Introduction to Civil Information Systems

Mark A. Austin

University of Maryland

austin@umd.edu
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Overview

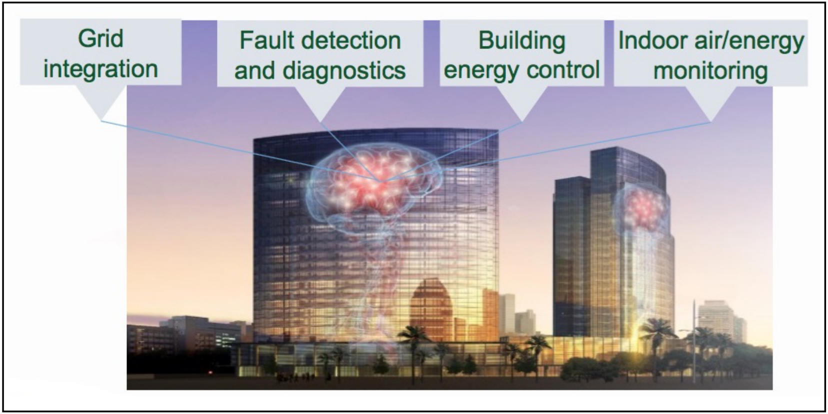
Part 5

Urban Applications

How do buildings and cities work?

Modern Buildings (Vision for Future)

Buildings that Think! (Work at NIST/UMD 2017)



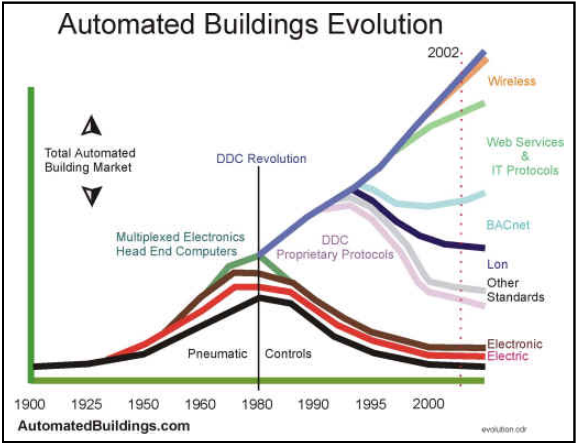
Modern Buildings (Key Features)

Modern buildings are:

- Advanced, self-contained and tightly controlled environments design to provide services (e.g., transportation, lighting, etc).
- Large size (e.g., 30,000 occupants, thousands of points of sensing and control for air quality and fire protection).
- Many stakeholders; highly multi-disciplinary.
- Building have networks for: arrangement of spaces; fixed circulatory systems (power, hvac); dynamic circulatory systems (flows of energy).
- Many sources of heterogeneous data.
- Necessity of performance-based design and real-time management.
- System functionality controlled by software!

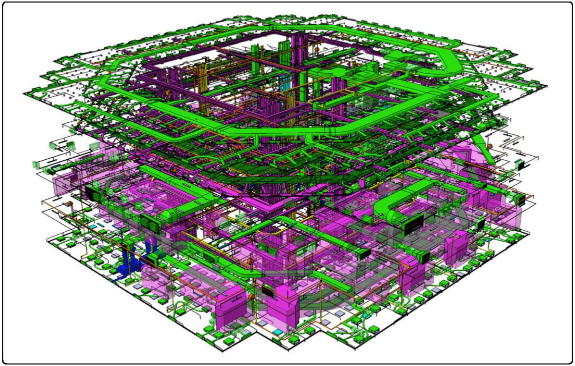
Modern Buildings (Key Features)

Large-scale building systems are packed with automation:



Modern Buildings (Key Features)

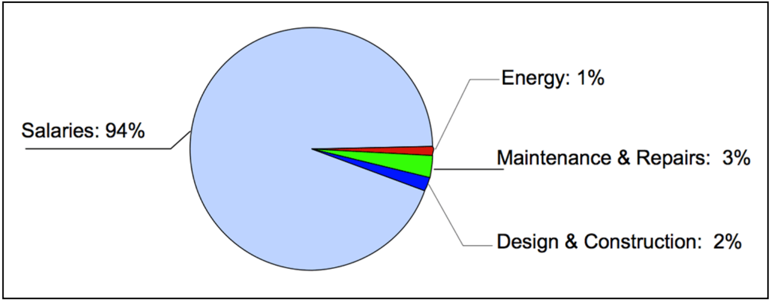
Large-scale building systems are intertwined networks of networks:



Understanding the relationships among the networks and their combined behaviors can be very challenging.

Modern Buildings (Economics)

Lifecycle costs in office buildings over a 30-Year period:



Energy systems have a huge impact on building occupant comfort and indoor air quality which, in turn, affects salary performance.

Source: United Technologies Research Center, 2009.

Modern Buildings (Integrated Energy Systems)

Trend toward Integrated Energy Systems:

- Commercial and residential buildings consume 1/3 of the world's energy.
- And by 2025, buildings will consume more energy than the transportation and industrial sectors combined.
- Standard models of building operation rely on centrally produced power as a source of high-grade energy.
- Advances in technology allow for consideration of alternatives, such as local production of power.

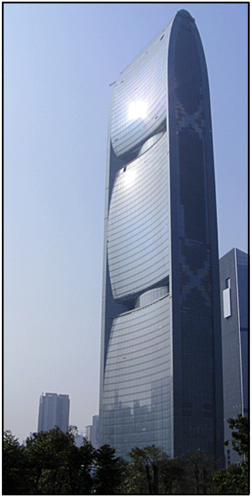
Examples:

- Solar power; small-scale combined heat and power systems.
- Electricity production through use of ducted wind turbines.

Modern Buildings (Integrated Energy Systems)

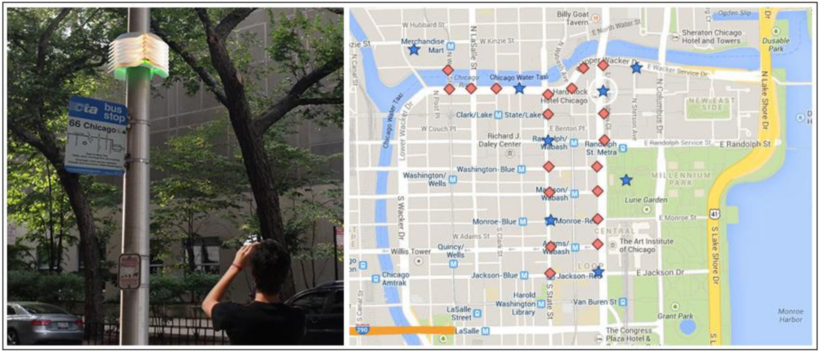
Pearl River Tower (2010):

- High performance structure designed to produce as much energy as it consumes.
- Guides wind to a pair of openings at its mechanical floors.
- Wind drives turbines that generate energy for the heating, ventilation and air conditioning systems.
- Openings provide structural relief, by allowing wind to pass through the building.



Smart Cities: Urban Sensing in Chicago

Array of Things, Chicago. Modular sensor boxes will collect real-time data on the city's environment, infrastructure and activity.



Basic Questions. How is the city used? What is going on?

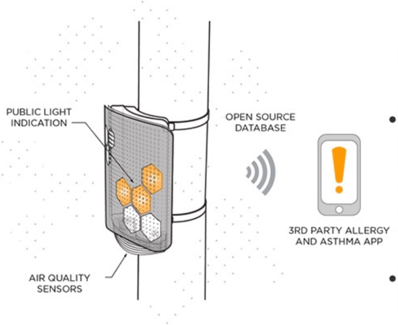
Smart Cities: Urban Sensing in Chicago

What Data is Collected?

The nodes will initially measure temperature, barometric pressure, light, vibration, carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, ambient sound intensity, pedestrian and vehicle traffic, and surface temperature. Continued research and development will help create sensors to monitor other urban factors of interest such as flooding and standing water, precipitation, wind, and pollutants.

Array of Things is interested in monitoring the city's environment and activity, not individuals. In fact, the technology and policy have been designed to specifically avoid any potential collection of data about individuals, so privacy protection is built into the design of the sensors and into the operating policies. Array of Things will not collect any personal or private information.

Smart Cities: Urban Sensing in Chicago



What Can be Done with this Data?

Potential applications of data collected by the Array of Things include:

- Sensors monitoring air quality, sound and vibration (to detect heavy vehicle traffic), and temperature can be used to suggest the healthiest and unhealthiest walking times and routes through the city, or to study the relationship between diseases and the urban environment.
- Real-time detection of urban flooding can improve city services and infrastructure to prevent property damage and illness.
- Measurements of micro-climate in different areas of the city, so that residents can get up-to-date, high-resolution "block-by-block" weather and climate information.
- Observe which areas of the city are heavily populated by pedestrians at different times of day to suggest safe and efficient routes for walking late at night or for timing traffic lights during peak traffic hours to improve pedestrian safety and reduce congestion-related pollution.

SONYC: Sounds of New York City

SONYC. A system for monitoring, analysis and mitigation of urban noise pollution.

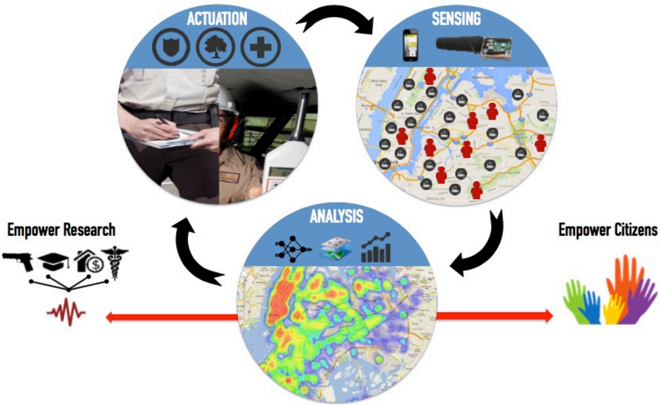
Motivation. Over 70 million people in US are exposed to noise levels beyond the limit of EPA considers to be harmful.

Short-term Problems. Sleep disruption.

Long-term Problems. Hypertension, heart disease, hearing loss.

SONYC: Sounds of New York City

Complaints. NYC authorities receive more than 800 noise-related complaints per day!



SONYC: Sounds of New York City

Noise Analytics. Analyze and understand noise pollution at a city-scale.

Global Applications

Answering Big Science Questions

NASA's Earth Observing System

NASA'S EOSDIS PROGRAM

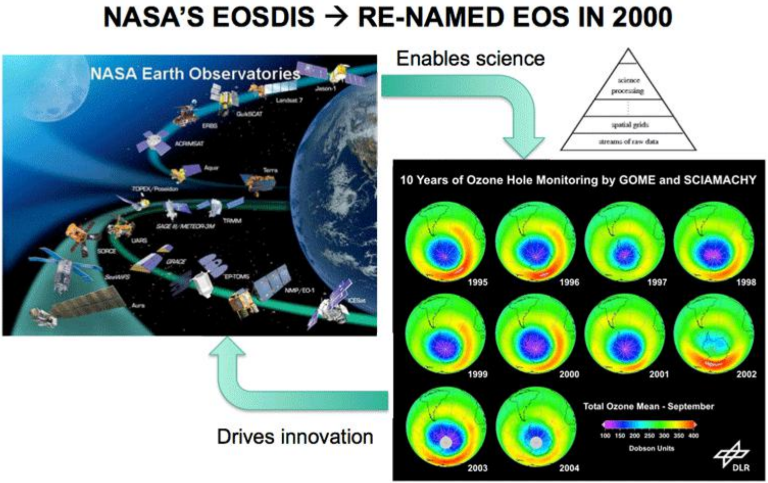
NASA / Hughes Contract in 1993

- Project planning begins in 1989.
- Proposal submitted July 1, 1991.
- Contract awarded 1992.
- $600 million to design and building the infrastructure for a global data and information system that can handle petabytes (2^50 bytes) of data.
- 13 participating countries: USA, Canada, Japan, etc.
- Data collection and information processing: 1995 – 2015.

Big Science Questions:

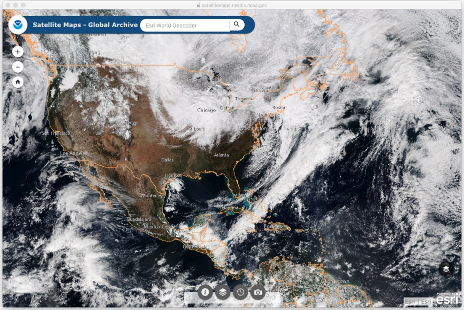
- How is the Global Earth System changing?
- What are the primary factors that influence change?
- How does the Earth System respond to natural and human-induced actions?
- What are the consequences of change in the Earth Systems for humans?
- How will the Earth System change in the future?

NASA's Earth Observing System



Satellite Imagery and Measurements

Understanding Climate Change

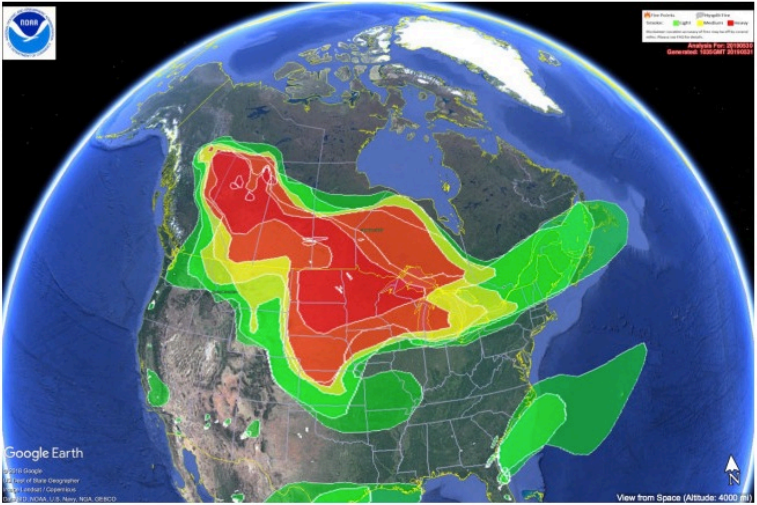


Example. Measure spatial and temporal extent of annual Snow Pack → Estimate water resources available for agriculture and urban consumption.

California Wildfires force Evacuations

Canadian Wildfires impact US

Wildfires in Alberta: Smoke covers millions of square miles:



Canadian Wildfires impact US Health/Food Chain

Poor Air Quality (Summer, 2018):

- Hundreds of wildfires in BC and WA.
- Smoke in BC drifts south to Washington State.
- Air quality in Seattle is very poor.

Wildfires impact Food Chain:

- Blankets of smoke obsure direct sunlight over orchards.
- Apples cannot grow to full size.
- Price of apples at Safeway goes up!

Canadian Wildfires impact NYC

Poor Air Quality in NYC (June, 2023):

Summary

Recurring Themes and Key Points

Recurring Themes

- Information-age systems offer enhanced functionality and better performance, but their design is more difficult than in the past.
- Physical systems and computational systems fail in completely different ways.
- Sensor networks will form the eyes and ears of complex control and information systems.
- As system complexity increases, more and more of the functionality will be managed by software!

Key Points for Building Better Systems

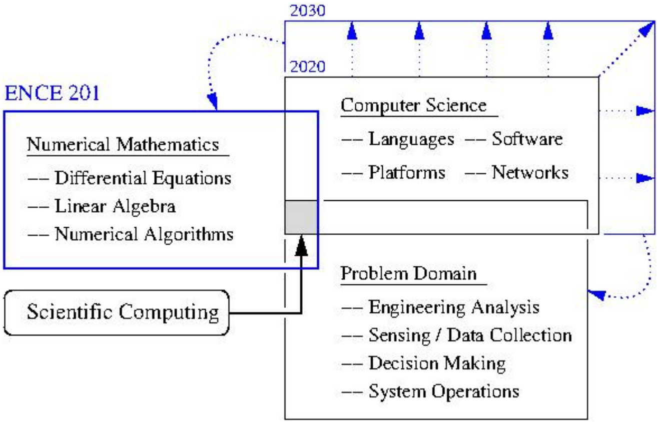
Looking Forward

Use sensing and software to build better systems:

- Improve situational awareness – to understand what is actually happending a building or city?
- Connect sensor measurements to short- and long-term urban needs (e.g., decisions on a bus stop; longer term urban planning).
- Capture the spatial, temporal, and intensity aspects of environmental phenomena (e.g., fires, flooding) and their impact on natural (e.g., air quality) and man-made systems (e.g., transportation networks, food chains).
- Look ahead and forecast future states of the system?

Central Role of Scientific Computing

Scientific computing lies at the intersection of computer science, numerical mathematics, and domain-specific problem solving.



Central Role of Scientific Computing

Computer Science and Software:

- Very fast computations.
- Mass collection of data.
- Rapidly growing importance of data sciences.
- Artificial Intelligence and Data Mining.
- Machine Learning.

Numerical and Applied Mathematics:

- Differential Equations
- Numerical Analysis and Linear Algebra.

Central Role of Scientific Computing

Large-Scale Simulation:

- Improved protection of buildings from extreme environmental loadings (e.g., earthquakes, fire, tsunamis, blast).
- To understand how consequences of global warming (e.g., sea-level rise; wild fires) will impact cities.

Improved Management of Urban Processes:

- Network systems analysis and optimization.
- New strategies for data-driven management of interdepenent urban networks.
- Prevention of cascading failures.

Computer Language for ENCE 201

Getting Started. We need learn to walk before we can run:

Capability	1970s	1980s	1990s
Languages	Fortran, C	MATLAB	Python, Java

Python

- Not too difficult – it's a reasonable place to start learning.
- Good support for data analysis and data analytics.
- Good support for numerical calculations.
- Provides a stepping stone to other languages.

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