HVAC Vent Control

Final Design Review
Project Definition

- Remote control of airflow through HVAC registers
- Balance airflow manually or automatically
- Reduce monthly energy bill and carbon footprint
- Low cost, modular unit
Why Balance Airflow?

- Most current households have inefficient systems
  - Rooms don’t get equal airflow
  - Rooms receive too much or too little heat/AC

- Some rooms in use only for part of the day
  - Energy wasted if air is directed to a room not in use
Environmental Impact

- Approximated average NC house and used 10 yr average NCDC heating and cooling degree data
- Energy savings per year
  - 96.2 gal. heating oil
  - 221.4 kWh
- CO₂ savings per year
  - 72 kg CO₂ from cooling
  - 976 kg CO₂ from heating

\[ \dot{Q} = \Delta T \frac{A}{R} \]

\[ \dot{Q}_{\text{tot}} = \dot{Q}_{\text{wall}} + \dot{Q}_{\text{window}} \]

\[ \frac{0.8 \text{ kg}_c}{32620 \text{ kJ/kWh}} \times \frac{3600 \text{ kJ}}{12 \text{ kg}_c} = \frac{0.3237 \text{ kg}_c}{\text{kWh}} \]

\[ \frac{0.3237 \text{ kg}_c}{\text{kWh}} \times 221.4 \frac{\text{kWh}}{\text{yr}} = 71.67 \text{ kg}_c \]

\[ 10.15 \frac{\text{kg}_c}{\text{gal.}} \times 96.2 \text{ gal.} = 976.43 \text{ kg}_c \]
Areas in Need

Heating Degree Days (base 65)

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HVAC systems generally inefficient due to varying register distances from the airflow source and poorly balanced ventilation systems.

Annually the average NC household spends $1,100 on heating and cooling. Our system can save nearly $350 in heating and cooling costs each year.
Marketability

- **Target**
  - New-home “green” construction
  - Areas with high HDD/CDD

- **Benefits**
  - Heating/cooling energy cost savings
  - Increased home comfort
  - Home climate customization
  - Lower energy use (less carbon emissions)
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<td>3</td>
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Actuator Pin Stress Calculation

- Pin connecting actuator to louver arm must be able to handle stress of opening and closing vent
- Assume worst case scenario of 15 lb
- Min pin diameter 0.0757 in.
- Actuator pin diameter $0.167 \rightarrow n \approx 11$
Actuator Pin Fatigue Calculation

- Goal of infinite cycles under worst case scenario of 15 lb of applied force
- Resulted in
  - Infinite Life
  - Factor of safety of 3.6

\[ S_f = k_\infty S_{f}^\prime \]

\[ \sigma_{\alpha}^\prime = k_{fb} \frac{32 * M_{\text{max}}}{\pi d^3} \]

\[ \frac{1}{n_d} = \frac{\sigma_{\alpha}^\prime}{S_f} + \frac{\sigma_{m}^\prime}{S_{ut}} \]

Source: Bannantine et al. (1990)
Register Lever

- Stress Plot
- Displacement Plot
FlowWorks Simulation

Vent Open
25%

75%

50%

100%
Vent Design
Linear Actuator Hinge Design
Protection

- Linear Actuator Cover
- Actuator Controller Dish
Innovation

Modular Design

- Design is modified off the-shelf register
- Replaces standard house vent with little modification of current structure
- Easy renovation and system expansion

Mechanics

- Back of actuator hinged to face of vent
- Piston end of actuator mounted on pivot to lever arm for louver control
- Unit protected by easily detachable casing
HVAC Test Rig

- Simulates ventilation system in a typical household
- Air flow supplied by two in-line duct fans
- Registers have average air speed of 1.1 m/s (3.6 ft/s) when 100% open

Conceptual Design

Actual Rig
Control System

**LabVIEW Control System**
- Manual position control of actuators by user
- Timer function permits automatic position control depending on time and date

**Linear Actuator Control Board**
- Stand alone closed loop control board
- Controlled via USB
- On board/computer adjustment of speed, sensitivity, and stroke limits
- Position feedback
- Battery powered

**Firgelli Linear Actuator**
- Specified force output of 15 lbs
- Lifetime = 1000 hrs
- Internal potentiometer for position feedback
- Stroke length = 50mm
- Gear Ratio = 50:1
- Voltage = 6 volts
Vent Damper Control
Controller Block Diagram
Testing

- Need to verify ability to balance flow and increase or decrease flow through any given vent
- Test with two vents cycling through all possible positions
- Measure air velocity exiting vent perpendicular to direction of travel
Testing Results
Trouble Areas

- Desire to have closed-loop system with anemometers providing feedback
- Purchasing anemometer would be too expensive ~$400 ea.
- Could not make anemometer sensitive enough for low air flows < 1 m/s
Prototype to Production

- **Linear Actuator:**
  - Use actuator with 30mm stroke length instead of 50mm to avoid modifying vent

- **Control Software:**
  - More visually appealing
  - Integrate room temperature sensors
  - Integrate vent anemometer inputs
  - Software can be obtained for free on all computers

- **Control Board:**
  - Use wirelessly controlled boards OR boards that rely on USB power
Product Future

- Use Bluetooth instead of USB for communication.
  - Requires solving power problems
- Use thermocouples to measure temperature in each room
  - Adjust louver position based on room temperature rather than CFM
Conclusion

Recommended for production

• System payback period of 5 years
• System easily upgradeable and expandable
• Easy installation
• Large target market
• Environmentally-friendly