Predictive Modeling Network for Performative Health Design, Agents and POE's

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The research paper is focused on several grants for predictive modeling networks in Health Design. It includes not only comparable real-world building case studies with metrics and POE's in Germany, the USA and in Brazil, but it also includes critical investigations for interdisciplinary education in architectural design, engineering and technology, computer science, information technologies, sociology, psychology, neurology, and others.

01_SALUTOGENESIS AND BUILDINGS FOR HEALTH

Roughly millions of patients every year contract worldwide infections while undergoing surgery, according to the International Centers for Disease Control and Prevention. For example, those infections cost billions of dollars in health-care services and millions of lives annually. Ironically, while hospitals are supposed to be designed to promote healing and well-being, they can be one of the most stressful of all built environments—they're often cold, sterile but also infectious, featureless, crowded, and noisy.

They same issues apply for other building types for health, well-being and even for education. In recent years, medical communities around the world have been incorporating a more salutogenic approach by re-emphasizing the vital importance a healthy and active lifestyle has on one's overall physical and psychological health. This move to a more preventative model is even seen in the World Health Organization's new definition of health: "a state of complete physical, mental, and social wellbeing and not merely the absence of disease or infirmity."

As salutogenesis became firmly embraced by physicians and healthcare professionals, the concept began also to multiply into the professions of architecture, design and engineering with increased predictive computational fluid dynamic simulations and in-situ post occupancy measuring with realtime sensor infrastructures.

In particular models and examples of cross-institutional education and research for salutogenic environments in sustainable human-building ecosystems, occupant behavior analysis, air quality and thermal comfort demand response, and energy saving behaviors for buildings in health and well-being are subject of some of the grant investigations presented at the ACSA Conference in Honolulu that includes research projects at FIU in Miami, in Freiburg, Germany and Goinioa, Brazil.

For example the FIU College of Medicine and FIU Nicole Wertheim College of Nursing & Health Sciences in Miami operate a "simulation center" to simulate, predict and train students from different disciplines in nursing, medicine, and partially also from computer science, engineering and architecture to gain insight of project integrated project delivery criteria for hospital and surgery room training, planning, analysis, and benchmarking. Other FIU related facilities include the Ambulatory Care Center (ACC) of the Miami Children's Hospital with its out-patient surgical center that collaborates with FIU researchers and students.

This paper will specifically display some specific Building Energy Reduction and Thermal Comfort work flows that have been performed by the author at a Brazilian Maternity Hospital in Goinioa, Brazil that was partly funded under the Energy and Climate Partnership of the Americas (ECPA) grant from 2013 to 2016.

Figure 1 below shows the typical criteria set and variables that were applied to perform a REVIT 360 insight sensor infrastructure to measure indoor and outdoor thermal comfort variables and indoor quality levels for the specific maternity hospital environments for three years to balance weather animolies.

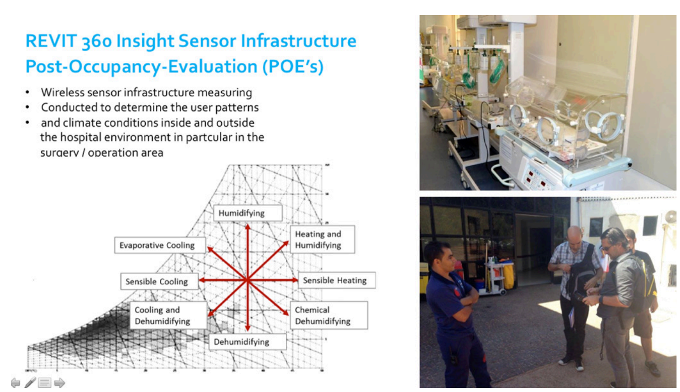


Figure 3: Excerpt of the Brazilian Maternity Hospital Research in Goinioa, Brazil of the Energy and Climate Partnership of the Americas (ECPA) grant. Source: Thomas Spiegelhalter, 2014.

Figure 2 View on a typical surgery environment with computational fluid dynamic test sequences with Autodesk CFD and Fusion 360 / Solid Works of controlled air and ventilation distribution avoiding the spread of pollutants, bacterias and other impacts. Source: Thomas Spiegelhalter, 2016.

02_COMPONENTS FOR POE'S AND CFD'S

In general, post-occupancy-analysis (POE) and sensor data recording within detailed in-situ analysis for salutogenic indoor and exterior environments consists of multiple components: sensor networks deployed in and outside of buildings that monitor and measure various parameters through self-learning and optimizing algorithms (Figure 2).

It includes air flows, air pressure, air quality, air and surface temperature, humidity, lighting, acoustics, energy/water demand, etc., that lead to efficiently operated and controlled dynamic models; Computational Fluid Dynamics (CFD) and parametric-algorithmic coded software components that allow human occupants to interact and provide feedback; and actuation outcomes that allow "control of building components". This includes also cooling, humidity, airflow and lighting sub-systems to optimize these controls in real-time via self-learning, genetic algorithmic optimizations (Figure 3).

Other variables and processes involve the following summarized components:

(a) Predicting internal variables and metrics for optimized coding for occupancy and user comfort preferences, and state variables as obtained from predictive dynamic models and rating systems;
(b) Extracting and then exploiting pattern repetition (daily, weekly, and yearly cycles in temperature, occupancy, usage, peak loads, etc.) for agent based selflearning algorithms that can dynamically predict behavioral patterns and peak loads; (c) Incorporating human, physiological, and psychological factors in the model, by obtaining and processing human-in-the-loop feedback effectively; (d) Forecasting of external variables, metrics such as energy, water pricing, energy, water demand, CO2 reduction and dynamic weather patterns, as can be determined from the smart grid, and validated by cloud-service operated real-time building automation with interactive and virtual dash boards and apps.

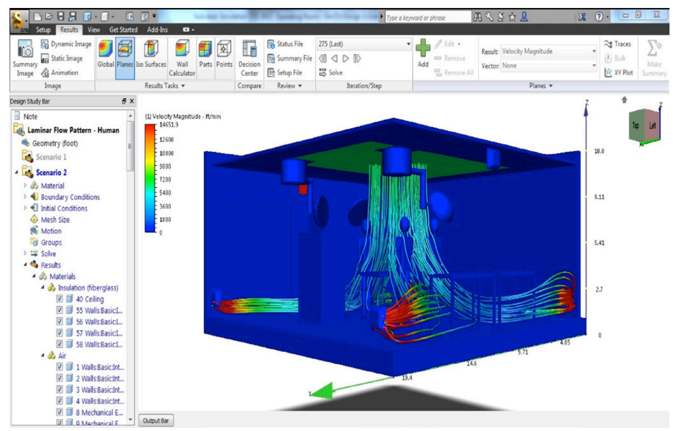


Figure 3: Excerpt of a typical Autodesk CFD testing and simulation sequence of optimised HVAC designs. Source: Autodesk CFD, 2015.

Furthermore, through the design of user-friendly human-machine interfaces, the creation of appropriate incentives for human participation and interaction with the environment, effective feedback collection and POE's, and integrated processing of sensory measurements (obtained from an in-building automated sensing network), the formentioned research projects aimed at providing "by-demand comfort level's" that are mediated by end-users through their personal communication apps. Another important component is Agent-Based (ABS) and Machine Learning as a real-time simulation and "what-if-scenario" method for modelling dynamic, adaptive, and behaviroral complex systems (Figure 4).

03_SALUTOGENIC DESIGN OF NEXT GENERATION BUILDINGS

This approach to include Agent-Based (ABS) and Machine Learning along with the traditional design work flows seems to significantly differ from the current academic courses, research and practices of modeling, controlling and optimizing health buildings energy sub-systems in isolation, and providing by-default comfort level everywhere in the building independent of occupancy level and demand level.

The unique aspect and project work flow and real time complexity includes course of actions by which multiple building users can

Agent-Based Design (ABS) and Machine Learning
is a simulation method for modelling dynamic, adaptive, and behavioral complex systems

Clash Detection
What-if-Scenarios

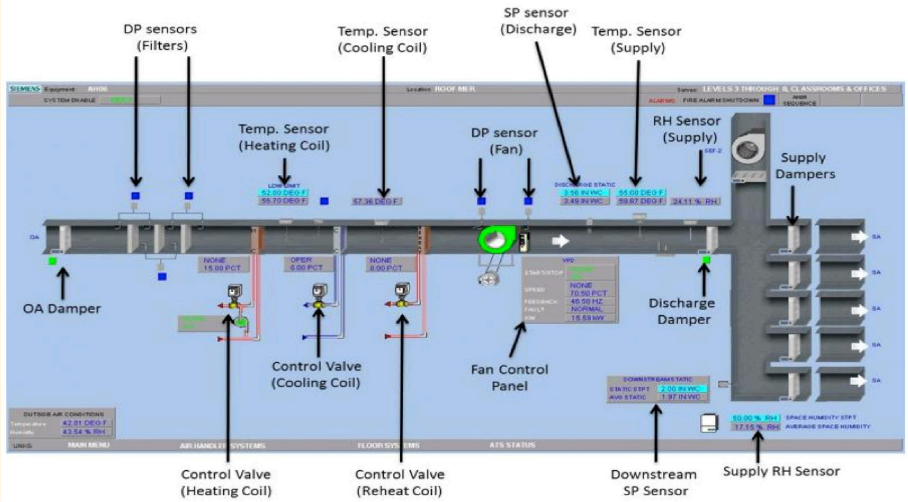
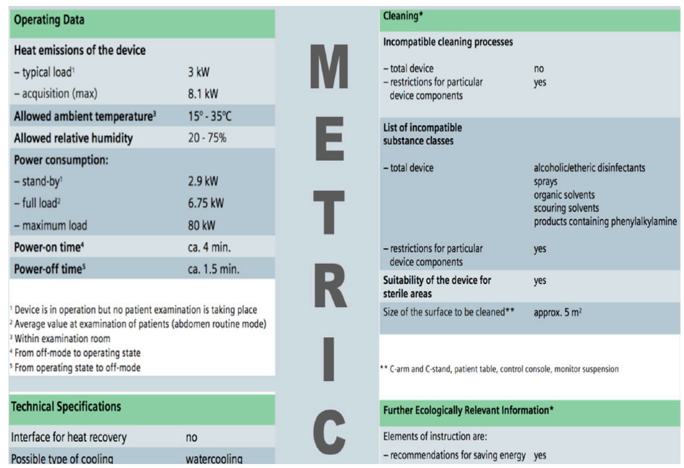


Figure 4: Excerpt of the Brazilian Maternity Hospital Research in Goinioa, Brazil of the Energy and Climate Partnership of the Americas (ECPA) grant. Source: Thomas Spiegelhalter, 2016.

participate in the Thermal Comfort and Air Quality and Energy Management process and allow the various control and actuation functions to efficiently meet their collective needs to develop a blueprint for a more sustainable, salutogenic design and operation of next-generation buildings.

Furthermore, through the design of user-friendly human-machine interfaces, the creation of appropriate incentives for human participation and interaction with the environment, effective feedback collection and POE's, and integrated processing of sensory measurements (obtained from an in-building automated sensing network), further research projects aims at providing a by-demand comfort level that is mediated by end-users through their personal communication apps (Figure 5).



Operating Data	
Heat emissions of the device	
– typical load[1]	3 kW
– acquisition (max)	8.1 kW
Allowed ambient temperature[3]	15° - 35°C
Allowed relative humidity	20 - 75%
Power consumption:	
– stand-by[1]	2.9 kW
– full load[2]	6.75 kW
– maximum load	80 kW
Power-on time[4]	ca. 4 min.
Power-off time[5]	ca. 1.5 min.

[1] Device is in operation but no patient examination is taking place
[2] Average value at examination of patients (abdomen routine mode)
[3] Within examination room
[4] From off-mode to operating state
[5] From operating state to off-mode

Technical Specifications	
Interface for heat recovery	no
Possible type of cooling	watercooling

METRIC

Cleaning*	
Incompatible cleaning processes	
– total device	no
– restrictions for particular device components	yes
List of incompatible substance classes	
– total device	alcoholic/etheric disinfectants sprays organic solvents scouring solvents products containing phenylalkylamine
– restrictions for particular device components	yes
Suitability of the device for sterile areas	yes
Size of the surface to be cleaned**	approx. 5 m^2

** C-arm and C-stand, patient table, control console, monitor suspension

Further Ecologically Relevant Information*	
Elements of instruction are:	
– recommendations for saving energy	yes

Figure 5: Excerpt of a typical semi and full automated End-User operating data and variable control, testing and simulation sequence of optimised HVAC designs. Source: Thomas Spiegelhalter, FIU Co-Director Structural and Environmental Technologies Lab, College of Architecture in Miami, 2016.

04_FURTHER WORK

It is obvious that the AEC community will use increased Automation, Machine Learning for healthy cities, regions, neighborhoods and buildings including large hospital HVAC / mechanical systems (Figure 4). Automation and Machine Learning with Design Agents will continue to help to optimize work flows and design protocols for more design and engineering efficient fault detection, fault prediction, thermal comfort, air quality and energy optimization, system modelling and system predictions that our human brain can't internalize and manage in the same required speed and complexity. It seems that the entire academia along with the AEC industry needs to catch up and retool their curricula and training methods to tackle the current literacy in designing and predicting healthy environments.

Today's and future Machine Learning Applications help to detect in seconds wide sets of input data with poorly defined or completely undefined interrelationships, small output data sets consisting of just one or a few numbers, noisy and/or irregular data samples that would prevent precise calculations of output, data sets that vary greatly from example to example, the availability of large blocks of real world input and output data pairs to be used for training. In summary, SIEMENS researchers predict that Artificial Intelligence (AI's) may analyze and prescribe in the future better treatment than doctors and architects designs or engineers plans for dynamically controlled and operated hospitals. A future that prompts academia to radically rethink and retool the curriculum and accreditation.