Energy Saving Room Scheduling System for Smart Hotels

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Group Project
Università degli Studi di Genova
Scuola Politecnica
Ambience Intelligence: Decision Taking Processes

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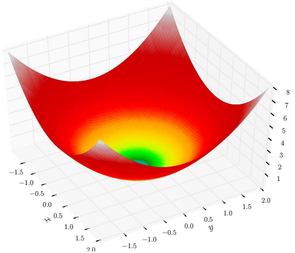
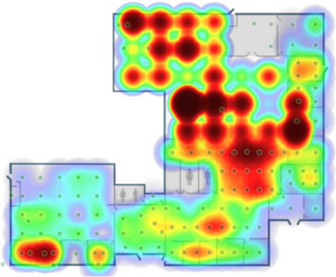
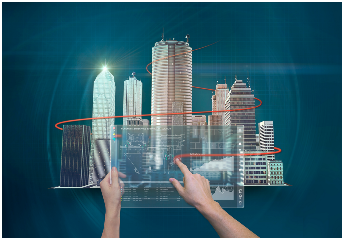
Outline

Outline

Introduction







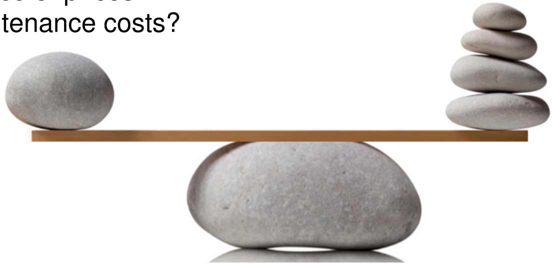
Objective

Scope of the topic

- Publications:
  - Elsevier: Energy Conversion and Management
  - Elsevier:Energy and Buildings
  - Elsevier: Data Processing: Automated hotel systems
  - IOS Press: Journal of Ambient Intelligence and Smart Environments
- Books:
  - Intelligent decisions
  - Smart environments
- Investment:
  - EU (27% - 2030)
  - Smart environments: Tip of the iceberg
- Robotics:
  - Domotic effects
  - Provider utility against local consumer management

Real Questions

- Questions:
  - Existing software?
  - How does it work?
  - Any rejections?
  - Room assignment?
  - Any optimisation used before?
  - How to estimate your demand?
  - Choice of prices?
  - Maintenance costs?



Real Answers: Genova

- Estimation of demand?
  - Not generally
  - Prefer external analysis
- Room assignment?
  - Random
  - Based on client assignment
- Optimisation ever used?
  - A few aware of profit optimisation
  - Absolutly no energy involvement

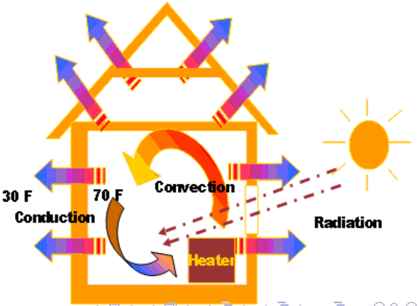
Outline

Basic principle up to the first order

$$q_{tot_t} = \Sigma q_{k_t} + \Sigma q_{h_t} + \Sigma q_{vent_t} + \Sigma q_{sun_t} + q_{pump_t}$$
$$q_{tot_t} = \rho V c_p \frac{dT}{dt} \tag{1}$$

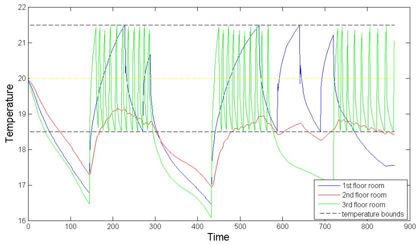
1. Blueprint approach
2. Parameter identification (reality or simulation)

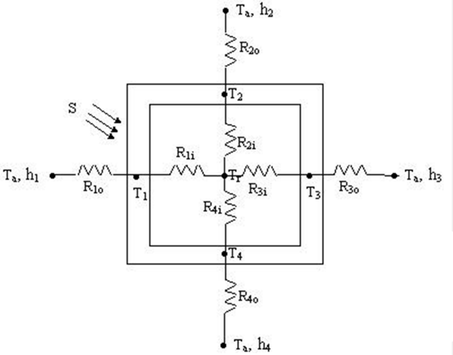
- Norm: UNI/TS 11300 (20±2 °C)



Blueprint: Generality

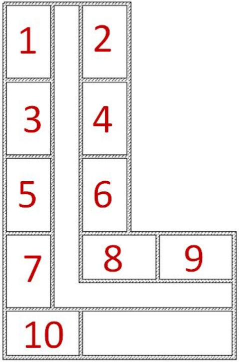
- Parameters: Dimensional characteristics and thermal characteristics



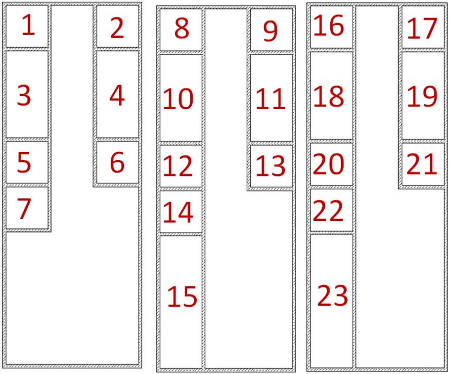


- Control proposal: ON-OFF Controller
- Adjacency proposal: Lumped parameter

Blueprints proposed



Hotel 1

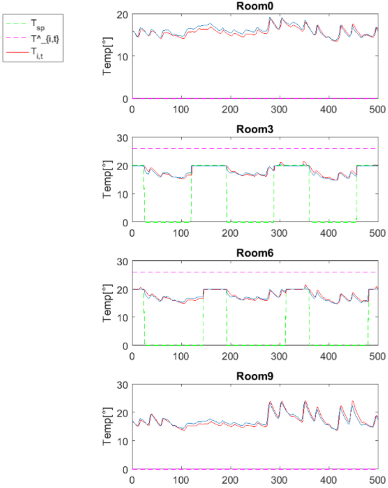


Hotel 2

Parameter Identification

$$
\hat{T}_{i,t+1} = \frac{1}{c_i}\left[\sum_{i\sim j \bigcup e} (\hat{T}_{i,t} - \hat{T}_{j,t}) + K_u u_{i,t} + q^S_{i,t} + \hat{T}_{i,t}\right] + S_p
$$
$$
u_{i,t} = u_{i,t-1} + K_{u,i}(e_{i,t} - e_{i,t-1})
$$
$$
e_{i,t} = T_{sp,t} - T_{i,t}
$$
$$
\forall i \mid 0 = 1 \ldots n_r
$$
$$
\forall t \mid t = 1 \ldots P \tag{2}
$$

$$
\begin{aligned}
\theta^* = \arg\min_{\theta \in \mathbb{R}} \quad & (T_{i,t} - \hat{T}_{i,t})^2 \\
\text{s.t.} \quad & \theta \geq 0 \\
& S_p = 0
\end{aligned} \tag{3}
$$



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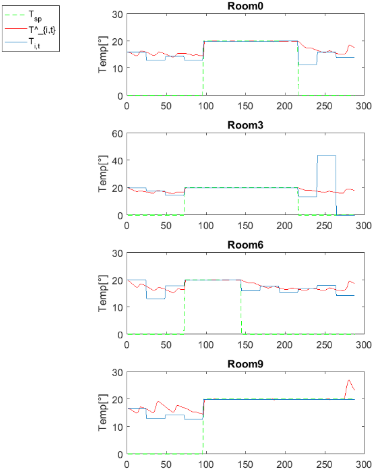
Rooms Assignment Problem

$$Y^* = \max_{x_{d,r}} \sum_{d\in D}\sum_{r\in R_d} Y_{d,r}x_{d,r}$$
$$\text{s.t.} \quad \sum_{r\in R_{dn}} x_{d,r} = 1 \ \forall d \in D$$
$$x_{d,r} + x_{k,r} \leq 1 \ \forall d \in D, \forall k \in D_a \text{ and } \forall r \in R_d \cap R_k$$

GUROBI OPTIMIZATION

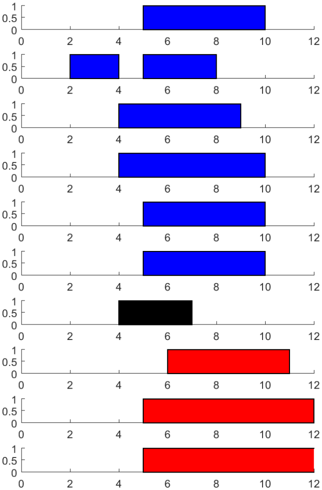
TABLE: Levels of daily profits used as a marketing strategy $Y_{d,r}$

Request	Room type: Low	Medium	High
Low	9	7	2
Medium	0	22	17
High	0	0	72



Energy optimisation problem

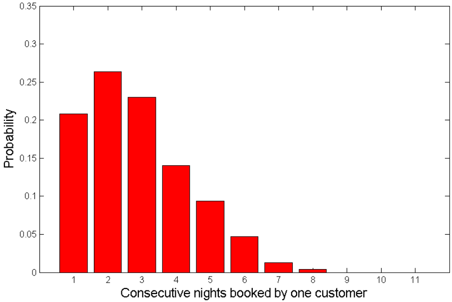
$$
\begin{aligned}
E^* = \min_{x_{d,r}} \quad & \textstyle\sum_{t\in T} \sum_{i\in R} u_{i,t} \\
\text{s.t.} \quad & \textstyle\sum_{r\in R_{dn}} x_{d,r} = 1 \ \forall d \in D \\
& x_{d,r} + x_{k,r} \leq 1 \ \forall d \in D, \forall k \in D_d \\
& \text{ and } \forall r \in R_d \cap R_k \\
& z_{i,t} = \textstyle\sum_{\substack{d\in D \\ t_d^{in} \leq t \leq t_d^{out}}} x_{d,r} \ \forall r \in R, \\
& \forall t \in T_1 \\
& \hat{T}_{i,t+1} = \tfrac{1}{c_i}(\textstyle\sum_{i\sim j \bigcup e}(\hat{T}_{i,t} - \hat{T}_{j,t}) \\
& \qquad + K_u u_{i,t} + q_{i,t}^S + \hat{T}_{i,t}) \\
& T_{i,1} = \hat{T}_{i,1} \\
& u_{i,t} \geq 0 \\
& u_{i,t} \geq (T_{sp} - T_{i,t}) - M(1 - z_{i,t}) \\
& z_{j,t} \geq z_{j,t} \geq 1 - M(1 - z_{k,t}) \ \forall j \in R_s \text{ a} \\
& Y_t \geq Y^*
\end{aligned} \tag{4}
$$



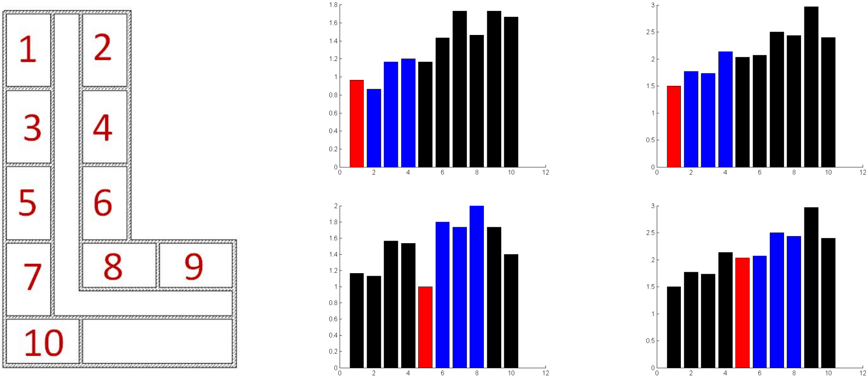
Outline

Instances generation

- Demand:
  - 30%
  - 50%
  - 65%
- Types of rooms:
  - High:10%
  - Medium:30%
  - Basic:60%
- 10 instances used:
  - Revenue optimisation
  - 5: Equivalent revenue solutions
  - 1: Energy consumption minimisation
- Time horizon: 14 days
- Figure of merit: RPD



Hotel 1: Final occupancy

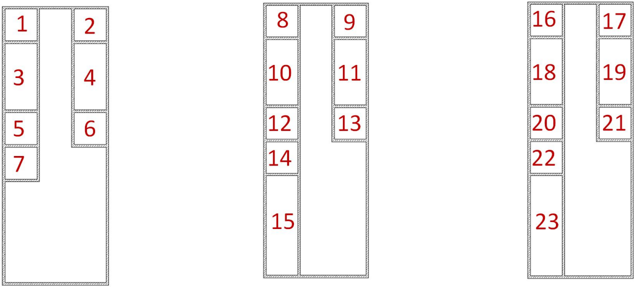


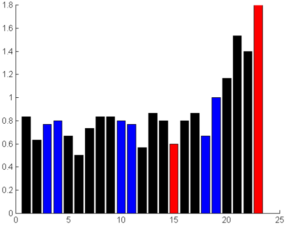
High

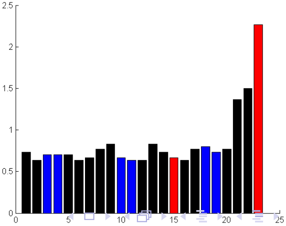
Medium

Basic

Hotel 2: Final occupancy







RPD and Conclusions

TABLE: Relative percentage difference (RPD)

	30%	50%	65%
Hotel 1.1	5.2	6.7	5.6
Hotel 1.2	2.9	9.5	5.2
Hotel 2.1	2.7	1.5	1.7

- Energy optimisation:
  - Biased to maximal revenue
  - Clustering growing solutions in time prefered
- Savings:
  - Structural dependence
  - Orientation to the sun
- Proposal:
  - High level rooms in warmest locations

THANK YOU FOR YOUR ATTENTION