Paradigm changes in lighting R&D
What 2017 changed

Pi Lighting

Who are we

Pi Lighting, SME tech company based in Switzerland, funded 2014

- R&D consulting in LED technologies :
  - General lighting : colorimetry, reliability, product design
  - Embedded systems (portable devices, automotive, aeronautics)
  - Project support, from idea to product
  - Technical audits for investors in LED technology
  - Advanced statistics, machine learning & AI for lighting

Profiles : LED application experts, Semiconductor experts, Data security & embedded systems, industrial PM, LED technology & application training

www.pi-lighting.com

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Major R&D trends in lighting in 2017

2017 : a shift in R&D demand

- VLC/Lifi/LifiX going mainstream
- Circadian lighting
- AI

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VLC / Li-fi / LifiX

Data through light

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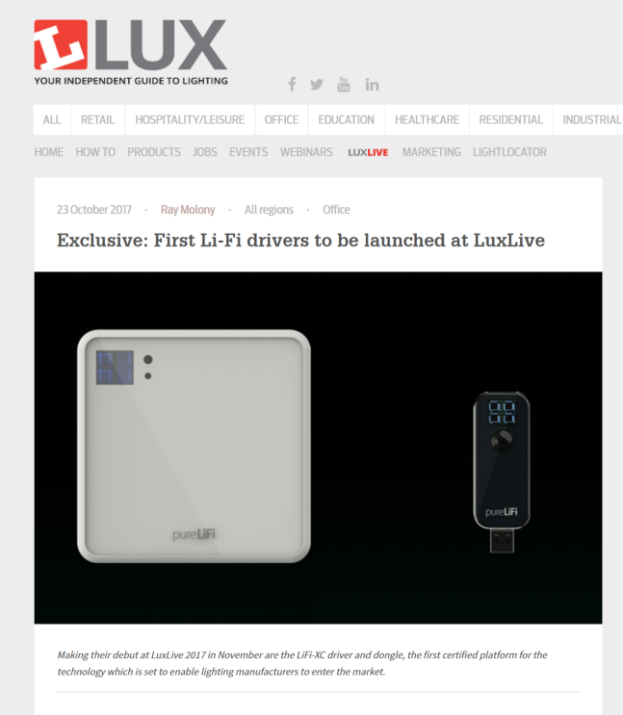
VLC/Li-fi/LifiX (1)



Li-Fi recognized as a viable alternative to WiFi

- Security :

  1-WiFi WPA2 KRACK Vulnerability

The 'Secure' Wi-Fi Standard Has a Huge, Dangerous Flaw – Wired.com 16 oct

  2 – IoT vulnerabilities

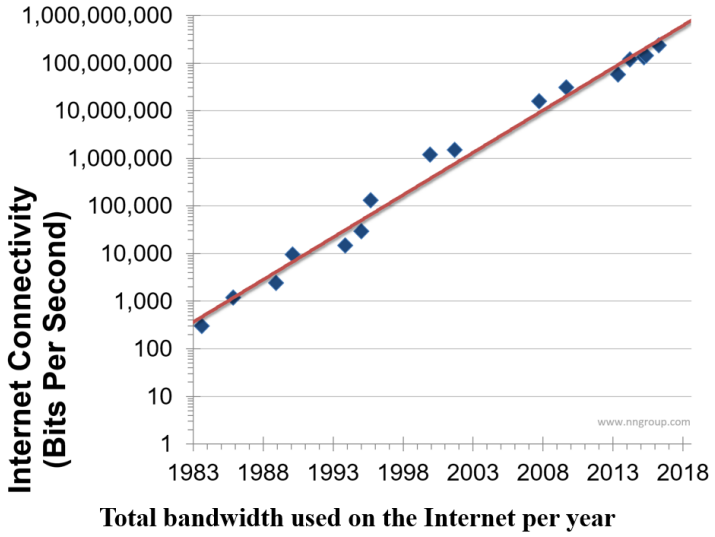
New Reaper IoT Botnet Leaves 378 Million IoT Devices Potentially Vulnerable to Hacking – PR Newswire Oct 24

- Radiosensitivity :

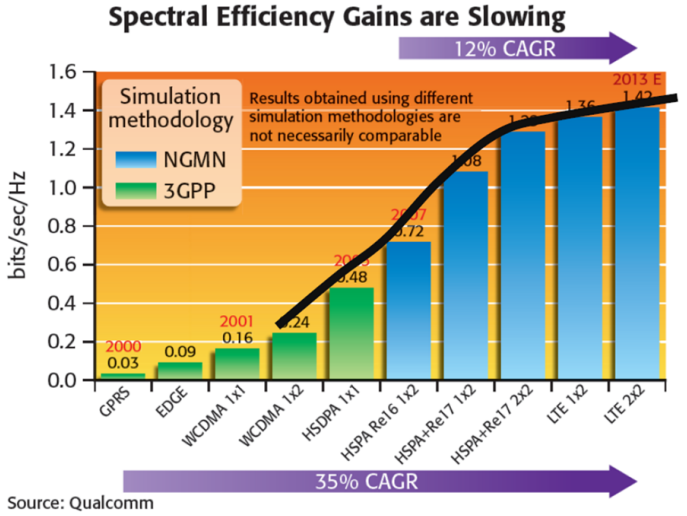
France: New National Law Bans WIFI In Nursery School

VLC/Li-Fi/LifiX (2) : hunger for bandwidth

Hunger for bandwidth, RF spectrum crunch



Total bandwidth used on the Internet per year



Source: Qualcomm

- *Source T.Merelle, VLC and Lifi state of the art, LPS 2017*

- ❑ Problem of bandwidth availability is known as the "Global Bandwidth Problem"*
- ❑ RF Spectrum crunch: spectral efficiency gains are slowing down**

*Supercomputing: 29th International Conference, ISC 2014, Leipzig, Impact of Future Trends on Exascale Grid and Cloud computing, T.H Szymanski

** M.Safari, Enhanced Visible Light Communications, Univ. Edimburg, LpS 2016

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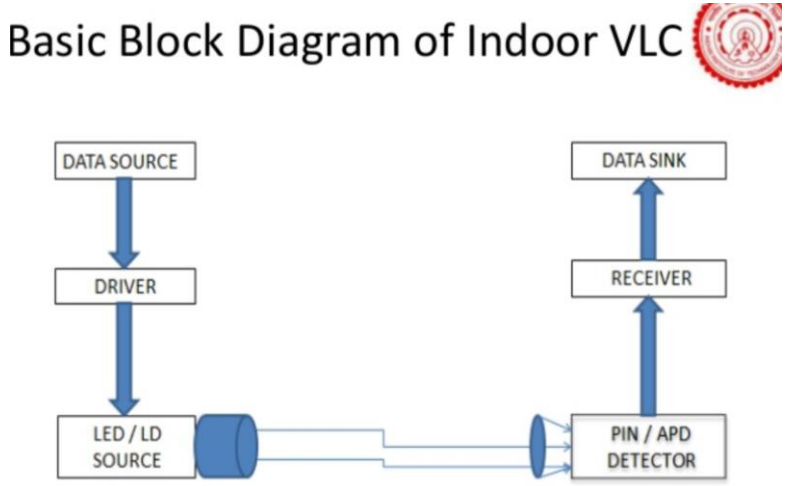
VLC/Lifi/LifiX

- VLC : Monodirectional : point to point network

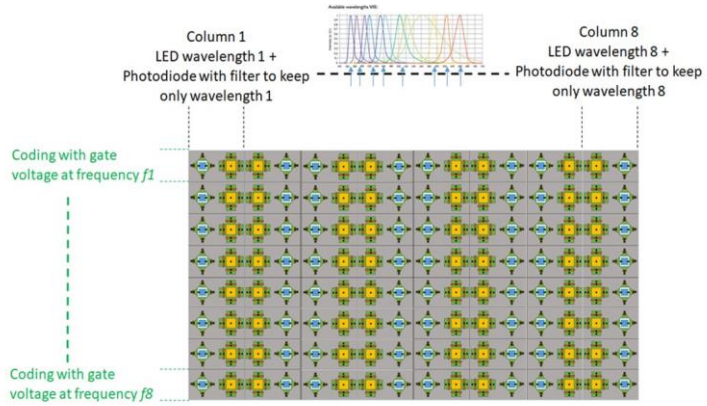


Source: https://www.slideshare.net/parthsaxena35/visible-light-communication-61038495

- Lifi : Bidirectional, uplink via IR/standard network

- LifiX : fully bidirectional (but still in dev) CMOS-technology based device

	Product name	Power consumption	Concept	Bandwidth
OLEDcomm	GEOLiFi XS	n/a	receptor + Light bulb	1Gb/s
Lucibel	Ores Lifi	2.5Wdongle/35W luminaire	USB dongle + Luminaire	42Mb/s
Velmenni	Jugnu	n/a	receptor + Light bulb	claim up to 8Gb/s
Pi Lighting	LifiX	< 20 W per device pair	2 CMOS devices	25.7Gb/s for 64 cells



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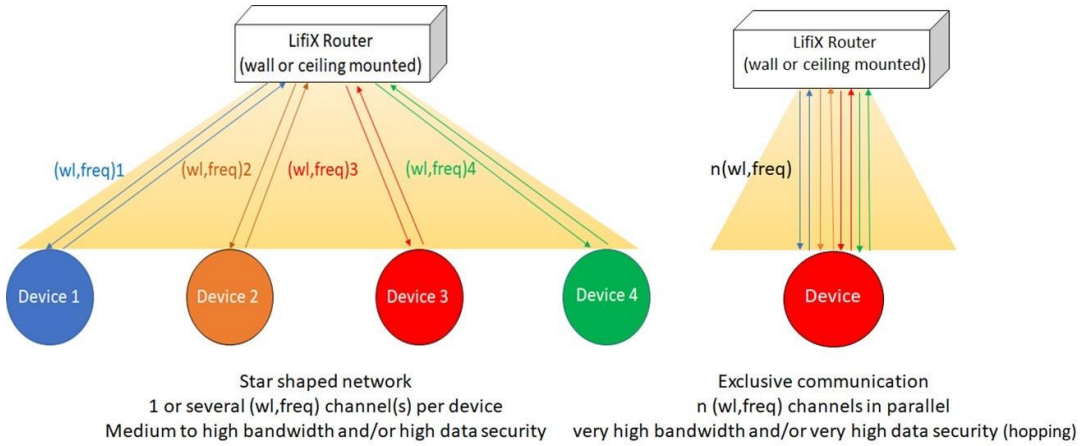
Luminaire vs beacon : design choices



- Luminaire : reuse of existing luminaire infrastructure. The main light source is the data device
- Beacon : dedicated light device for communication

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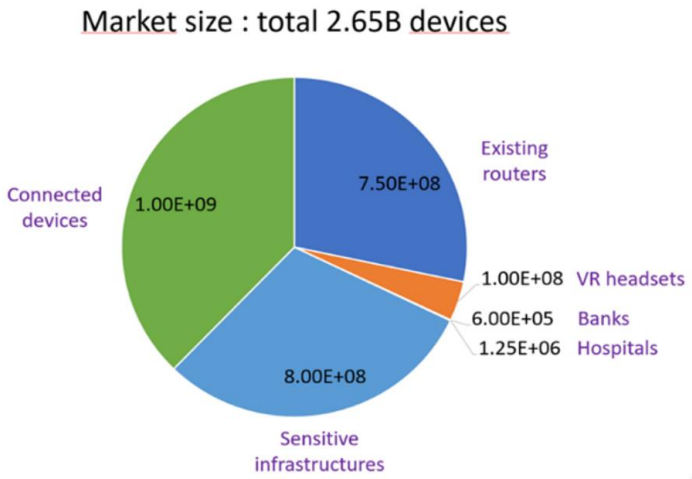
Market volume for VLC/Lifi/LifiX



Expected market total volume for each segment in 2018 (internal research)

- VLC/Lifi/LifiX have the potential to compete with all LAN network devices(Wifi & others)
- 100% Market size is 2,65B billion devices :

IoT connected objects, High bandwidth (optical router), secure specific environments (hospitals, bank, sensitive infrastructures)

Mobiles, connected cars, etc…

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Conclusion on VLC/Lifi/LifiX

- Fully bi-directional high bandwidth(&cheap) opens up router/LAN market
- Embedded security + « radio-neutral » are major advantages
- A serious competitor for Wi-Fi and all LAN technologies
- Will require technology consolidation and major players entering

- One day : a VLC/Lifi/Lifix router at home?

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Circadian Lighting

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Circadian Lighting : reason to believe

MEDICINE

3 Americans Win Nobel Prize for Circadian Rhythm Research

Jim Heintz and David Keyton / AP
Updated: Oct 02, 2017 9:15 AM ET

(STOCKHOLM) — Three Americans won the Nobel Prize in Physiology or Medicine on Monday for their discoveries about the body's daily rhythms, opening up whole new fields of research and raising awareness about the importance of getting enough sleep.

Jeffrey C. Hall, Michael Rosbash and Michael W. Young won the 9-million-kronor ($1.1 million) prize for their work on finding genetic mechanisms behind circadian rhythms — which adapt the workings of the body to different phases of the day, influencing sleep, behavior, hormone levels, body temperature and metabolism.

Source : Time.com

- Circadian Rythm disruption linked to Depression, Diabetis
- Proven effect of light on Circadian rythm
- Proven results of optimized circadian light on patients in mental institutes
- Proven results of light on mood & sleep in office workers
- Pioneers : Light & Health Alliance, LRC, RPI, NY(US)

Disruption of Circadian Rhythms by Light During Day and Night, M.Figuero & Al

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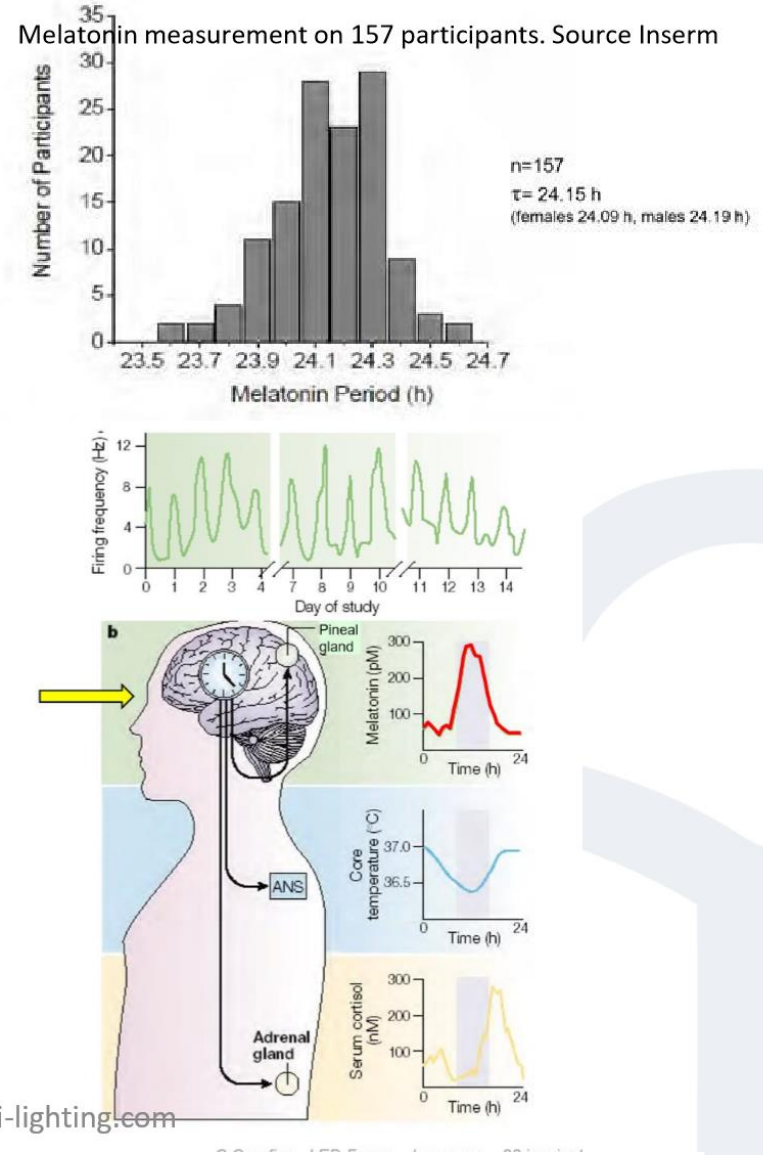
Light impact on circadian rythm

- Light resets the circadian clock (and can delay it..)
- Light level **and** spectrum matter



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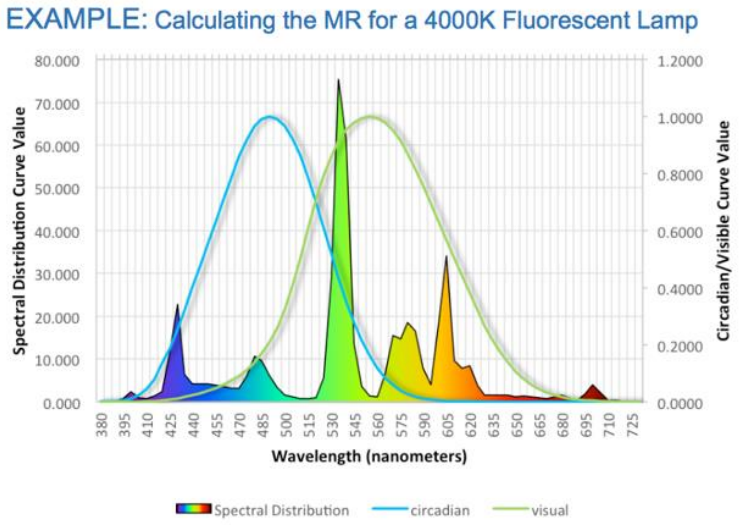
Circadian metrics

- Two concurrent metrics : both are spectral calculations
  - Melanopic Ratio (& EML) – WELL building standard. Straighforward
  - CLA/Cs – Light and Health alliance. Two stage calculation. SPD=> CLA => Cs



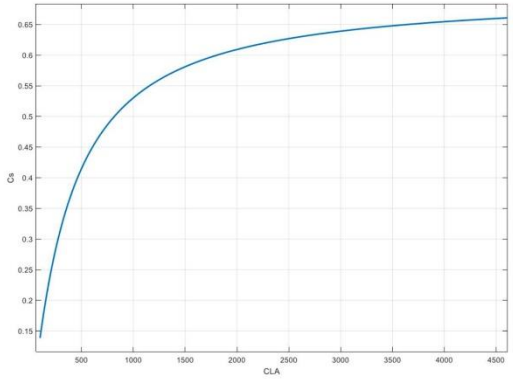
MR = ratio under normalized blue curve
EML Linear with illuminance (lux)

Case A / Case B

$$CL_A = \begin{cases} 1622\left[\int Mc_\lambda E_\lambda d\lambda + \left(a_{b-y}\left(\int \frac{S_\lambda}{mp_\lambda} E_\lambda d\lambda - k\int \frac{V_\lambda}{mp_\lambda} E_\lambda d\lambda\right) - a_{rod}\left(1 - e^{-\frac{E_v}{RodSat}}\right)\right)\right] & \text{if } \int \frac{S_\lambda}{mp_\lambda} E_\lambda d\lambda - k\int \frac{V_\lambda}{mp_\lambda} E_\lambda d\lambda \geq 0 \quad \text{Condition 1} \\ 1622\int Mc_\lambda E_\lambda d\lambda & \text{if } \int \frac{S_\lambda}{mp_\lambda} E_\lambda d\lambda - k\int \frac{V_\lambda}{mp_\lambda} E_\lambda d\lambda < 0 \end{cases} \quad (1)$$

Macula · S-cone · Visibility · Rod suppression · Macula

***CS** = .7*(1 - (1./(1 +(CLA/355.7).^(1.1026))));*



Cs (circadian impact) **saturates** with light level

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Arguments pro/cons

- Doubling light level doubles EML (linear with flux)
- Cs takes into account saturation of circadian impact
  - CLA « similar » to EML, simulates the Circadian signal sent to your brain
  - Cs tells what your brain does of this signal

Complexity : Requires some smart controls

Three complexity (and benefit) thresholds :
Dimming curve => Multichannel => spectrum optimization

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Conclusion :

- If the implementation of circadian light allows a reduction in worker depression (even if a minimal amount)

- Should we compare the extra cost of circadian fixtures vs standard fixtures
  - Or should we compare including the human/financial cost of depression/burnouts ?

=> A Major trend in office lighting

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AI

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AI & Machine Learning

- A technology with one of the widest field of application ever invented
- Daily « buzz » in the news
- Does it apply to our industry?

"In the last year only, AIs have busted criminals, have read your email, have checked your pictures, have wrote articles, translated any language into another, beat you at chess, at Go, at League of Legends, at planting salads. It also drove your cars safely, invested your money, helped doctors find tumors, detected risky behaviour from facebook posts, and managed your powergrid."

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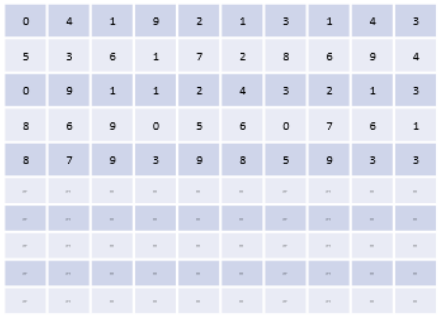
Machine Learning/AI in one slide

- Build a set of parameters giving a result (example, pixels doing an image, result is « a cat picture »)
- Record parameters and result. This is a **training set**
- Machine Learning : finds relation parameters/result in a Neural Network
- Ex: MNIST

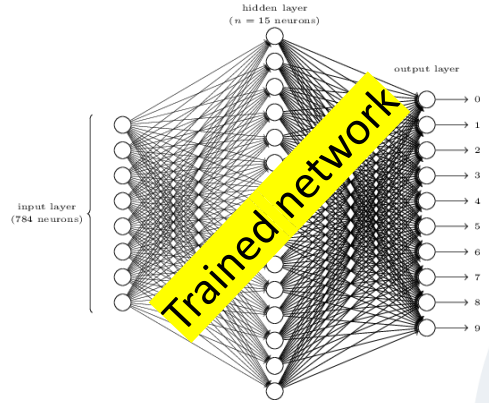
  Handwritten digits, 28x28 pixels

Step 1 : Learning

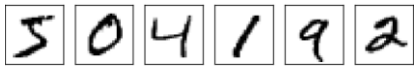
&

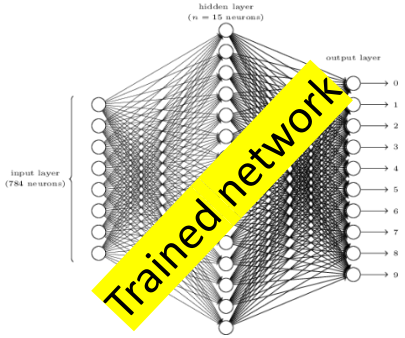


train



Step 2 : prediction





5 0 4 1 9 2

Here, AI is a function which performs prediction based on ML training

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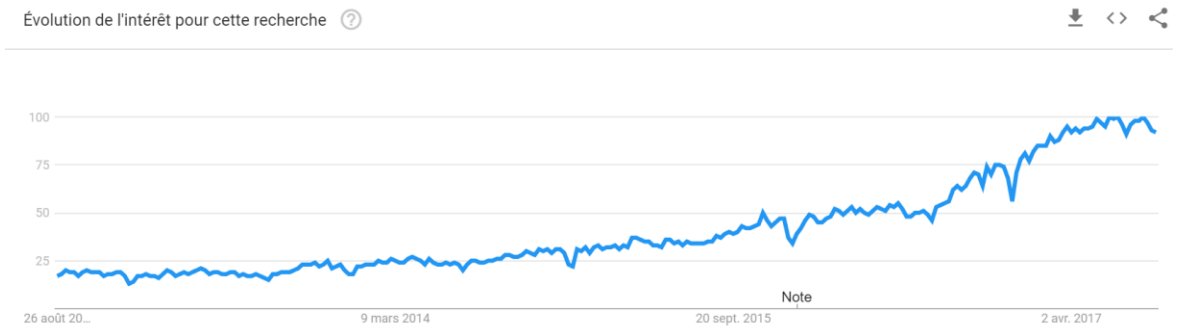
What is it? What is it NOT?

- ML allows to find patterns and correlations in **very large dimensional spaces**
- ML allows for predictions within the scope of the training set
- ML is not « magic »
- As of today (31/10/2017), a very « trendy » subject… too much
- Current Arms Race between major companies for largest GPU datacenters
  - Attempts to « lock » market behind large infrastructure needs
  - Very strong « overhype » on the quality of the results. Long road to do !



Google trend on Machine Learning

AlexNet labelling of different images
Source http://www.evolvingai.org/

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Pi Lighting approach of AI/ML

- Partnership with AI Services (www.ai-services.ch)

- Develop Lighting specific models from their platform

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Applications within production

- 02/2017 :
  - Car manufacturer
  - 1800 car models (including options)
  - 7 factory line with different settings
  - 393 inline tests during production
  - Training set shared with us : 45 000 examples
  - Final test bench : measurement times from 2 mins to 34 mins depending on problems found <- Production bottleneck
  - Can we predict how long the final test bench occupation will be?

95% prediction precision (<1 min precision)
Overall process improvement was 2-fold (customer indicators)
Production throughput increased

model | Line setup | Inline tests results | Final test time

ID	model	submodel	paint	factory	line	timeshift	optionA	optionB	testresult0	testresult1	testresult2	testresult3	testresult4	testresult5	testresult6	testresult7	testresult8	testresult9	testresult10	testresult11	testresult12	testresult13	testresult14	testresult15	testresult16	testresult17	testresult18	testresult19	testresult20	testresult21	testresult22	testresult23	testresult24	testresult25	Measured Test time
0	k	v	at	a	d	u	j	o	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	130.81
6	k	t	av	e	d	y	l	o	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	88.53
7	az	w	n	c	d	x	j	x	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	1	0	76.26
9	az	t	n	f	d	x	l	e	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	1	0	80.62
13	az	v	n	f	d	h	d	n	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	1	0	78.02
18	t	b	e	c	d	g	h	s	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	92.93
24	al	r	e	f	d	f	h	s	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	128.76
25	o	l	as	f	d	f	j	a	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	91.91
27	w	s	as	e	d	f	i	h	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	108.67

Translatable to LED//LED Fixture assembly line

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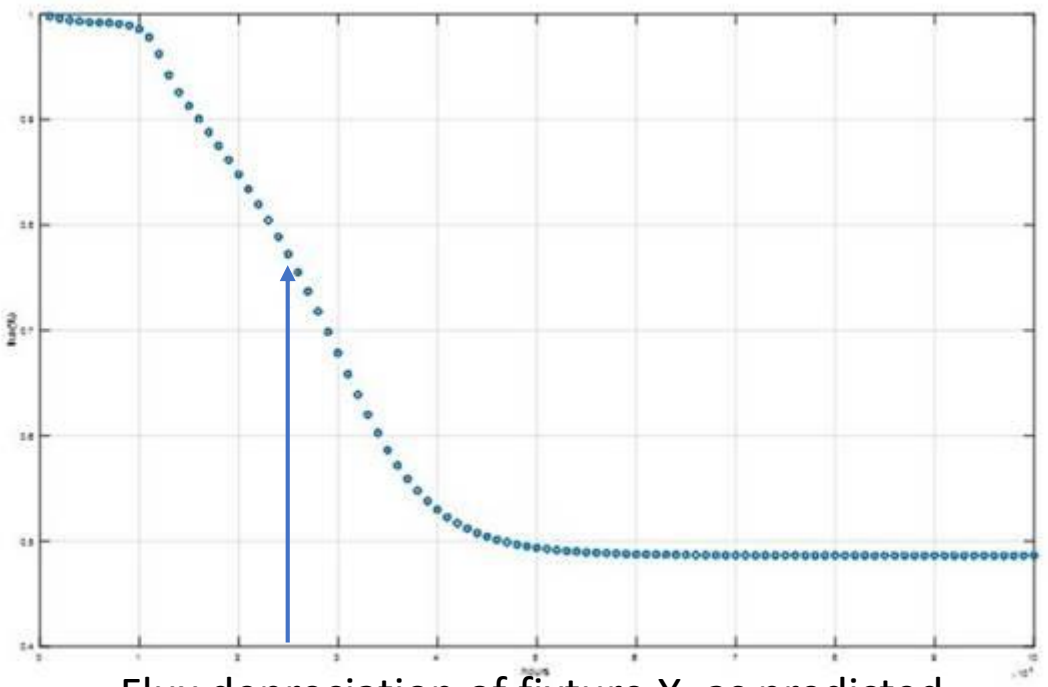
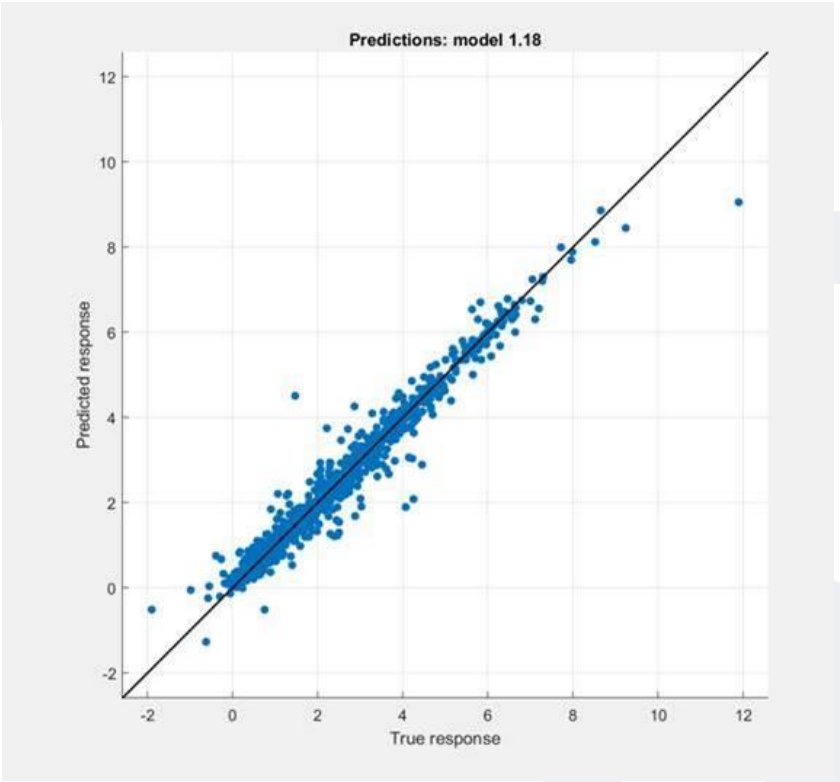
Applications in reliability/quality

- Predictions on LED/fixture lifetime
- From a set of LED measurements & LED characteristics
- Can i predict the flux depreciation?



Flux depreciation of fixture X, as predicted



25K hours accuracy, model vs reality(value in % depreciation)

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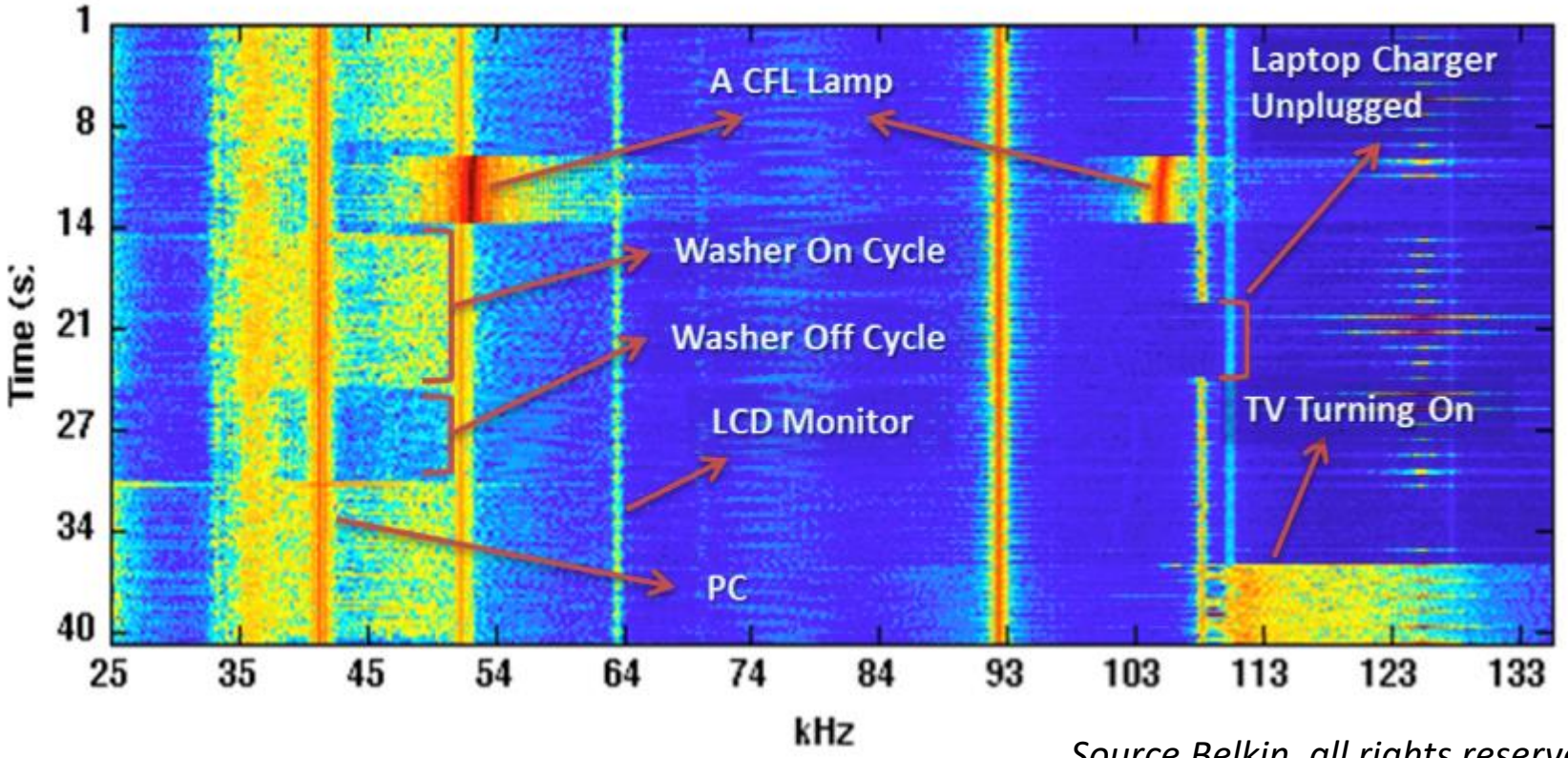
Applications within connected lighting

- Make sense of IoT sensor data
- Ex : wall controller voltage variation measurements :



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Applications in Marketing / Sales

- Campaign targeting (improve engagement, improved relevance with better targeting)
- Customer profiling (Understand better prospects & clients, customer lifetime & order value)
- Anomaly detection (early warning to reduce wasted advertising budgets)
- Churn reduction (rank customers by risk of defection)
- Pattern detection (do we find different customer populations?)
- Financial forecasting (improve accuracy of forecasted cashflows and visibility on acquisition costs)

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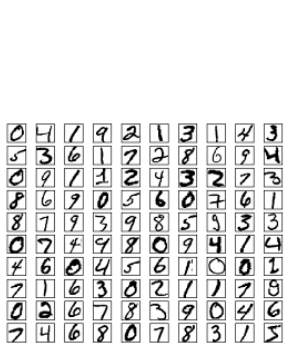
Extra : Customer data protection

- Exclusive « Protect your process » method
  - We provide a way to encrypt training set data
  - You keep the key, we do not see the data in clear
  - We run ML on obfuscated trainingsets



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0	4	1	9	2	1	3	1	4	3
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8	6	9	0	5	6	0	7	6	1
8	7	9	3	9	8	5	9	3	3
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encrypt

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97	73	109	1	61	73	1	85	73	13
97	85	109	37	109	97	61	109	37	37
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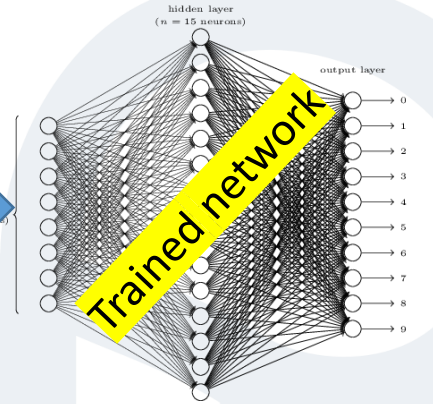

No need to share sensitive data

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Conclusion on AI

- AI will deeply impact lighting industry
  - Quality Managers typical job will change a lot
  - IoT//Connected lighting must implement AI techniques

- Still, it’s not magic. A New tool !

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Conclusion, 2017 paradigm changes (from Pi Lighting view)

- Lifi market expected to go from « specific » solutions to mainstream
- Circadian lighting is changing office lighting
- AI, a new powerful tool for our (and most) industries.

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Q ?

Pi Lighting

www.pi-lighting.com

benoit.bataillou@pi-lighting.com