CPS: TTP Option: Medium:

Touch Sensitive Technologies for Improved Vineyard Management

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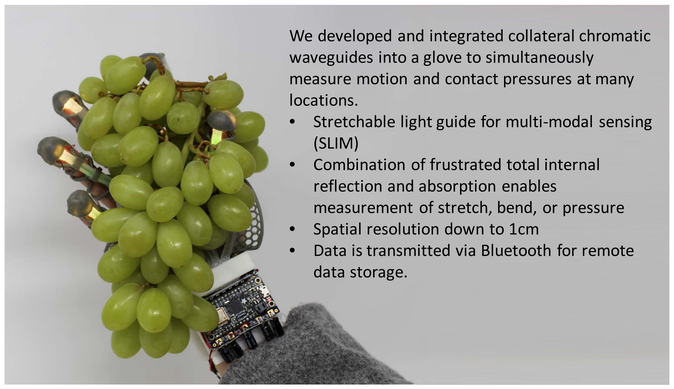
https://cei.ece.cornell.edu/research-2/agricultural-robotics/

Challenge

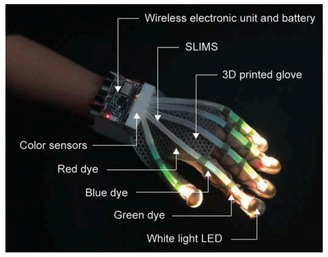
Improving the way we monitor grape vine health and predict crop yield using low-cost, accessible or simple-to-manufacture, cyber physical systems integrating computer vision, soft grippers, and ultrasonic transducers.

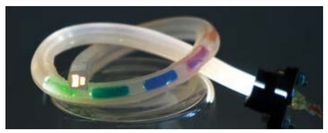
Soft Touch Sensors for Berry/Cluster Assessment



We developed and integrated collateral chromatic waveguides into a glove to simultaneously measure motion and contact pressures at many locations.

- Stretchable light guide for multi-modal sensing (SLIM)
- Combination of frustrated total internal reflection and absorption enables measurement of stretch, bend, or pressure
- Spatial resolution down to 1cm
- Data is transmitted via Bluetooth for remote data storage.





Bai, Hedan, Shuo Li, Jose Barreiros, Yaqi Tu, Clifford R. Pollock, and Robert F. Shepherd. "Stretchable distributed fiber-optic sensors." *Science* 370, no. 6518 (2020): 848-852.

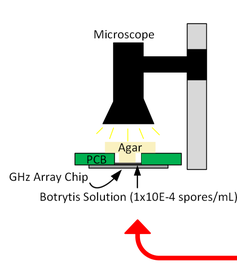
Ultrasonic Transducers to Detect Fungal Infections

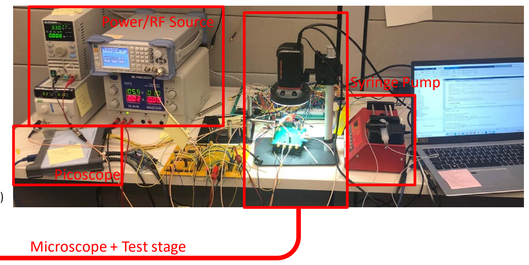
GHz 128x128 pixel ultrasonic imager (setup shown on the right):

- 130 nm CMOS process with monolithically integrated AlN transducers
- Transducer array area: 6.4 mm x 6.4 mm.
- Transducer elements / resolution: 50 x 50 µm
- Describe growth stages of spores in field samples

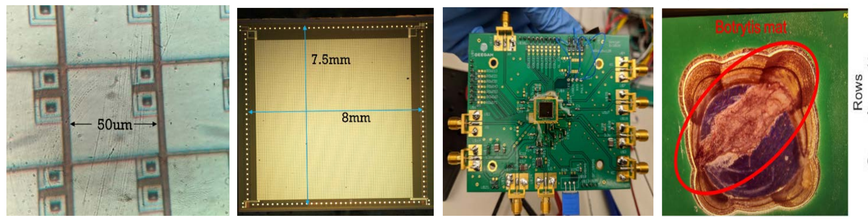
Grape cluster detection using an inexpensive 12x12 40 kHz transducer array (not shown here):

- Murata MA40S4S ultrasonic sensors
- Enable cluster scans at the resolution of individual berries (20 mm)
- Can complement optical data via detection of mechanical parameters, such as geometry and density





128x128 pixel 1.85GHz ultrasonic frequency imager from the SonicMEMS spinoff, Geegah LLC., alongside *Botrytis* mat taken by camera and GHz transducer array

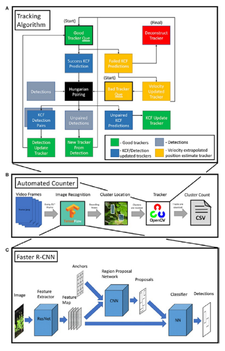


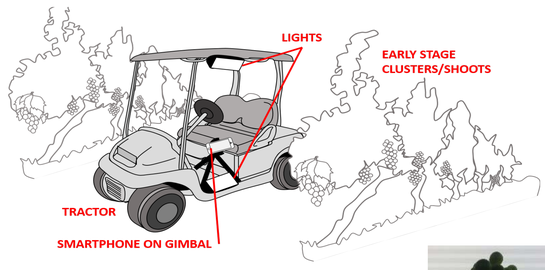
Y. Liu, J. Kuo, A. Lal, J. Sharma and N. Singh, "Characterization of Metal Effect on Solidly Mounted AlScN on CMOS," *2020 IEEE International Ultrasonics Symposium (IUS)*, Las Vegas, NV, USA, 2020, pp. 1-4, doi: 10.1109/IUS46767.2020.9251681

Computer Vision for Early-Season Cluster Counts

We developed an end-to-end pipeline for pre-bloom yield prediction, using low-cost, easily-accessible methods based on computer vision.

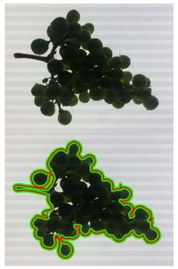
- Cost: Smartphone + <100$
- Labor: Unskilled, one quick drive/walk through each row in the vineyard
- No need for pruning, cultivar agnostic, training data works across seasons
- Avg. and max error: <8% and <15% depending on year





Ongoing and future work

- *Small farm tech adoption*: Ongoing app development to guide users in data collection and interpretation.
- *CV methods*: A broader range of similar-style CV technologies to automate estimates of the Ravaz index and leaf area to fruit ratio.
- *Cluster closure:* Scientific methods for monitoring cluster closure to inform spray practices.
- *Predictor models:* Data collection across cultivars and NY regions on weather, shoot and cluster number.



Jaramillo, Jonathan, Justine Vanden Heuvel, and Kirstin H. Petersen. "Low-Cost, Computer Vision-Based, Prebloom Cluster Count Prediction in Vineyards." *Frontiers in Agronomy* 3 (2021): 8.

Broader Impact

- Help farmers save money through better resource allocation
- Reduce pesticide use through variable rate application enabled by foliage, crop load, and fungus density mapping
- Ugrad/MEng research opportunities
- K12 outreach events, farmer tail gate meetings, and "Robots, Wine, and Food" seminar class

Scientific Impact

- Merging soft robots and vision for automated non-destructive assessment of crops
- Using ultrasonic transducers to detect micro-scale fungal infections in the field
- Interpreting multi-modal sensor data to inform crop care
- Supporting rapid technology adoption in small and medium-scale farms through low cost, easily accessible methods

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