Herrick Laboratories PURDUE UNIVERSITY

NANYANG TECHNOLOGICAL UNIVERSITY
School of Electrical & Electronic Engineering

2016 Purdue Conferences
Compressor Engineering
Refrigeration and Air Conditioning
High Performance Buildings

A Non-iterative Balancing Method for HVAC Duct system

Cai Wenjian

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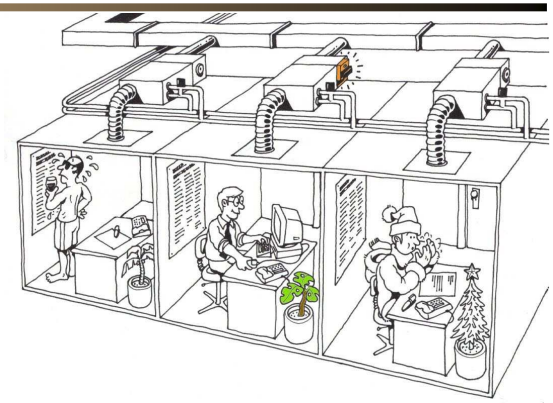
Center for High Performance Buildings at Purdue

Air balancing



- Duct system distributes airflow to each zone. Control of airflow by dampers is complicated and tightly coupled.
- If not well-balanced, lack of ventilation leads to sick-building syndrome while over-ventilation is a waste of energy.
- Air balancing is needed to supply proper ventilation rate to each room and achieve accurate airflow distribution.

Existing Methods

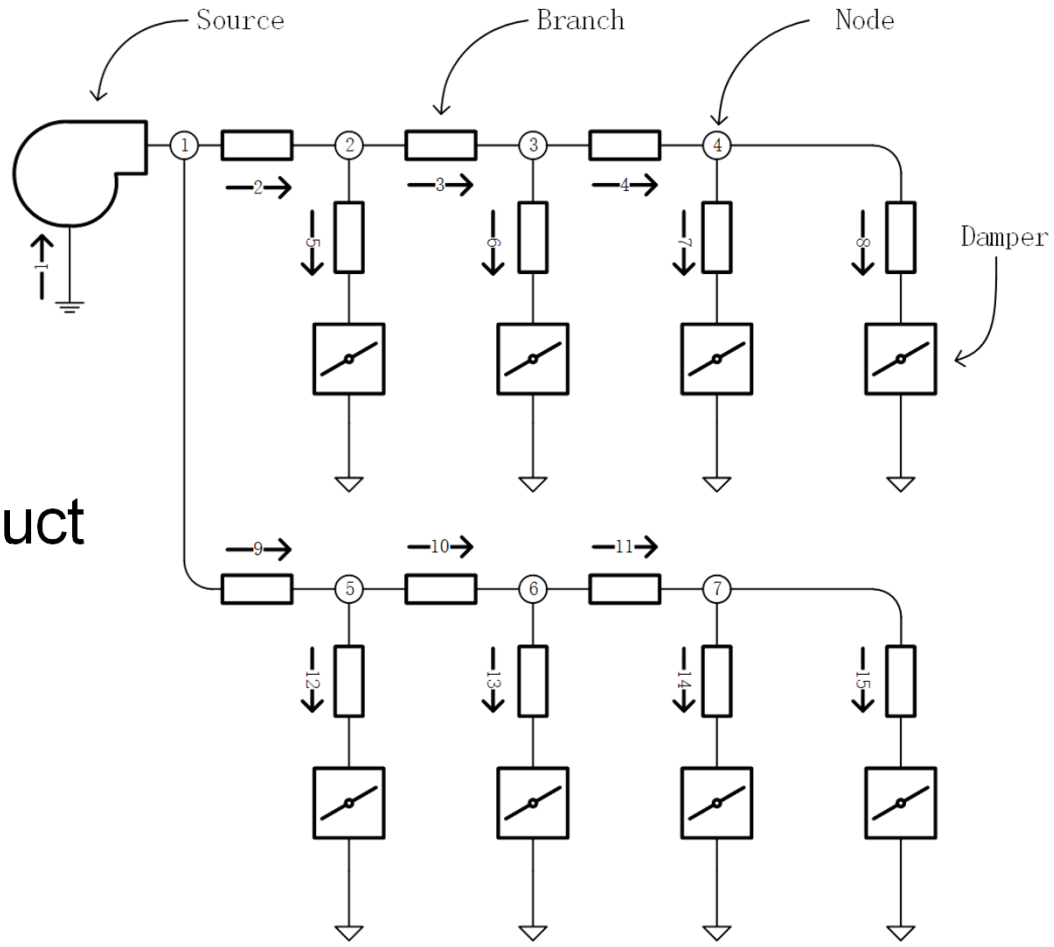
- Testing Adjusting and Balancing (TAB) performed by professional engineer.
- Rule of thumb

$$Damper\% = \frac{Design\ Airflow}{Measured\ Airflow}$$

- Interactions between ducts is not considered due to lack of model
- Slow, inaccurate, high cost

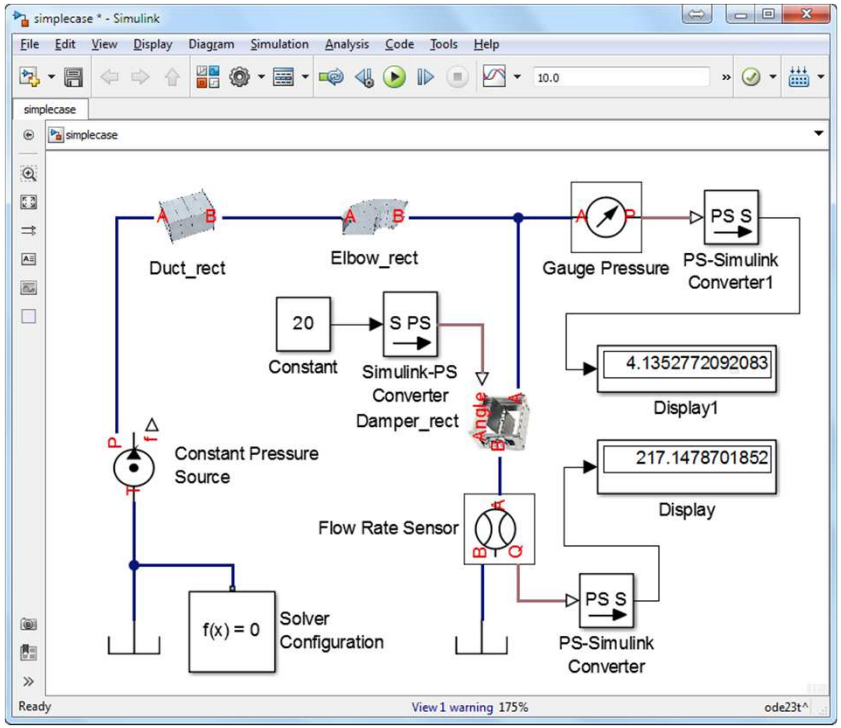
Duct model

- Build up model from components: source, ducts, dampers
- Frictional loss: Darcy-Weisbach
- Local loss: ASHRAE duct fitting database



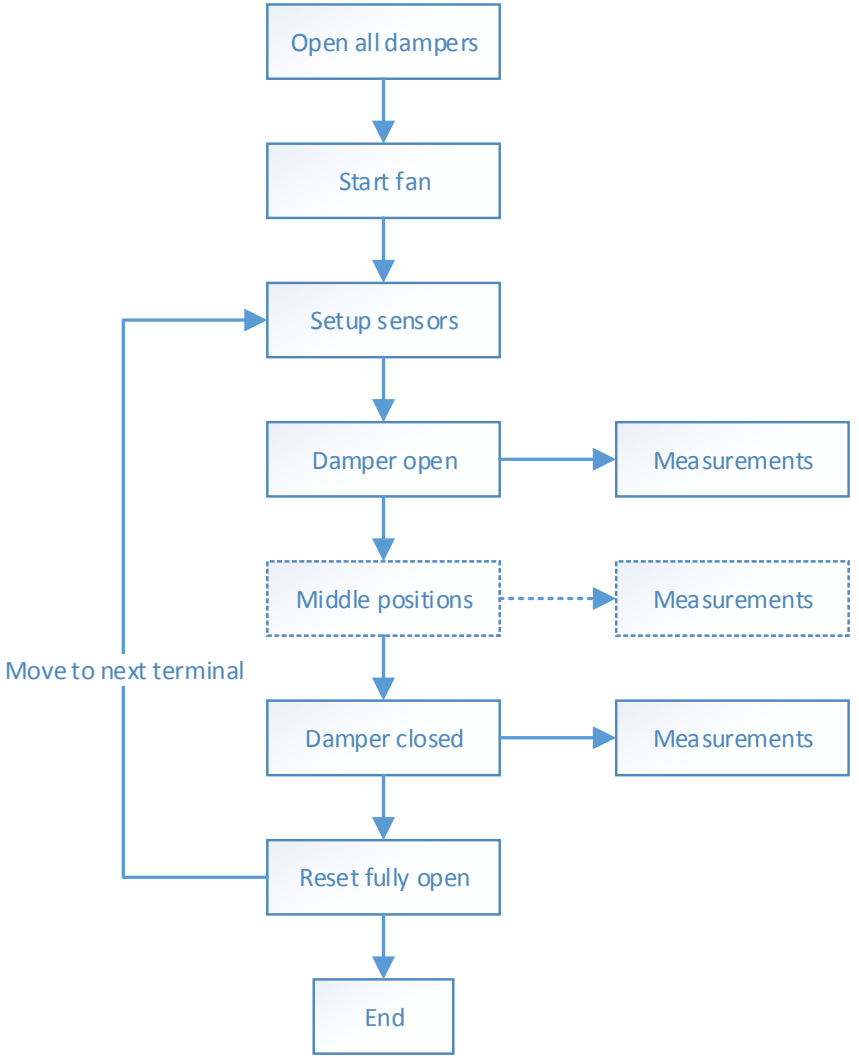
Simulation: Simscape

- Multi-domain physical modelling
- Differential algebraic equation solver
- Matlab/Simulink environment
- Customized domain:
  - » Through variable: flowrates
  - » Across variable: pressure
- Customized components
  - » Encode equations to relate pressures and flowrates



On site measurements

- Measure the airflows of each terminal and pressures before damper
- Adjust damper position from fully open to fully close for each damper.
- Take at a minimum of 2 measurements for each terminal.



Model identification

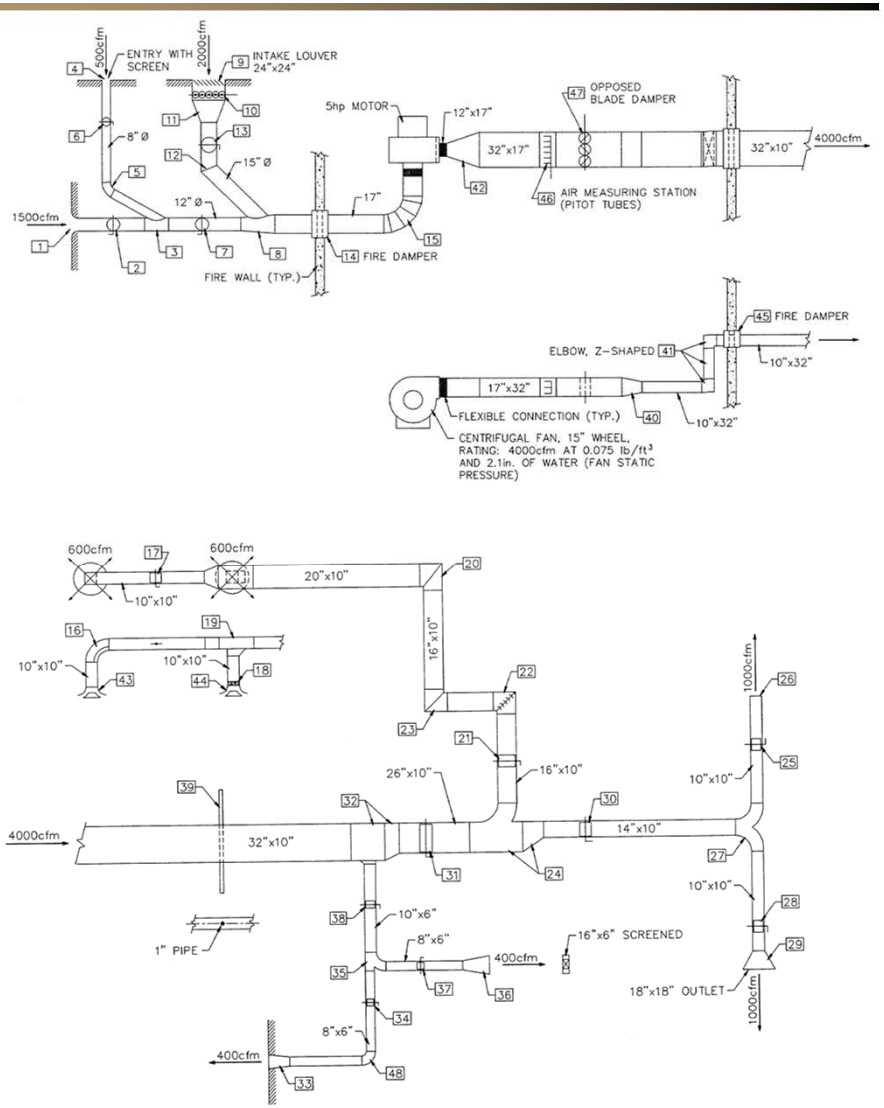
- Maximum a Posteriori
  - » Compute probability of undetermined coefficient β given measurements Z
  - » Predict system states at damper positions for any β
  - » Reduce discrepancy of predicted values by model
  - » Global optimization applies to estimate $\tilde{\beta}$

Damper Optimization

- Adjust dampers to proportion airflow:
  - » Get target airflow: q_d
  - » Compute airflow at any damper position θ
  - » Keep a damper open to minimize fan power
  - » Adjust other dampers to minimize discrepancy between estimated airflow to the target airflow.
  - » Sequentially tuning dampers to proper position according to the airflow rate measurement.

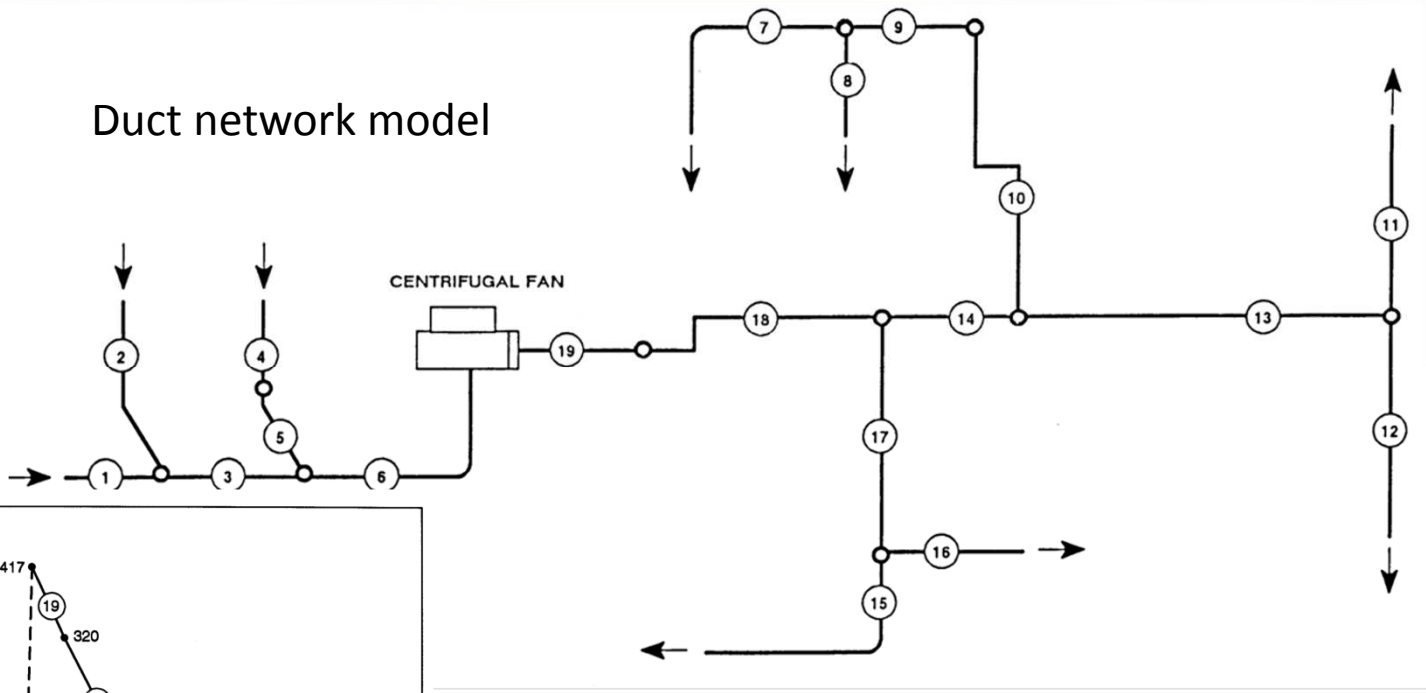
Example

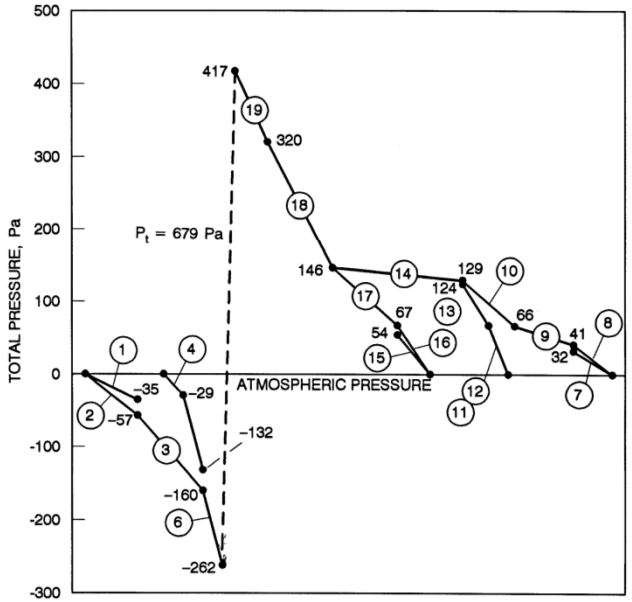
Target Airflow Rates (L/s)	
700	275
250	275
950	475
	475
	200
	200
3 Inlets	**6 Outlets**



Modeling

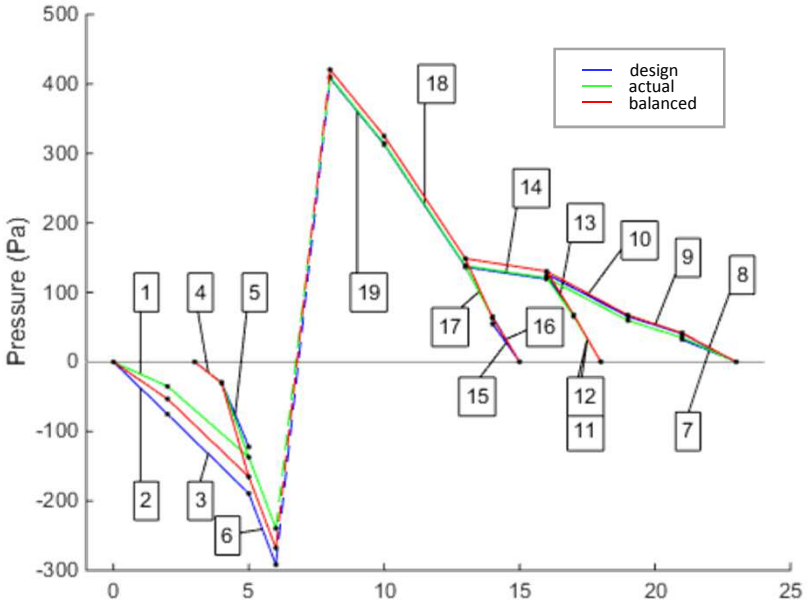
Duct network model



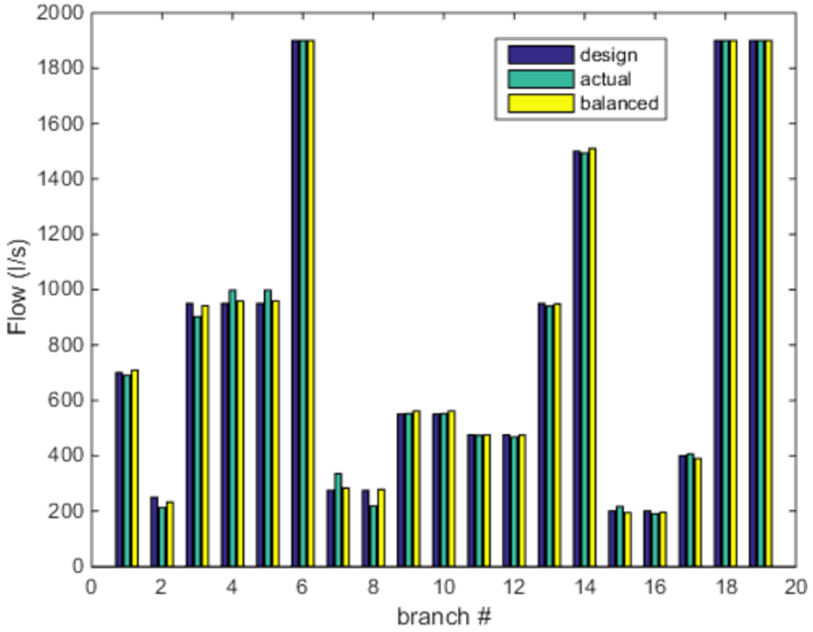


Pressure drop analysis

Results



Pressure drop curve



Airflow rate distribution

Optimal Damper Position		
5.7°	15.7°	3.5°
0°	0°	12.5°
14.0°	2.5°	10.7°
Inlets	**Outlets**	

Final Airflow Rate (L/s)		
702	275	474
246	275	200
951	474	200
Inlets	**Outlets**	

Q&A

Thank you!