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***PREDICTION OF HEATING ENERGY CONSUMPTION IN
UNIVERSITY BUILDINGS BASED ON ARTIFICIAL NEURAL
NETWORKS***

Radiša Ž. Jovanović

Aleksandra A. Sretenović

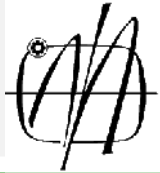
Branislav D. Živković

***University of Belgrade, Faculty of Mechanical Engineering
Kraljice Marije 16, Belgrade, Serbia***



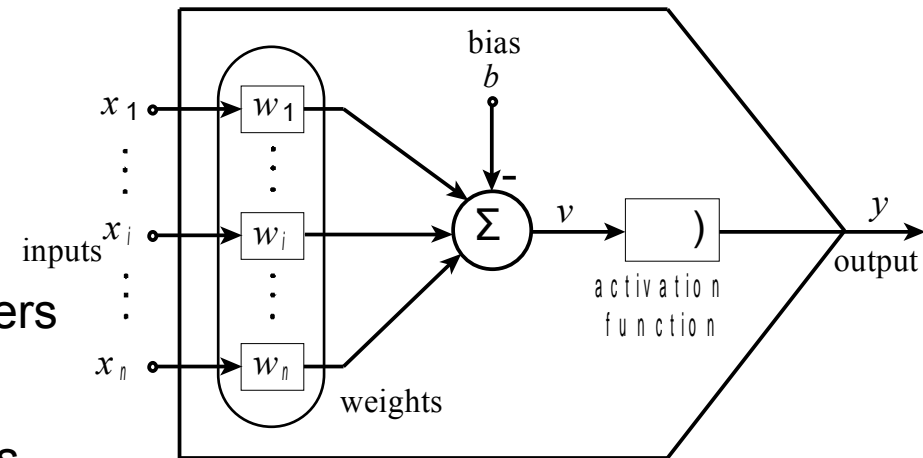
INTRODUCTION

- In Europe, buildings account for 40% of total energy use and 36% of total CO₂ emission
- University campuses provide an excellent testbed to characterize and understand energy consumption of group of „mixed use“ buildings
- Classic (forward) approach vs Data-driven (inverse modelling)
- “You cannot improve what you cannot measure”

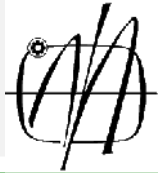


ARTIFICIAL NEURAL NETWORK (ANN)

- Widely used for a range of applications in different engineering areas: industry processes, digital signal processing, robotics, speech recognition, controls, medical engineering, energy modeling
- Usually arranged in one input layer, one output layer and one or more hidden layers
- ANNs learn from key information patterns allowing discovering complex relationships between the variables.
- No clear relationship between the input variable and output needs to be defined before the model is used in the prediction process

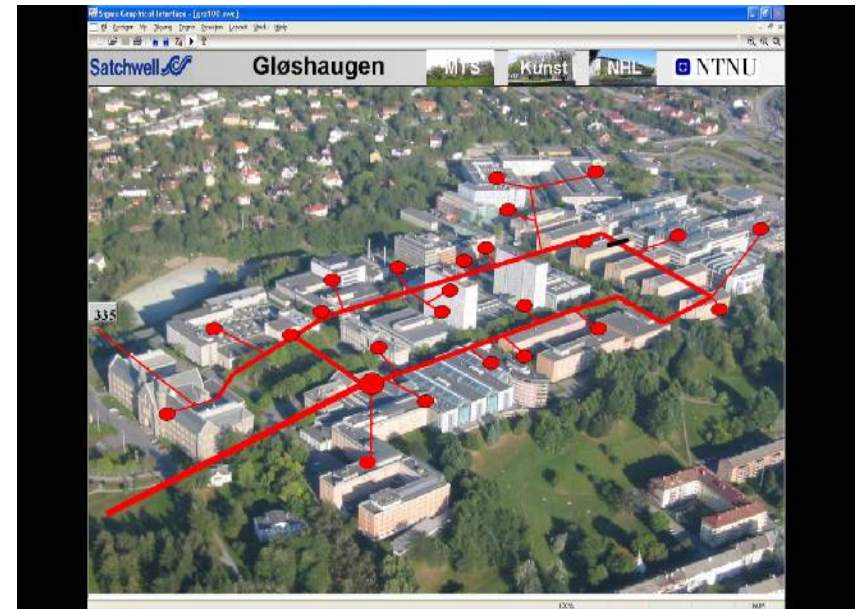


Model of neuron

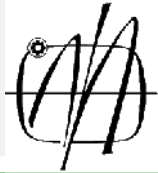


NTNU campus Gløshaugen

- NTNU campus Gløshaugen consists of 35 buildings, with total area of approximately 300,000 m²
- Building types: office, educational, laboratory workshop and sport facilities
- Building and Energy Management System (BEMS) and web-based Energy Monitoring System (Energy Remote Monitoring – ERM) are available
- Hourly heating and electricity consumption can be collected on ERM

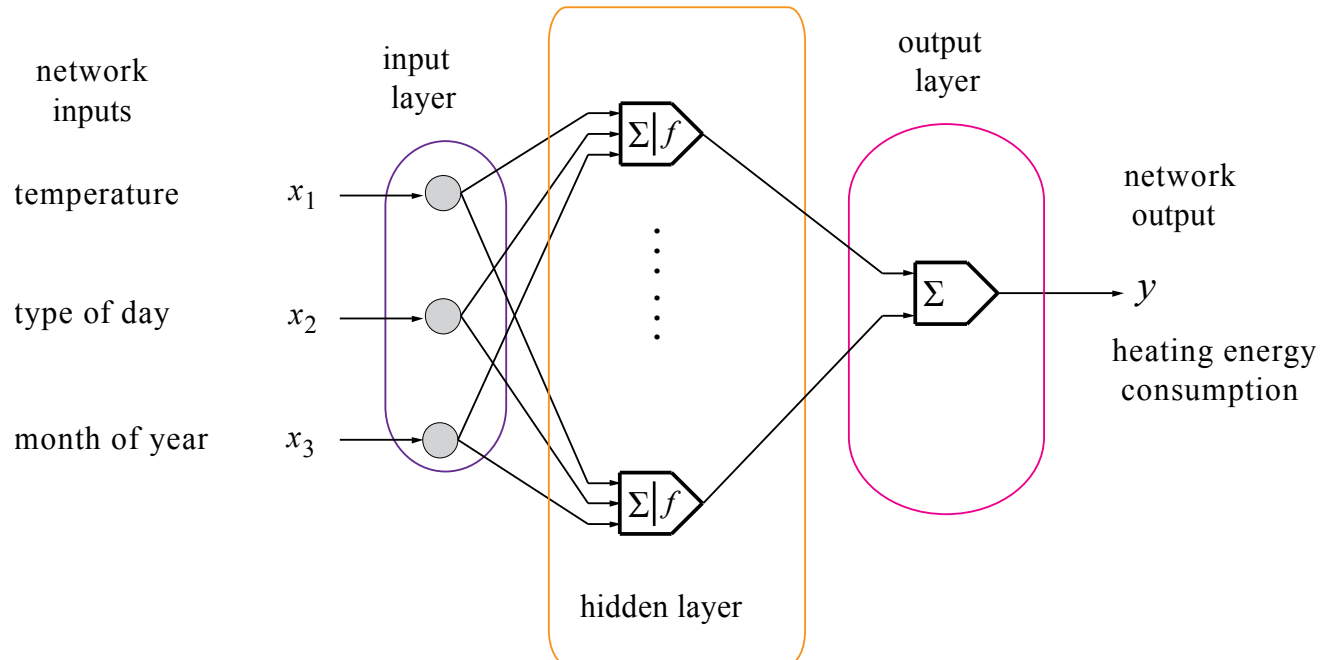


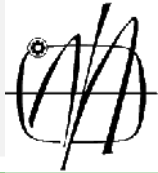
District heating net in NTNU campus Gløshaugen



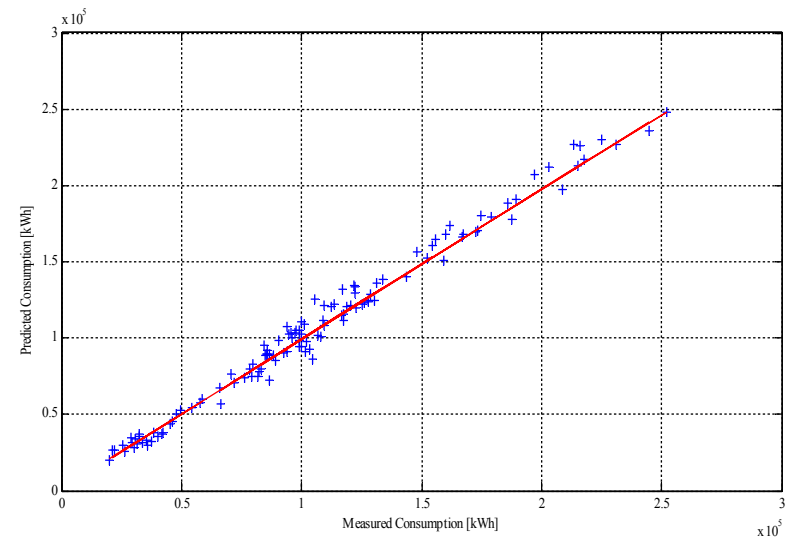
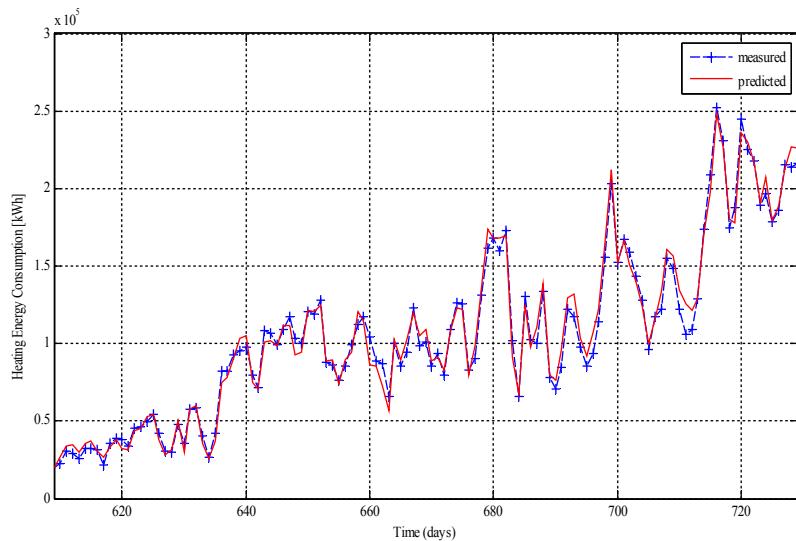
ANN Model

- Heating energy consumption of the University campus has been analyzed (Main meter installed by district heating supplier).
- The ANN model is a three-layer feedforward neural network composed of one input layer, one output layer and one hidden layer



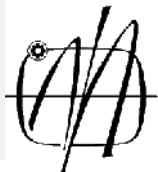


Training Results

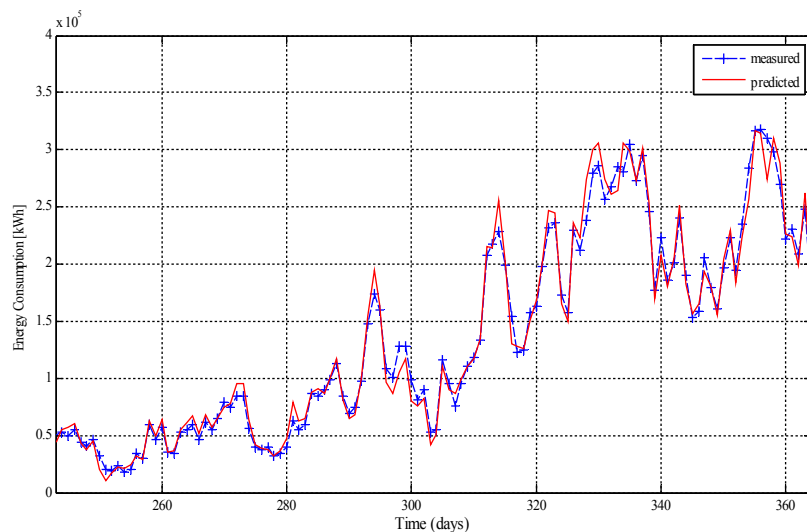


*Measured and predicted values for
September to December 2009: training
results*

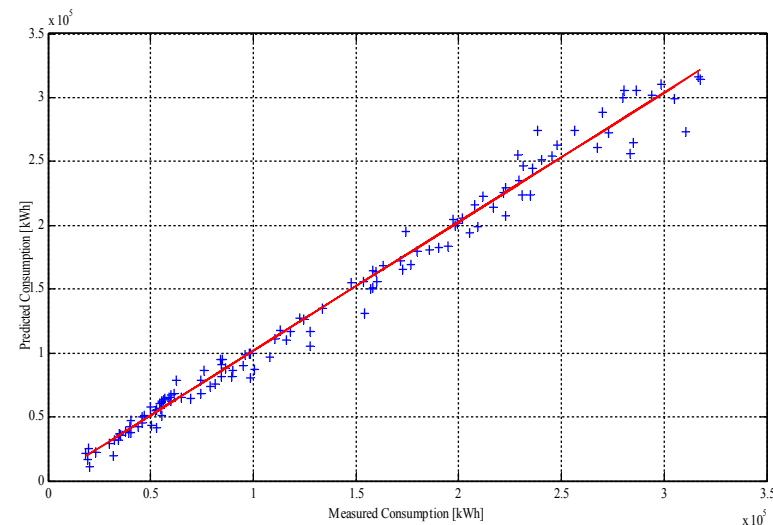
ANN model training results



Test Results

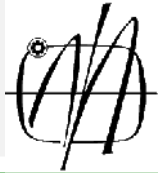


Measured and predicted values for September to December 2010: test results



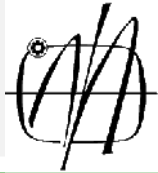
ANN model testing results

Year/period	R2 [-]	RMSE [kWh]	CV [-]	MAPE [-]
2008-2009; training period	0.9840	7 908	0,0886	10.92
2010; testing period	0.9864	10. 54	0.0926	11.17



CONCLUSION

- Simplified neural network model for heating energy consumption for University campus Gløshaugen was trained based on daily data for 2008 and 2009 and tested for the year 2010.
- ANN is a very effective method for this type of predictions
- Once an accurate ANN model is developed, engineers can easily apply this method to predict and evaluate building heating energy consumption without detailed knowledge of the ANN method, while using minimum data input (mean daily temperature).



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