Learning partial correlation graph for multivariate sensor data and detecting sensor communities in smart buildings

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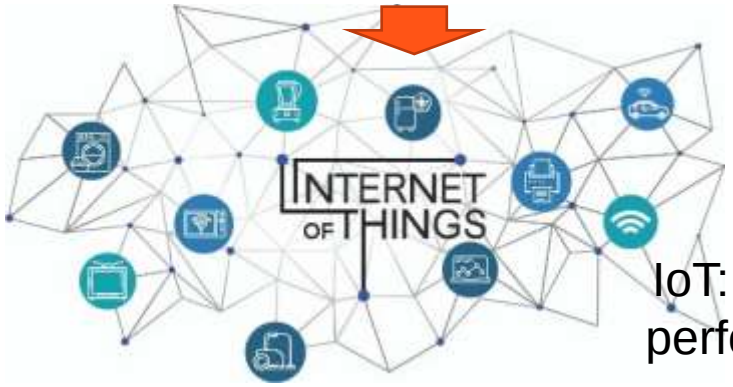
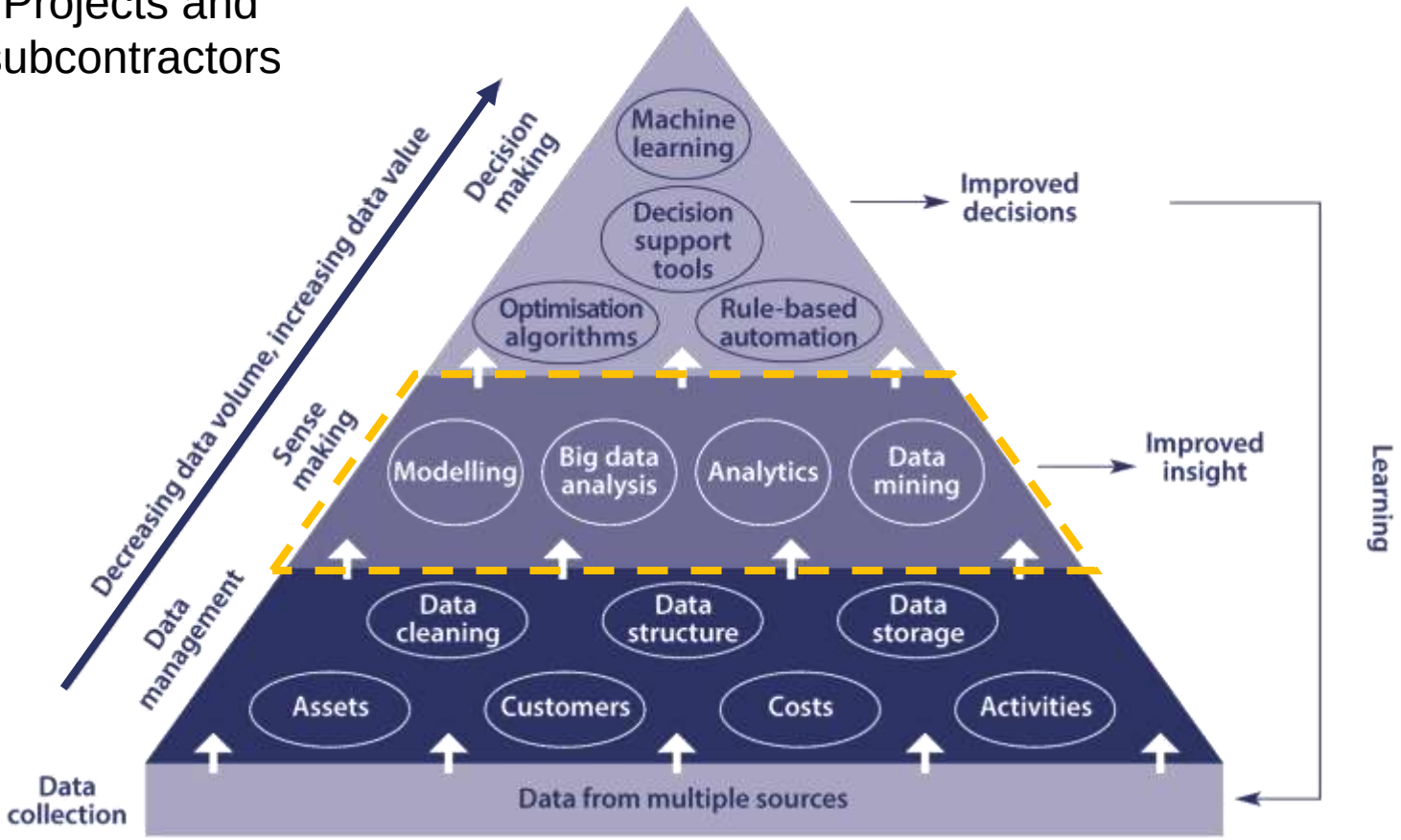
Data for modern buildings

Projects and subcontractors

BIM / COBie: geometry, systems, materials

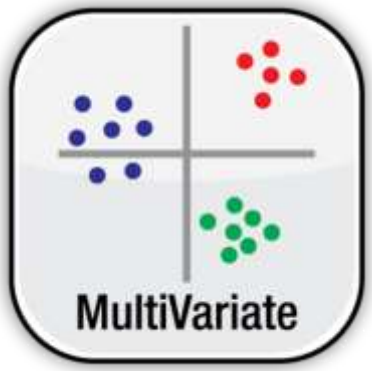


IoT: building performance

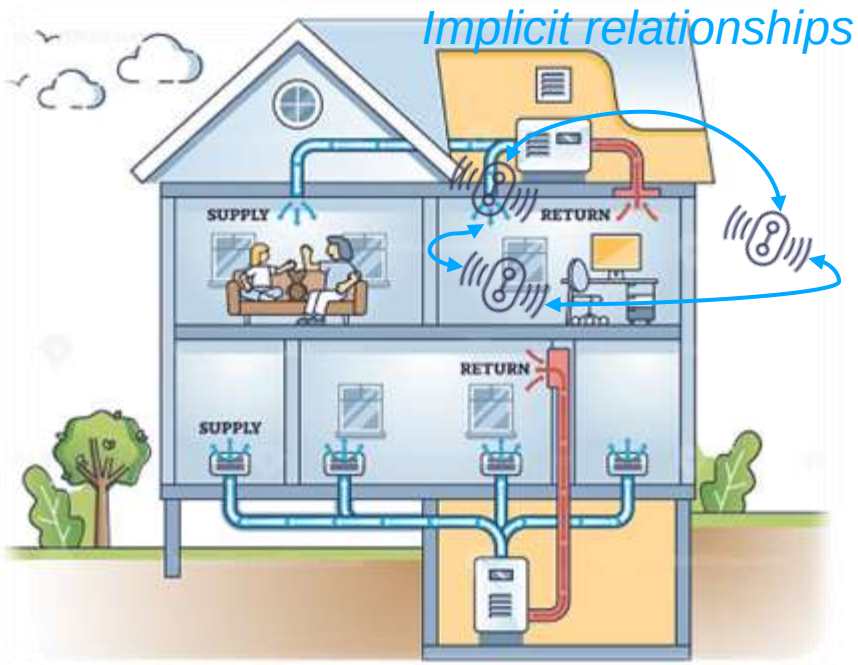


Data-Information-Knowledge-Wisdom Pyramid

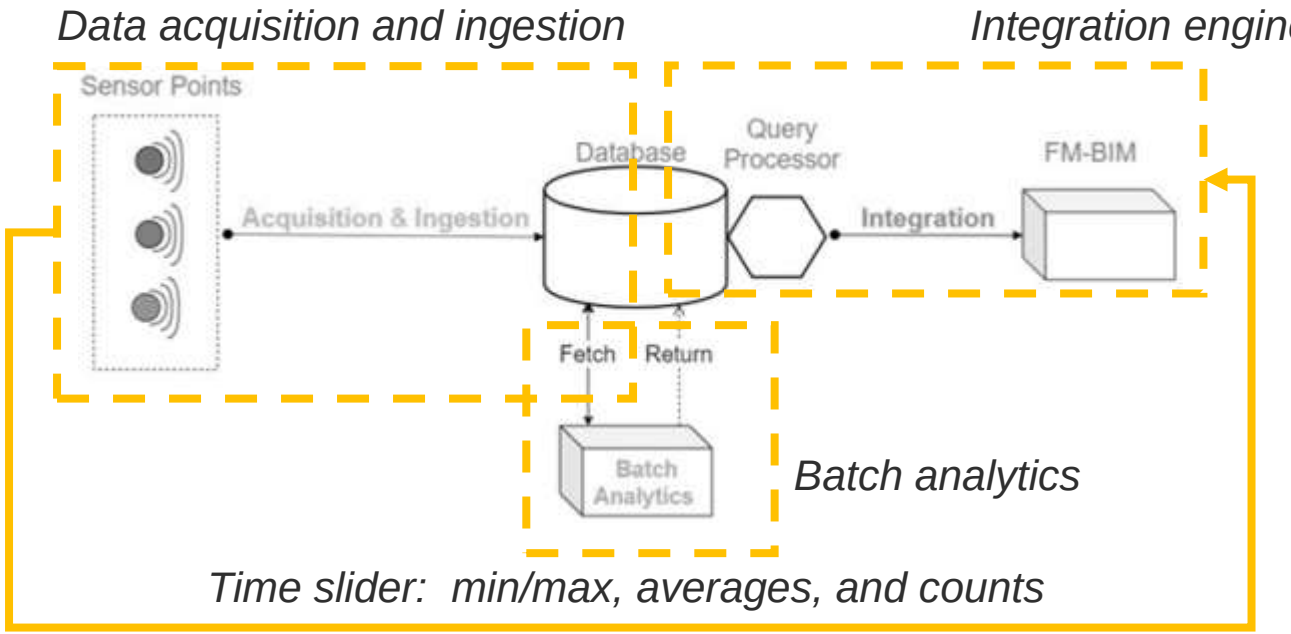
Reveal implicit relationships in time-series

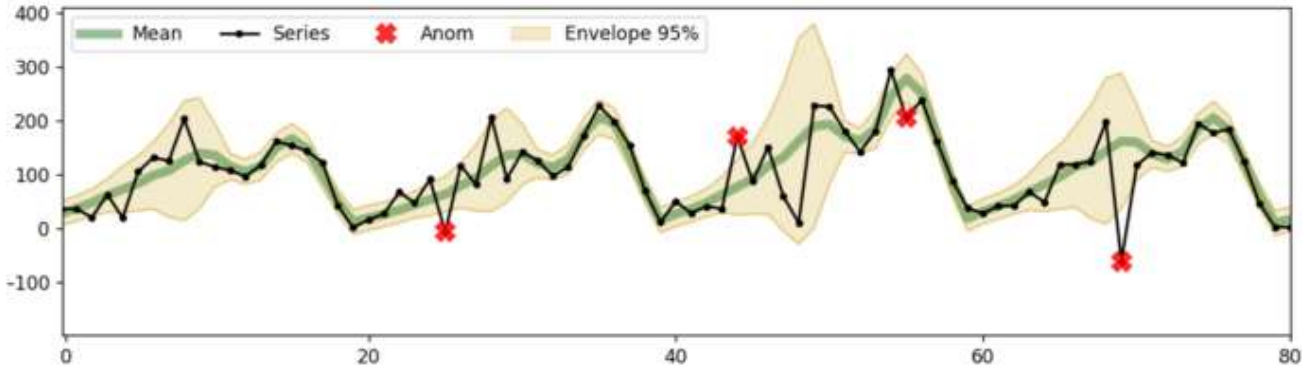


IoT sensors



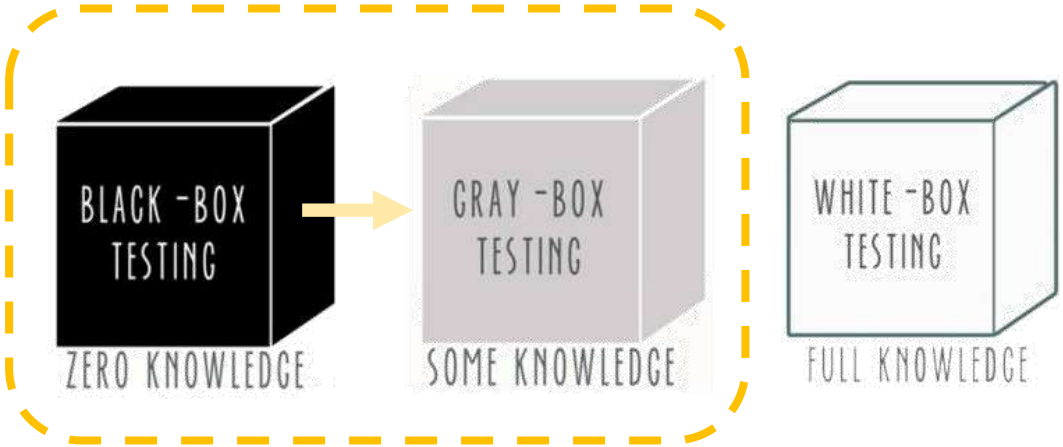
Linked data approach (FM-BIM)*





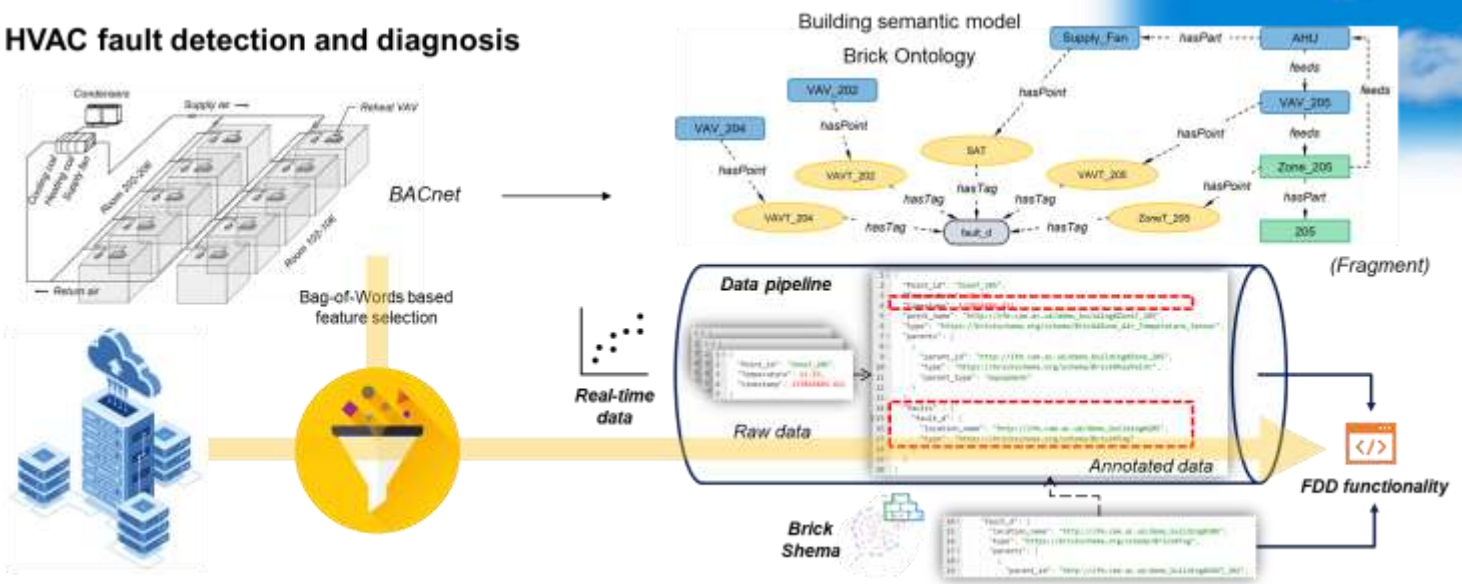
*Quinn, C., Shabestari, A.Z., Misic, T., Gilani, S., Litoiu, M. and McArthur, J.J., 2020. Building automation system-BIM integration using a linked data structure. Automation in Construction, 118, p.103257.

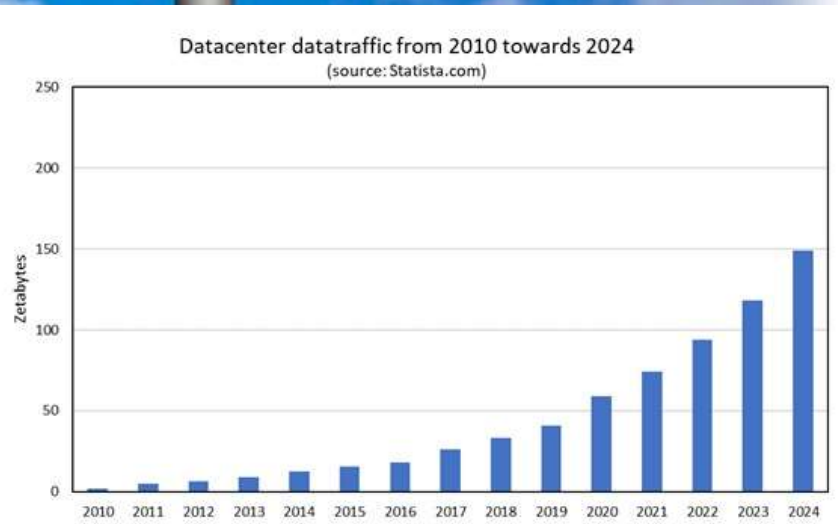
Turn Left or Right



Task specific*

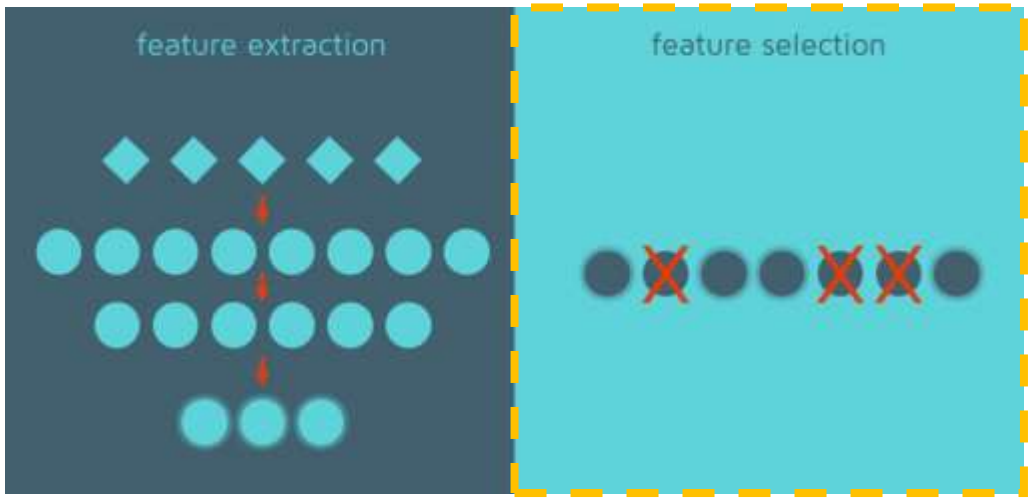
HVAC fault detection and diagnosis





*Xie, X., Merino, J., Moretti, N., Pauwels, P., Chang, J.Y. and Parlikad, A., 2023. Digital twin enabled fault detection and diagnosis process for building HVAC systems. Automation in Construction, 146, p.104695.

Sparse modelling of multivariate data



Principal Component Analysis (PCA)

Multidimensional scaling (MDS)

Isometric Mapping (ISOMAP)

Filter methods

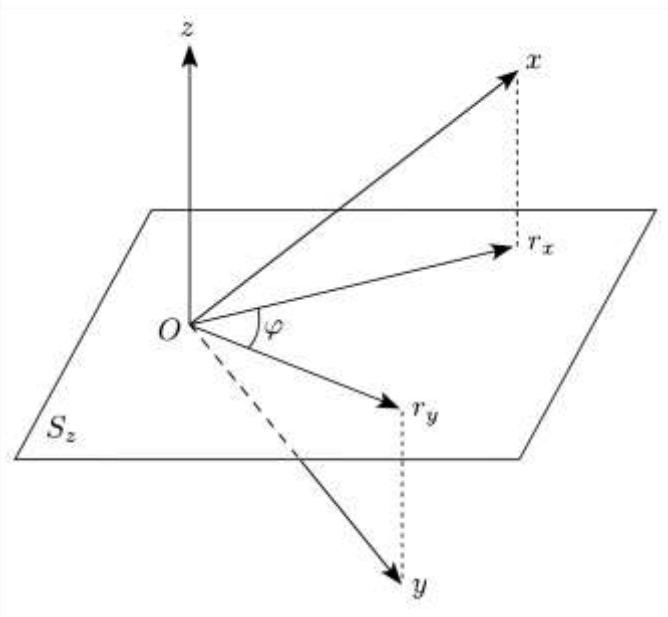
Pearson correlation coefficient

Fisher score

Mutual information

Wrapper methods

Embedded methods



Partial correlation

Geometrical interpretation of partial correlation for the case of N = 3 observations

The spurious correlation can be eliminated where only the "unbiased relationship" of *x* and *y* remains.

Sparse PArtial Correlation Estimation (SPACE) method

$$\boldsymbol{x}_n = a_1\boldsymbol{x}_1 + \cdots + a_{n-1}\boldsymbol{x}_{n-1} + a_{n+1}\boldsymbol{x}_{n+1} + \cdots + a_N\boldsymbol{x}_N \quad \min\|a_i\|_0$$

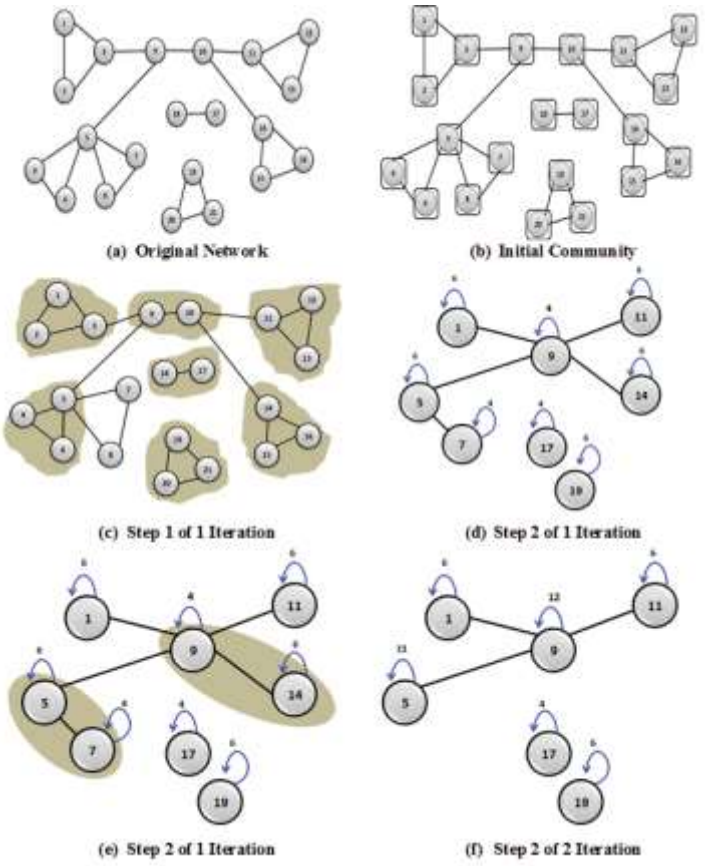
$$L(\boldsymbol{P},\Theta) = \frac{1}{2}\sum_{i=1}^{p}\|\boldsymbol{x}_i - \sum_{j\neq i}^{p}\boldsymbol{P}_{ij}\sqrt{\frac{\boldsymbol{\Theta}_{jj}}{\boldsymbol{\Theta}_{ii}}}\boldsymbol{x}_j\|_2^2 + \lambda\sum_{1\leq i<j\leq p}|\boldsymbol{P}_{ij}|$$

$$\boldsymbol{P}_{ij} = -\frac{\boldsymbol{\Theta}_{ij}}{\sqrt{\boldsymbol{\Theta}_{ii}\boldsymbol{\Theta}_{jj}}}$$

J. Peng, P. Wang, N. Zhou, J. Zhu, Partial correlation estimation by joint sparse regression models, Journal of the American Statistical Association 104 (2009) 735–746.

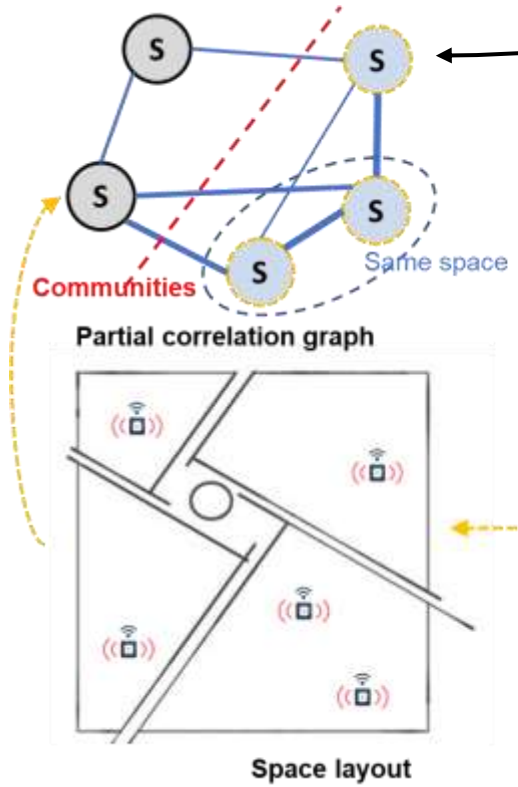
Partial correlation graph

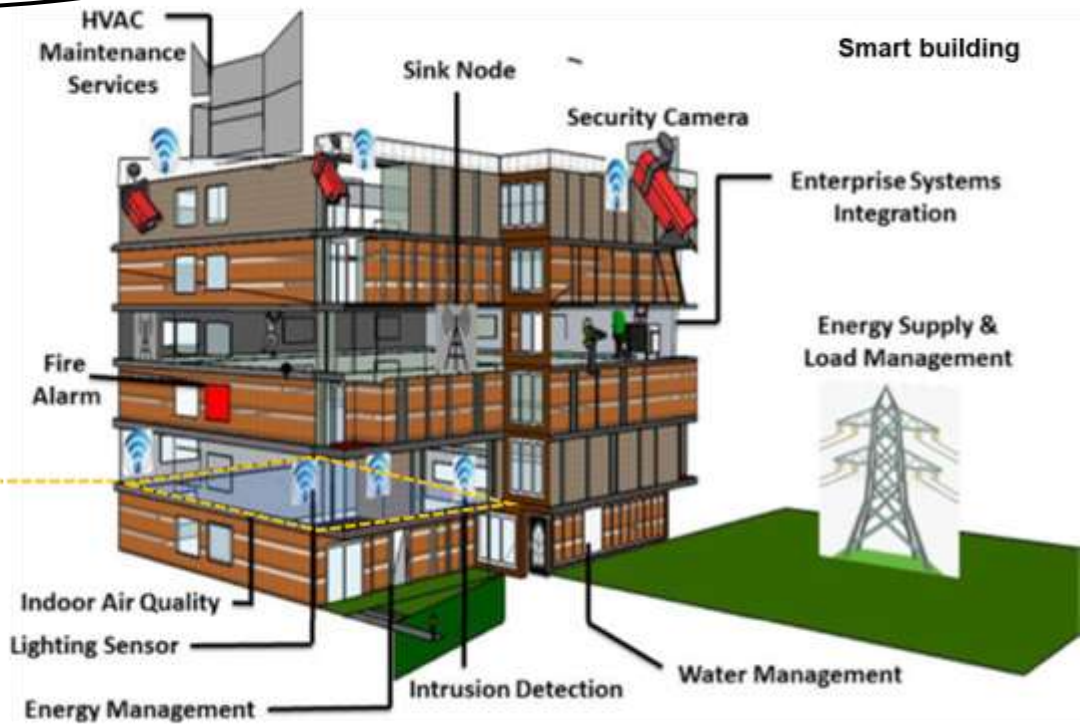
Community detection



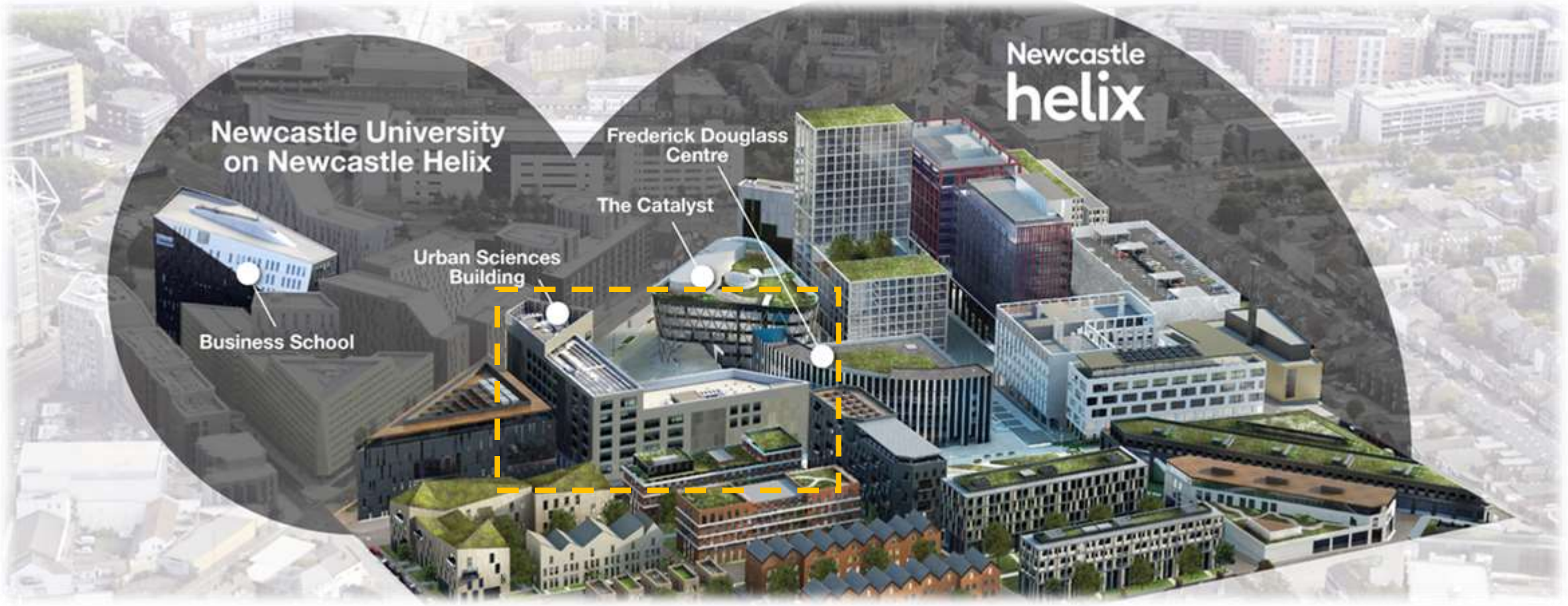
Louvain algorithm: find the communities of well-connected nodes

This is the piece of information that is not available from physical knowledge.



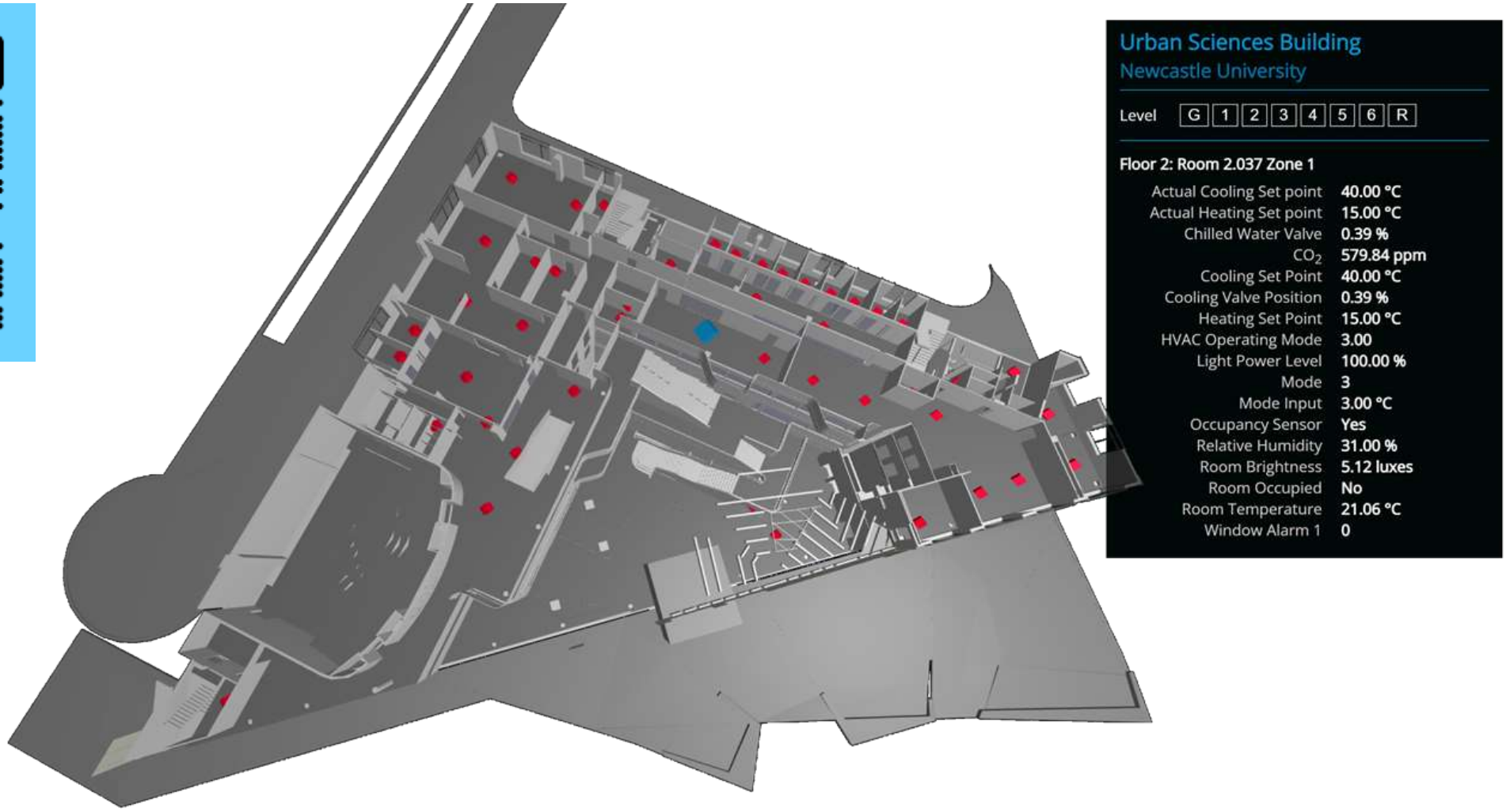


Case study


Newcastle University on Newcastle Helix
Business School
Urban Sciences Building
The Catalyst
Frederick Douglass Centre
Newcastle
helix

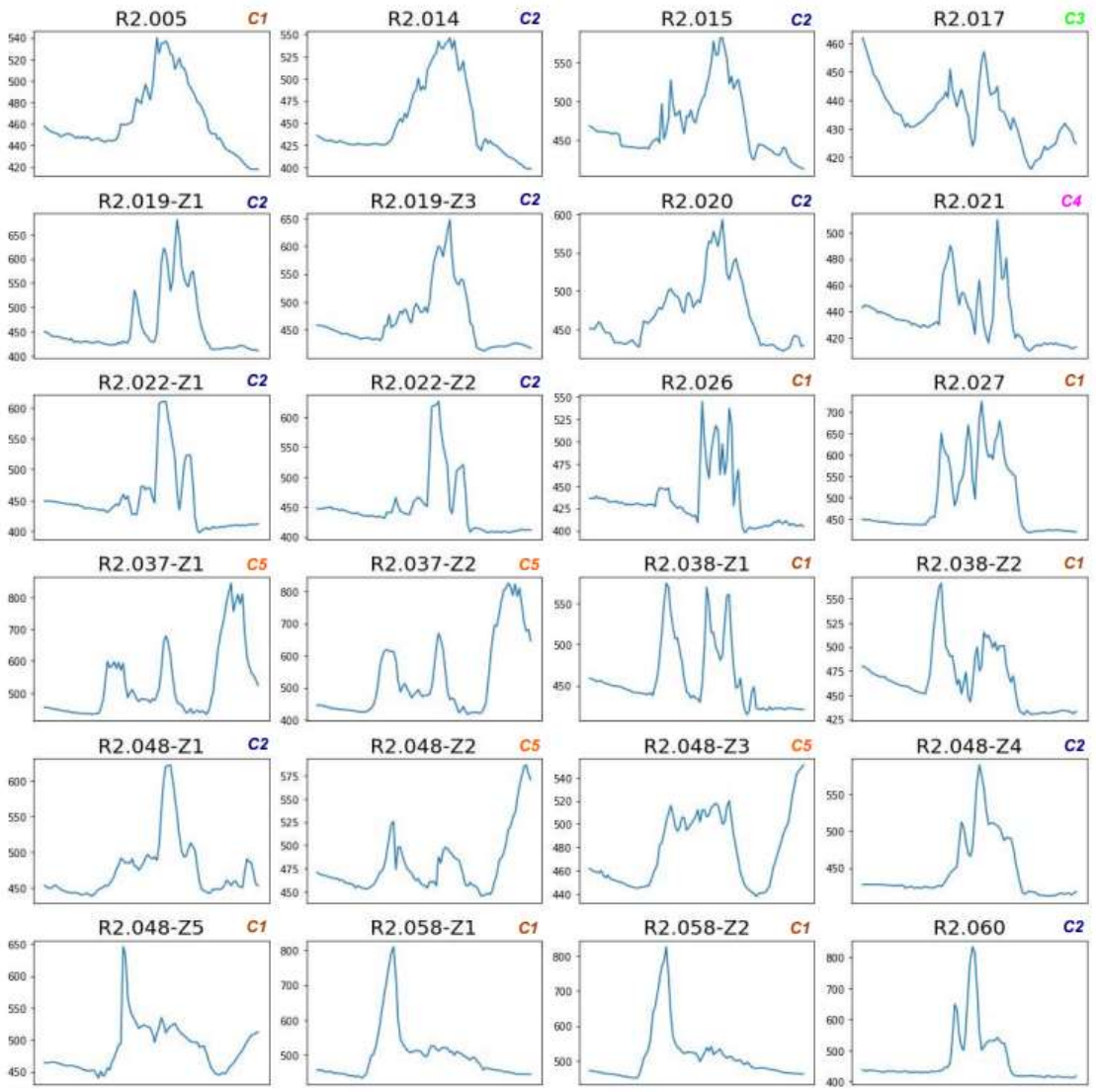
Case study

Case study

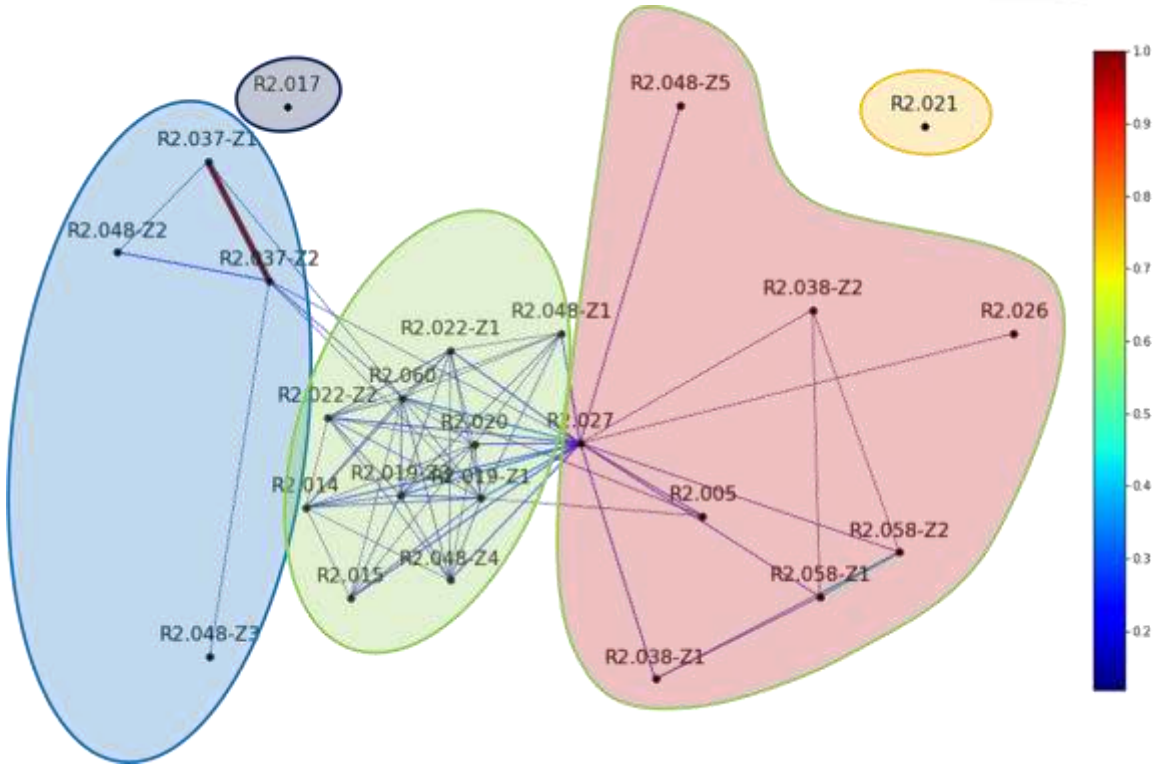


urban observatory newcastle

Case study



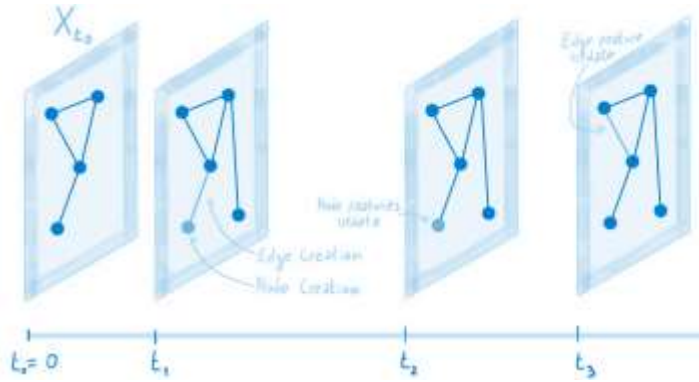
Carbon dioxide concentrations measured by 24 sensors on the 2nd floor of the USB



A question that remains

Multivariate time series

Temporal graph learning



Knowledge

BIM

Facility management decision making