Optically Chopped PIR Sensor for Occupancy Detection and Activity Tracking

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OUTLINE

- **MOTIVATIONS**
  - Background introduction
  - Issues with existing PIR sensors
  - Our solution
- **OPTICALLY CHOPPED PIR SENSOR**
  - Working principles
  - Chopper optimization
  - Results and analysis
- **SUMMARY AND CONCLUSIONS**

Acknowledgements

- **NES Team Member**
  - Ph.D. candidates: M. Yuan, L. Wu, Zh. Chen, R. Hua
  - Ph.D. students: J. Chen, M. Z. Zhang
  - M.S students: D. Ventura, H. Liu, M. Masoumi, D. Deland
  - Alumni: W. Deng (Texas A&M), M. Chen (Harvard), G. Hu & B. Ferber (Stanford), A. Karnati (Berkeley), A. Ke (Caltech)
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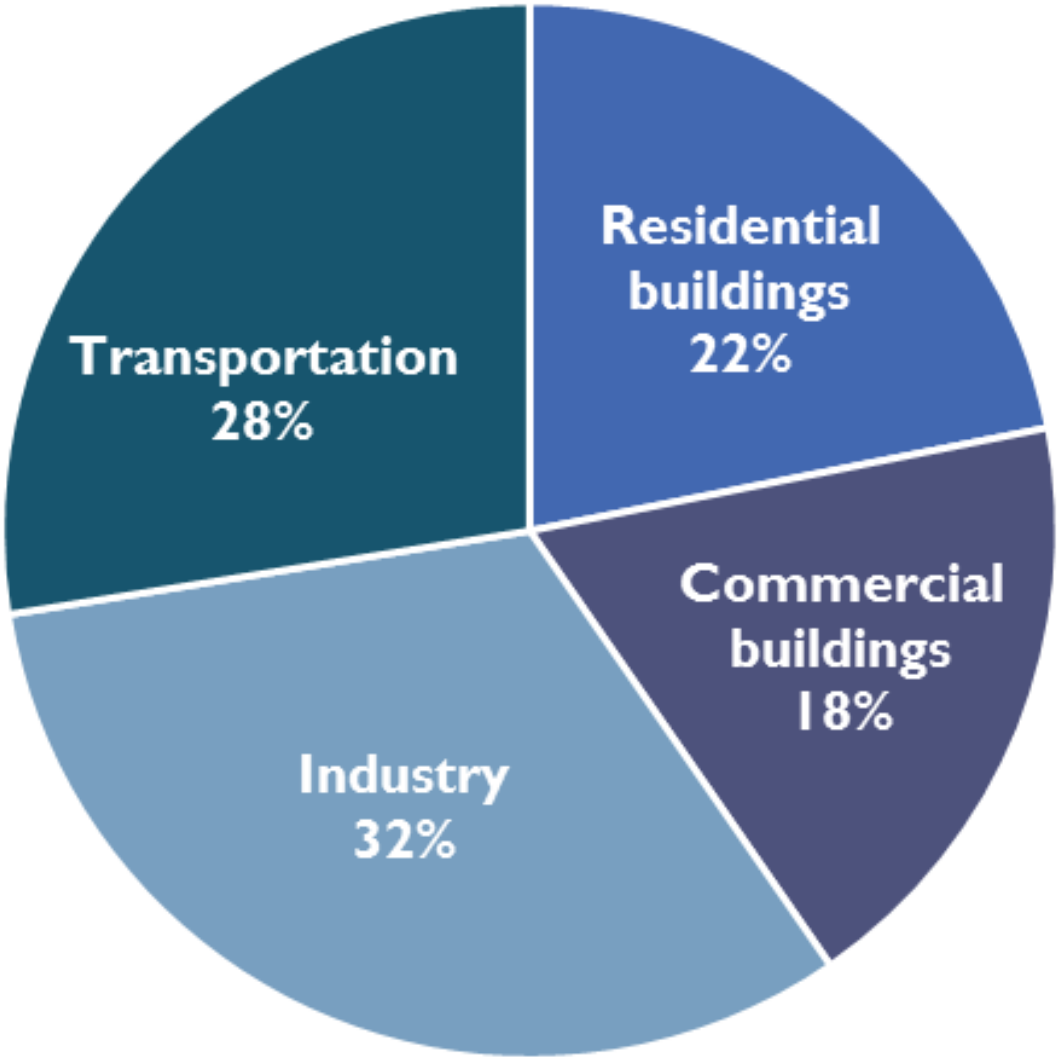
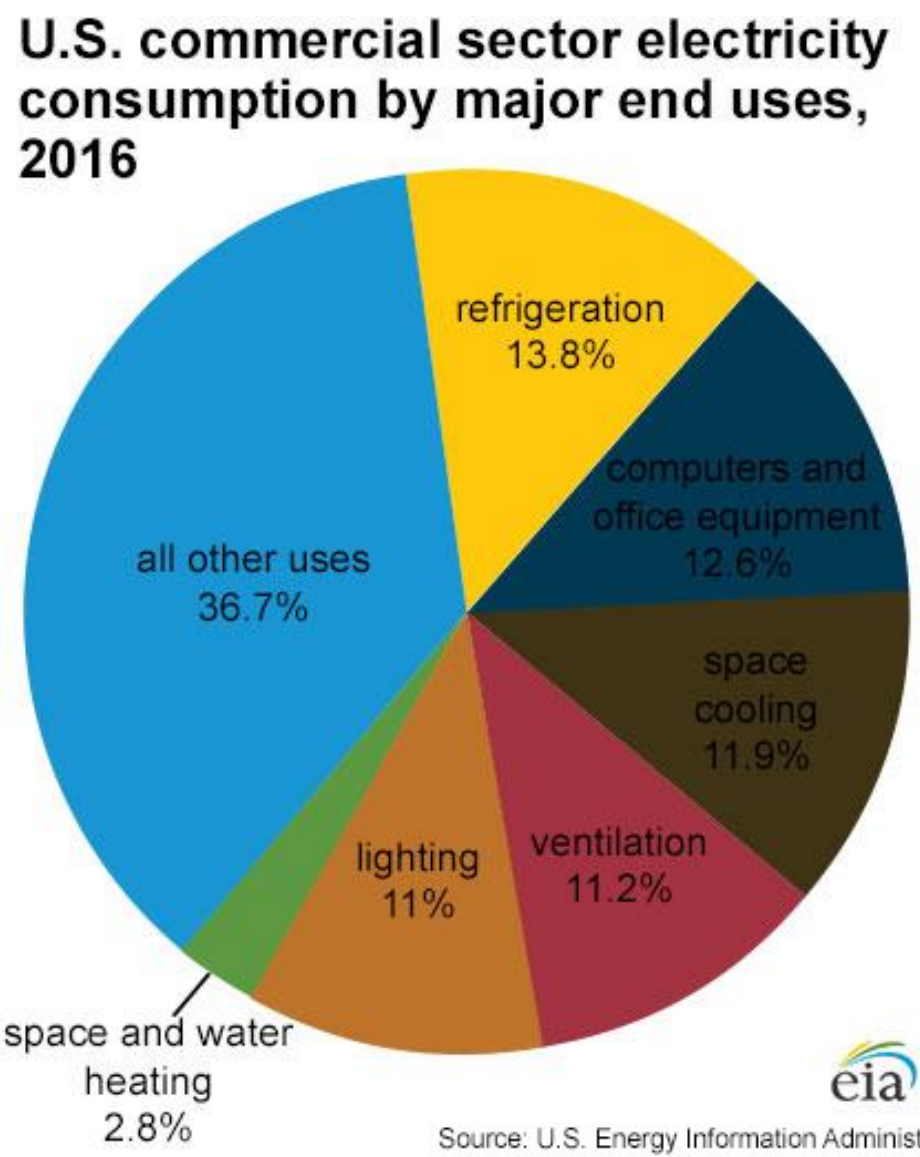
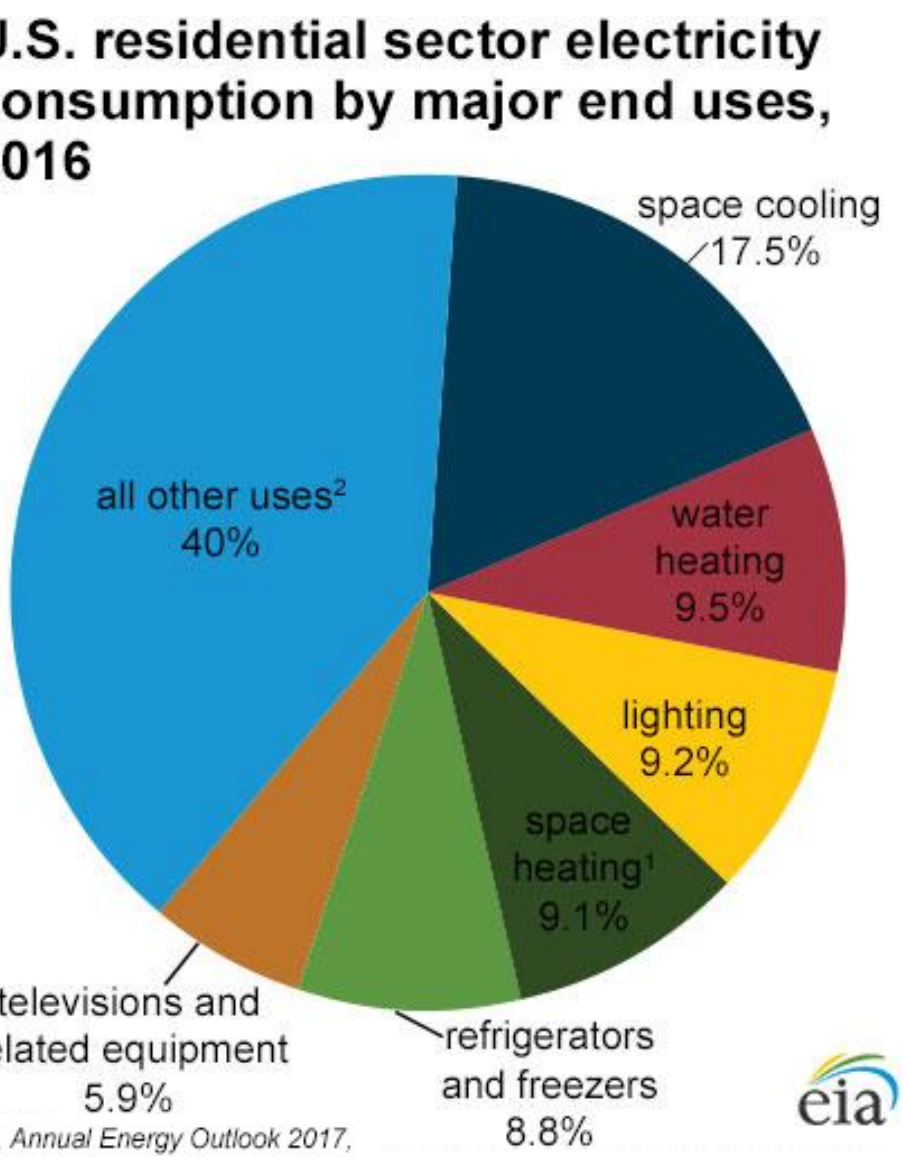
RES + COMM BUILDINGS = 13 QUADS OF ENERGY



- **We wasted so much of it!**
- **7.5% REDUCTION = 1 QUAD**
- **USING TECHNOLOGY TO STOP WASTING WHAT WE DO NOT NEED?**

HVAC + LIGHTING = 50%





Source: U.S. Energy Information Administration, *Annual Energy Outlook 2017*, Table 5, January 2017

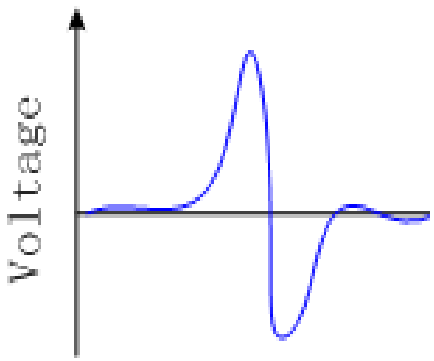
Existing Occupancy Sensors

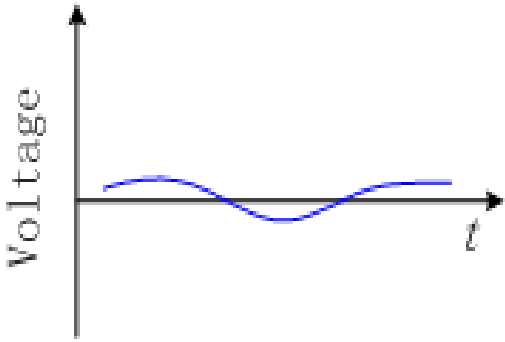
Sensor type	Stationary occupants	Cost	Accuracy	Other comments
PIR sensor	**No**	**Low**	**Low**	**Motion sensor**
Camera	Yes	Medium	High	Does not work in dark; Privacy invasion
Ultrasonic	Yes	Medium	Low	Needs several nodes; Complicated installation
Radio frequency (WIFI)	Yes	Medium	Medium	Need several nodes; complicated installation
Thermopile	Yes	Medium	High	Narrow Field Of View (FOV)

Existing Pyroelectric Infrared (PIR) Sensors

- **Benefits**
  - Passive sensing
  - Low cost
  - Large Range (12 m)
  - Wide FOV (120º x120º)

- **Can not detect stationary objects**





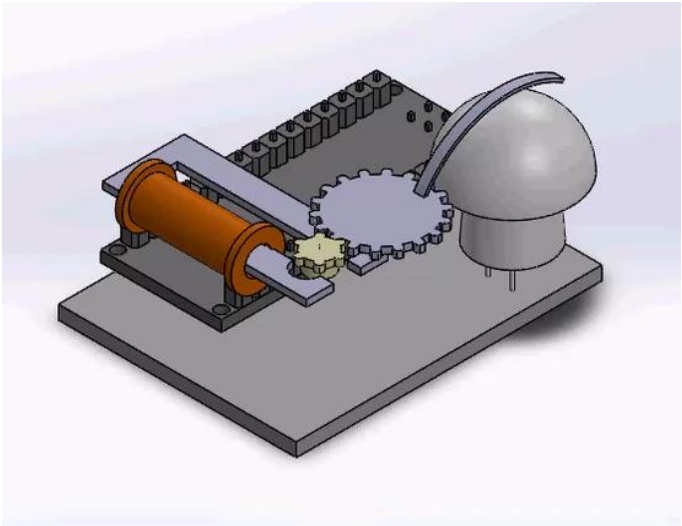
Detectable

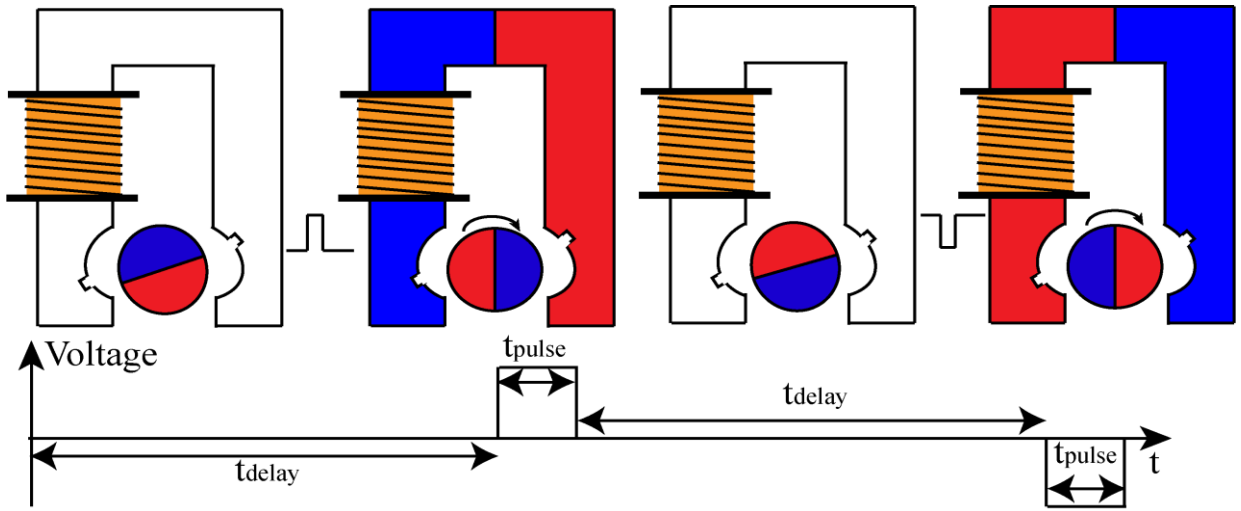
~~Not Detectable~~

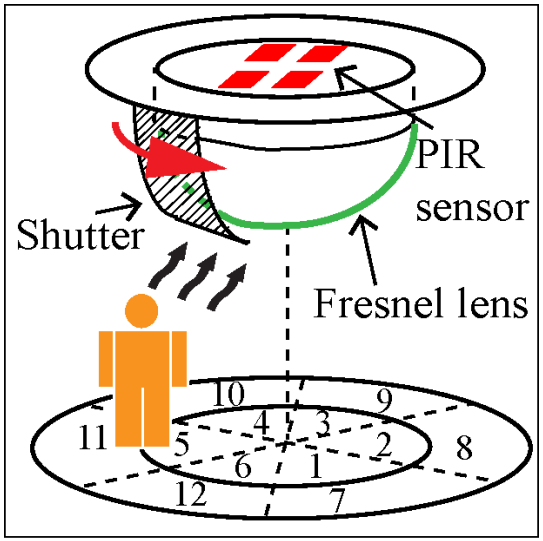
- **How to address this?**

Introducing a Vibrating Chopper to PIR sensors

- Use a **single-phase rotary vibrating chopper** to create varying infrared radiation
- currentless: rotor at cogging point: reluctant force (air)
- pulse: rotates (190mW)



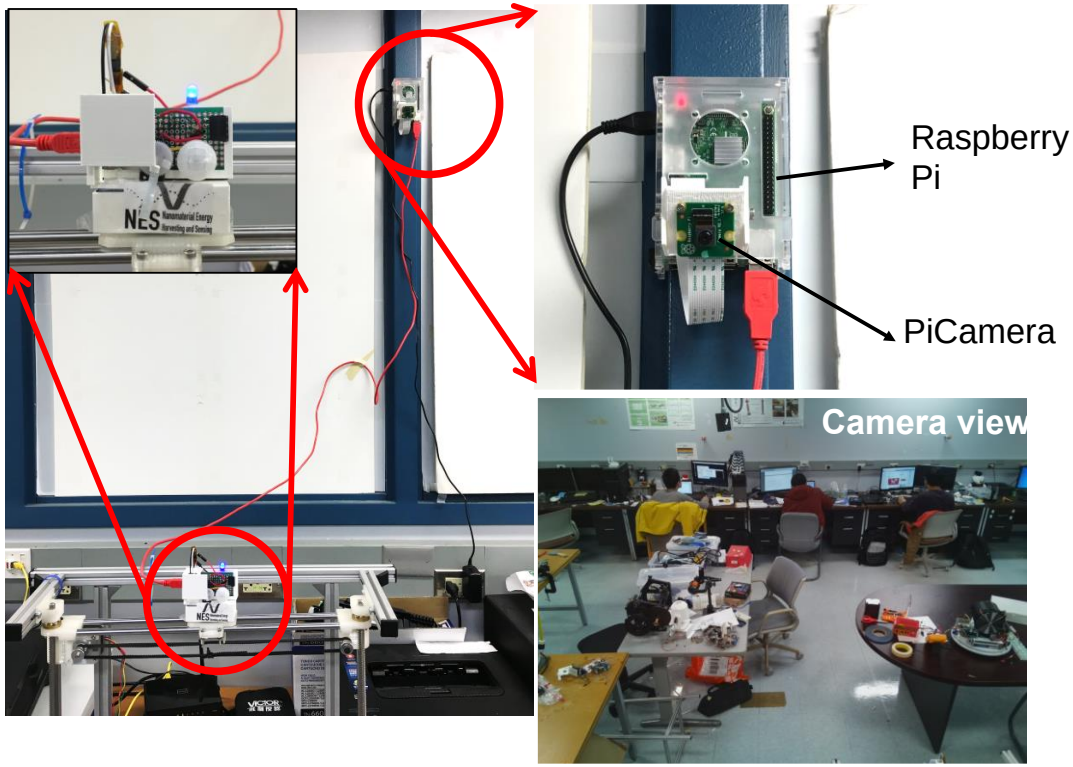


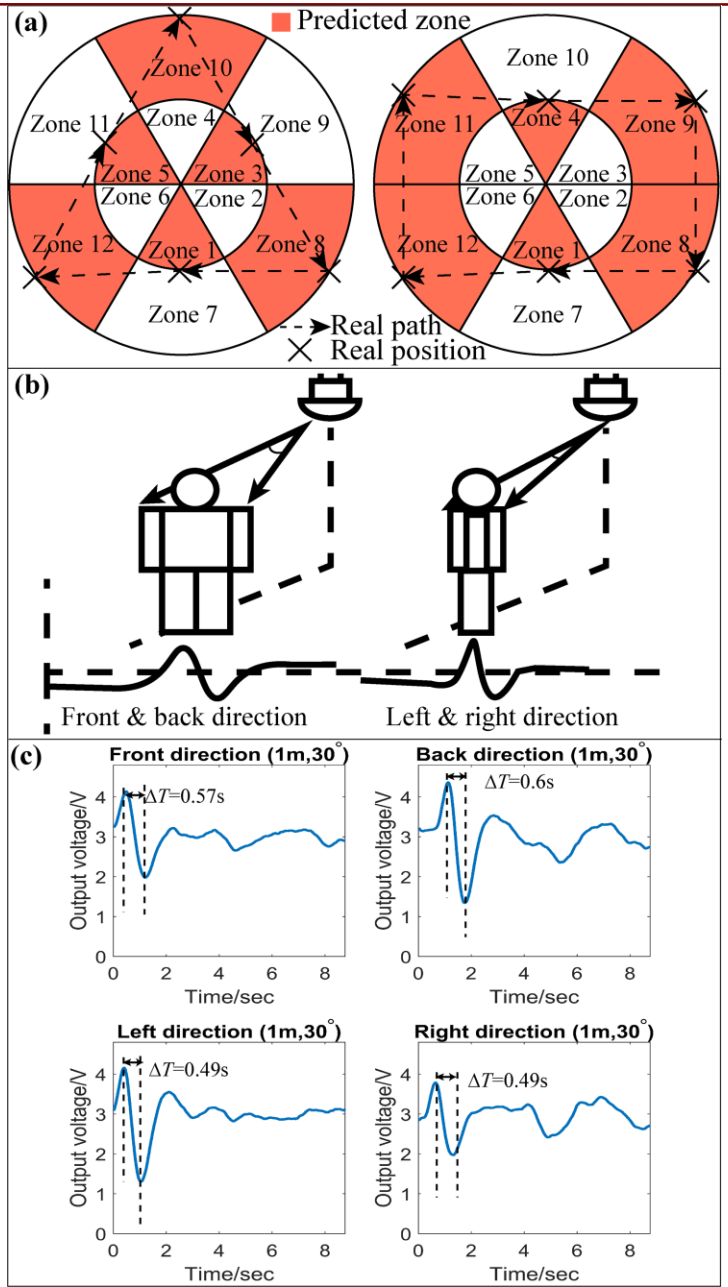


* Wu, **Wang**, 2018, *Appl. Phys. Lett.* **In Submission**.

Extended Functionality: Activity Tracking

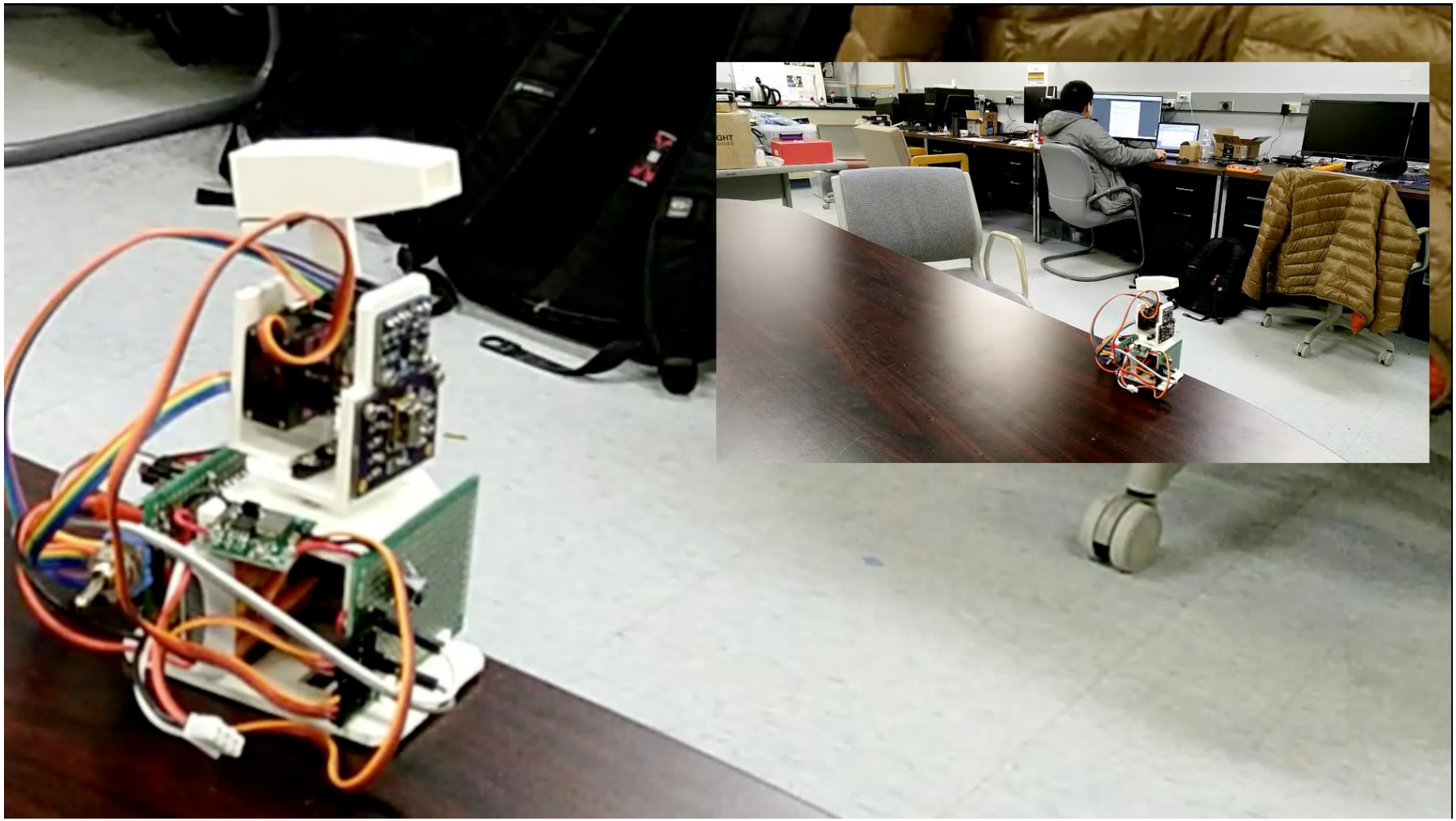
- Phase of a peak-peak signal corresponds to zone
- Duty cycle: facing direction





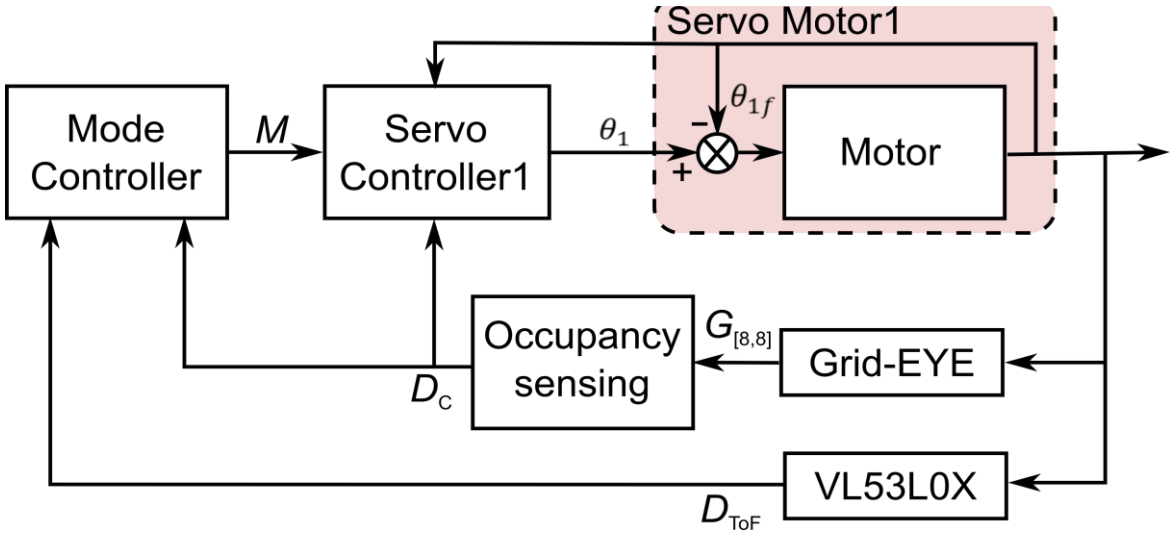
* Wu, **Wang**, 2018, *Appl. Phys. Lett.* **In Review**

ACTIVITY TRACKING SENSOR: ARGUS



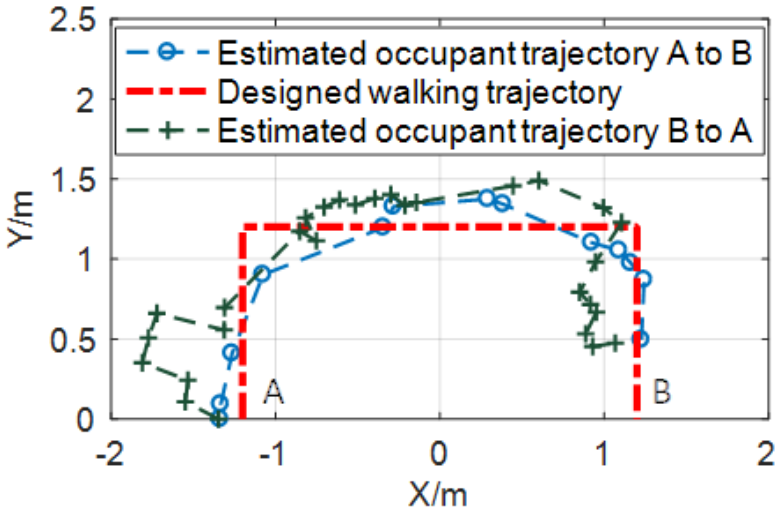
* Chen, **Wang,** 2018, *J. Intell. Mater. Syst. Str.*

ACTIVITY TRACKING SENSOR: ARGUS



M : Mode number
$\theta_{1,2}$: servo motor input signal
$\theta_{1,2f}$: servo motor feed back
D_c: Heat center deviation
$G_{[8,8]}$: Raw data of Grid-EYE
D_{ToF}: Raw data of VL53L0X

RMSE: 19 cm



* Chen, **Wang,** 2018, *IEEE Sensors J.* **In Review**

NES Nanomaterial Energy Harvesting and Sensing

QUESTIONS?