Intelligent and Adaptive Lighting Systems of the Future

LIGHTFAIR International

May 5-7, 2015

Tess Perrin – Lighting Scientist
Michael Poplawski – Senior Engineer
Pacific Northwest National Laboratory
What is the Internet-of-Things, and who cares?

Information from the Internet of Things:
We have gone beyond the decimal system

Today data scientist uses Yottabytes to describe how much government data the NSA or FBI have on people altogether.

In the near future, Brontobyte will be the measurement to describe the type of sensor data that will be generated from the IoT (Internet of Things).

- Brontobyte: This will be our digital universe tomorrow...
- Yottabyte: This is our digital universe today = 250 billion DVDs
- Zettabyte: 1.3 ZB of network traffic per day
- Petabyte: The CERN Large Hadron Collider generates 1 PB per week
- Exabyte: 1.1 EB of data is created on the internet each day = 230 million 100GB worth of information.
- Terabyte: 3,000 terabytes of new data per day are ingested in Facebook, LinkedIn, etc.

More data has been created in the last three years than in all past 40,000 years.
Almost all of this data has a location.
Business and government decision-makers must have a strategy for dealing with location-based data.
What technologies are enabling the IoT?

- Cheap sensors
- Cheap intelligence
- Cheap data transport
- Cloud Computing?
- Smart Phones?
- Lighting?
Why lighting? SSL is the catalyst...

• Solid-State Lighting (SSL) is the most energy efficient, flexible, controllable lighting technology in history
  – Spectral power distribution (color characteristics, e.g. CCT, CRI, Duv), light output (e.g. luminous flux, intensity, distribution)
  – System architecture, partitioning, and power conversion

• SSL is blurring the traditional lines between lighting system devices (e.g. lamps and ballasts/drivers, luminaires, and lighting controls)

• SSL is poised to catalyze the deployment of intelligent, networked lighting devices that collect and exchange data
  – Embedded intelligence (e.g. for managing power conversion) can be leveraged for other purposes (e.g. output control, network interface)
  – Microelectronic platform facilitates the cost-effective integration of additional functionality (e.g. network interfaces, sensors)
How can the IoT benefit lighting and buildings?

- Enabling intelligent lighting systems with data can result in reduced energy consumption and improved lighting performance.
- The data collected (via sensors) by advanced lighting devices and exchanged (via network interfaces and interoperability protocols) with other lighting and non-lighting devices can facilitate reduced energy consumption and improved performance of those devices, as well as a growing number of non-lighting and non-energy related benefits.
  - Lighting is pervasive (in all buildings and spaces), well-distributed, and AC powered.
  - Leverage SSL transition driven by energy and maintenance savings.
Lighting is poised to dramatically change in the future

- **Many integration possibilities**
  - Single-function (e.g. sensor-only) devices
  - Multi-function devices (e.g. controllable light source and sensor(s) and network interface)

- **Not clear that any particular device integration or system architecture will dominate**
  - Many will be likely be able to succeed in the market
  - Solutions for retrofits and new install
Future advanced lighting systems

Data exchange between devices and systems

- Advanced Lighting Device
- Advanced Lighting Device
- Advanced Lighting Device
- Non-Lighting System
- WAN, Internet

[data]
[kWh data]
[Temp data]
[Light data]
Aren’t there already technologies for controlling lighting?

- Lighting control is a function that requires the integration of devices; while a controlled lighting system can far out-perform a static system, performance depends on much more than device capabilities.
- Lighting control strategies have been overly focused on devices that are tightly coupled to installed luminaires, with not enough consideration given to system issues and intangibles such as owner organizational maturity.
- Lighting control energy savings have been widely varying and unpredictable, and limited by the number of installations, failure to adopt performance monitoring and continuous optimization, and lack of interaction with non-lighting systems.
- Complex configuration requirements, high total cost of deployment, poor user satisfaction, and difficult to predict performance have been and remain significant barriers to adoption (estimated as < 1%) and energy savings.
DOE Museum Resources

Survey responders:
- 39% incandescent dimming
- 42% 0-10V/DALI/DMX
- 12% combination
- 33% no controls
Control of Lighting in Museums

MECHANICAL METHODS are the dominant approach for limiting exposure

INTEREST IN AUTOMATIC CONTROL

65% would use lighting controls if they worked with existing infrastructure and afford lamp-by-lamp control

“It is hard to imagine having the money for replacing existing equipment with these options when what we have [filters, screens] works fine with manual installation.”

Flicker?

Dim down to 50 lux?

Additional wiring?
Why does DOE work with museums?

LEDs have the potential to save **80% or more** in energy, with further savings from controls.

Museums use approximately **twice** the electricity compared to other commercial buildings due to the increased HVAC used to regulate the relative humidity.

Museums require optimal lighting conditions, need to control exposure, and are highly visible, public applications.

**Common goals:** sustainability and energy savings

National Museum, Stockholm
*Intelligent combination of daylight with SSL*
Museum Interest in Advanced Lighting Systems

Control of more than just light intensity

• Specification of lighting exposure (illuminance, spectrum, time) in order to
  • Minimize damage
  • Optimize viewing conditions
  • Maintain color performance

• Integration with sensors that monitor
  • Ambient light (e.g. daylight)
  • Physical environment (RH, T)
  • Use of space

• Adaptive exposure control

• Network interfaces to enable
  • Reporting of logged data
  • Central management
How adaptive exposure control helps conservators

Enable more accurate evaluation of potential damage for the selected spectrum, intensity, and material

Reduce the burden of frequent handheld monitoring

Complement more nuanced tracking of condition over time

Minimize the labor involved in precision measurements

Eliminate the subjectivity of using the ISO Blue Wools

Blue Wool Standards

3,500 K PLANCKIAN RADIATOR

SAME CHROMATICITY
How adaptive exposure control helps industry

Log measurements

User-driven database on performance

Benefit Manufacturers
Improved products and innovation

Benefit Primary Institution
Long-term performance supports warranty claims

Benefit Other Institutions
Long-term performance helps decision making
How adaptive exposure control helps visual performance

Canadian Conservation Institute
Benchmark value

50 lux

- For dark surfaces
- For low contrast detail
- For fine detail or complex tasks
- For older viewers

up to 150 lux

http://www.lumenetix.com/araya-video-02

Norman Brommelle, Color and conservation, Studies in Conservation, 1955
Potential application of adaptive exposure control

Integrate with other environmental monitoring strategies → combining three major agents of deterioration (light, RH, T) to:

- **Measure** (sensor)
- **Analyze** (controller, logic)
- **Cause action** (controlled device)

Are there any other Dutch paintings with little dogs in this museum?