goal to exceed three previous design requirements established in REACHE 3, to make the sensor kit smaller, more durable, and easier to deploy. Additionally, MKThink committed to two new design requirements, to make data collection private (non-identifying) and affordable. The updated design requirements are outlined below:

- Quick & Easy (Easy-to-Use)
- Non-technical
- Accurate & Verifiable
- Inter-operable
- Redeployable (Durable)
- Private
- Affordable

The REACHE 3 Sensor Kit effectively evaluated environmental quality, but did not collect Utilization, Occupancy, and Activity (UOA) and Architectural Asset (AA) data. After evaluating the current sensor market, MKThink decided to develop its own UOA and AA Sensor Kit.

To fill the identified gap in the UOA and AA sensor market, MKThink established the following functional requirements for the REACHE 4 Sensor Kit:

- Field dimensions: the length, width, and height of features in the camera's field of vision
- Utilization: time-stamped data indicted when given rooms are being used
- Occupancy: time-stamped data indicating the number of people in a given room
- Activity: user behaviors in space, including:
- The location of individuals relative to the field
- The proximity of individuals to one another
- The path of movement of individuals within space



These data layers reveal opportunities to mitigate operational inefficiencies. The REACHE 4 Baseline Measurement collects quantitative and qualitative data about users in space to inform design solutions better catered to the user experience. The REACHE 4 Kit informs solutions to maximize energy efficiency and user productivity while maintaining the cultural integrity of the organization.

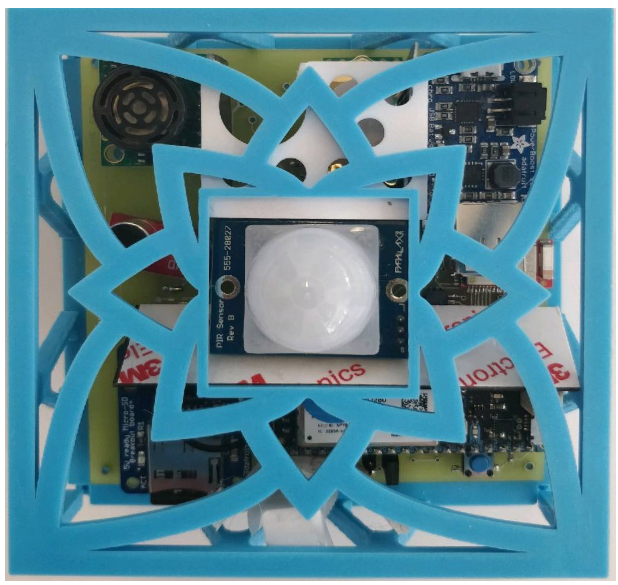
DEVELOP SENSOR KIT

MKThink developed a sensor kit to measure UOA and AA. To meet the design requirements, the team developed a custom housing unit for the sensor kit in-house using a 3D-printer. The housing unit consolidates all sensor kit components for easy deployment and provides durability to protect the kit if it drops.

A camera serves as the sensing device onboard the Sensor Kit. The sensor kit is paired with a Computer Vision software, a form of Cognitive Computing, which employs human-coded data sets and custom algorithms to translate the video feed into reportable data.

With Computer Vision, the REACHE 4 sensor kits are able to collect both Utilization, Occupancy, and Activity (UOA) data and Architectural Asset (AA) data, representing the Cultural and Architectural spheres of REACHE.

The Computer Vision algorithms can detect people, track their movement and location throughout space, and divide the field of view into zones.



The algorithm uses an online database of human forms to detect people in the video feed. The algorithm totals the number of detected people to generate an occupancy count. To track people throughout space, the algorithm places a tracking point at the person's center. If a person's center is detected with a certain radius frame-to-frame, then the computer identifies them as the same person and tracks their movement throughout the field. The individual's location within the space and their proximity to other people or areas is also timestamped and recorded. Additionally, users have the option to assign zones around areas of interest and track occupant activity in and out of the zones.

In addition to UOA data, the Computer Vision algorithm can also determine space dimensions. If the measurements of a set of parallel lines in the camera's field of view is known and identified by the user, a vanishing point can be calculated, and pixel distances can be transformed to actual distances.

CONCLUSION + NEXT STEPS

The REACHE 4 Sensor Kit is smaller, more durable, and easier to deploy. The Kit responds to gaps in the sensor market and the previous kits developed under REACHE contracts. The Kit can effectively collect UOA and AA data to augment REACHE datasets and allow organizations to make more informed decisions.

The REACHE 4 Sensor Kit needs to be tested to ensure usability and function. Results from these tests will inform necessary steps to bring the Kit to market.