Applying ANN technology to determine acceptable microclimate parameters for the National Library of Scotland's Collections to inform energy efficiency improvements in the UK Heritage Sector

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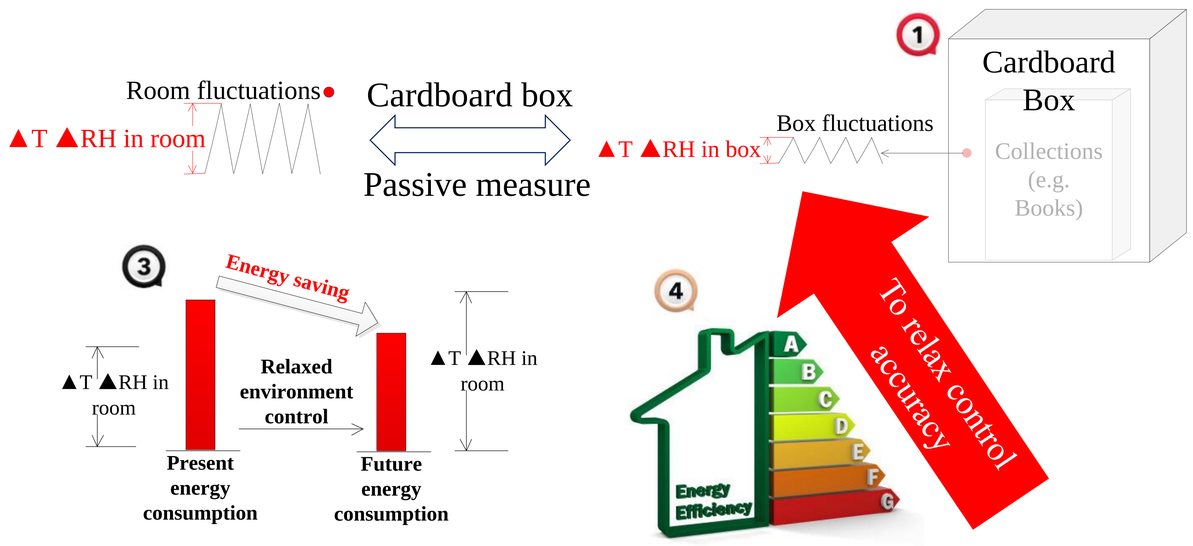
Introduction

To improve energy efficiency in maintaining stable temperature and relative humidity (RH) for safeguarding the heritage collections

The question for the logic of energy efficiency:
How can we improve the efficiency without any detrimental effect for the collections?



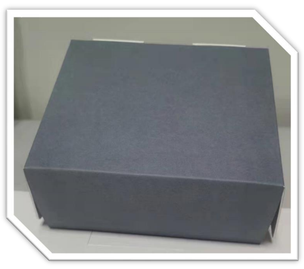
Methods

We trained the ANN model using the data generated from heat air and moisture (HAM) transfer simulation. The HAM model was based on a hygrothermal property test of the carboard material and microclimate data for model creating and calibration.

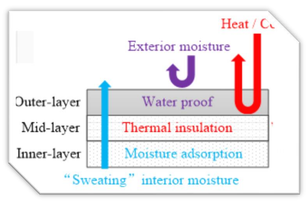
Step 1

Conduct experimental tests to prepare data for modeling

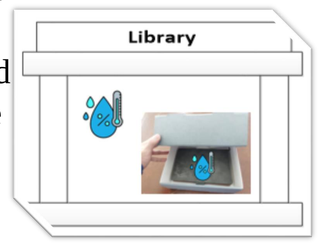
A general storage box (230x180x80mm with 1.15mm thickness) was tested.



The hygrothermal property parameters were tested. i.e., water vapor permeability, equilibrium moisture content, and so on.



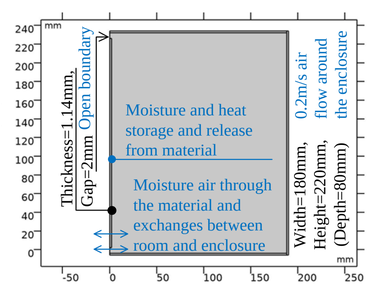
The microclimate data of the storage room and box were collected in various temperature and RH fluctuations.

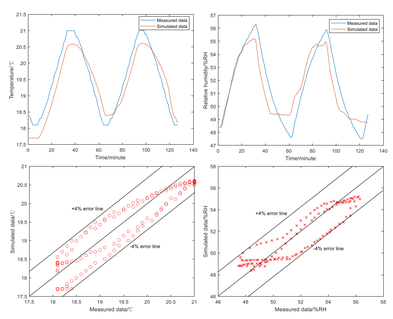


Step 2

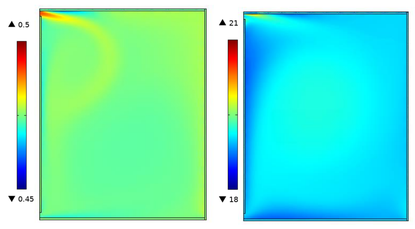
Create HAM simulation model to map the room and box environment

The test data was used to create and calibrate the HAM model.





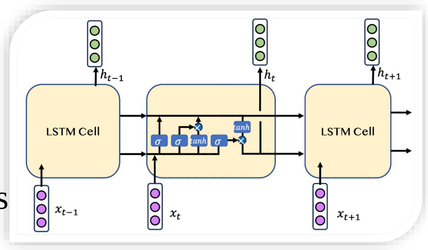
This model was used to generate data in various of room temperature and RH fluctuations.



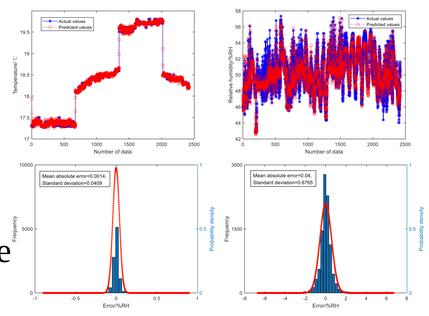
Step 3

Train an ANN model as the agent of HAM simulation for real-time prediction

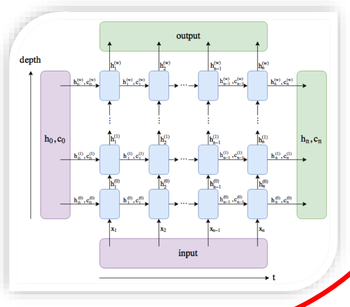
The Long Short Term Memory neural network was used to train the data which was input (Room data) and output (box data) from the HAM simulation.



The time-series data relationship between room and box was remembered by the ANN.



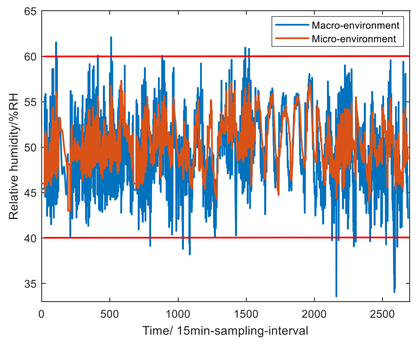
The room temperature and RH with relaxed control can be input and then corresponding box ones were output.



Findings

The tight control, ±5℃ and ±10%RH can be relaxed to ±5℃ and ±16%RH without any detrimental effect inside the box.

Because there is a coupled relationship between temperature and RH, the temperature control focuses on maintain a desirable RH.



The energy consumption can be saved 1.2% and 1.5% when the tight control was relaxed from ±5%RH to ±10%RH and ±16%RH, respectively.

24h simulation for a ~100m^2 storage room in Edinburgh
Outdoor temperature: 20.3~25.5℃
Outdoor RH: 65%~90%RH

The energy-saving potential is limited by the stable weather in Edinburgh.

The room environment without air conditioning can achieve ±10%RH fluctuation for most of time, there is not big difference between case 2 and 3.