Closed-Loop Sustainable Precision Animal Agriculture

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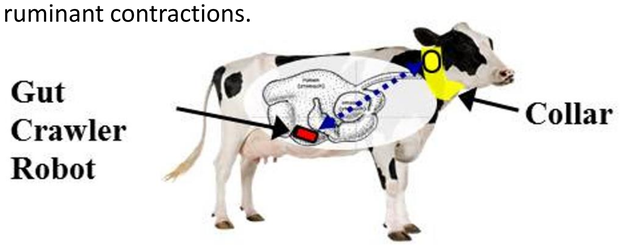
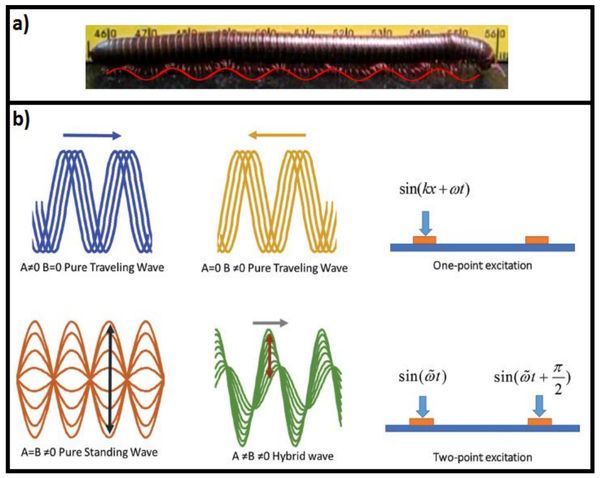
PURDUE POLYTECHNIC

Precision Animal Ag - Robotics

Rumen Understanding through Millipede-Engineered Navigation and Sensing (RUMENS) is an active robotic sensor to gather data when and where needed, regardless of ruminant contractions.



- Sensors in the robot (figure below) extract Big Data from multiple cows for more accurate models of ruminant health and well-being and, in turn, populate those models for each individual cow.
- Newly-developed sensors will extract the most detailed picture, yet, of volatile fatty acid (VFA) concentrations indicating fermentation efficiency.
- Data indicates feed efficiency, physiological stress, risk of acidosis, estrus, parturition, or other illnesses.



Traveling wave locomotion: (a) inspiration from millipedes' powerful metachronal gait, (b) mechanical traveling wave formation from a beam and piezoelectric ceramics with no appendages.

Project Support

This work is funded in part by NSF/USDA-NIFA CPS grant #1016136 for the networking component and by NSF/USDA-NIFA NRI grant #1018075 for the Robotic RUMENS sensor component, and by the NSF Center for Robots, Sensors and the Human Well-Being (RoSe-HUB) under grant #CNS-1439717.

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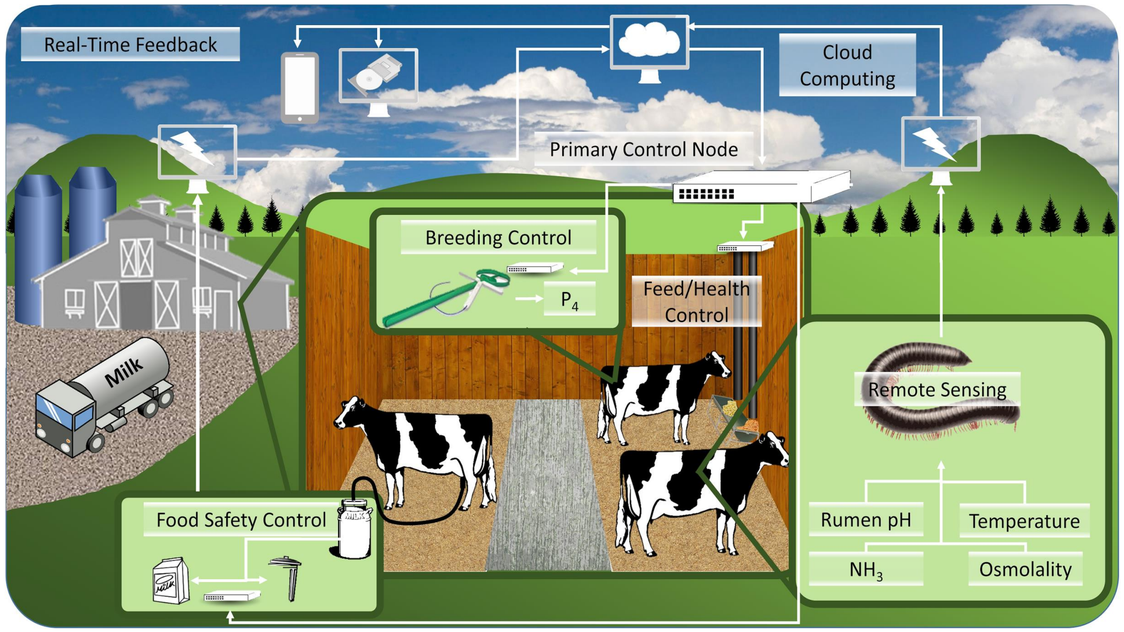
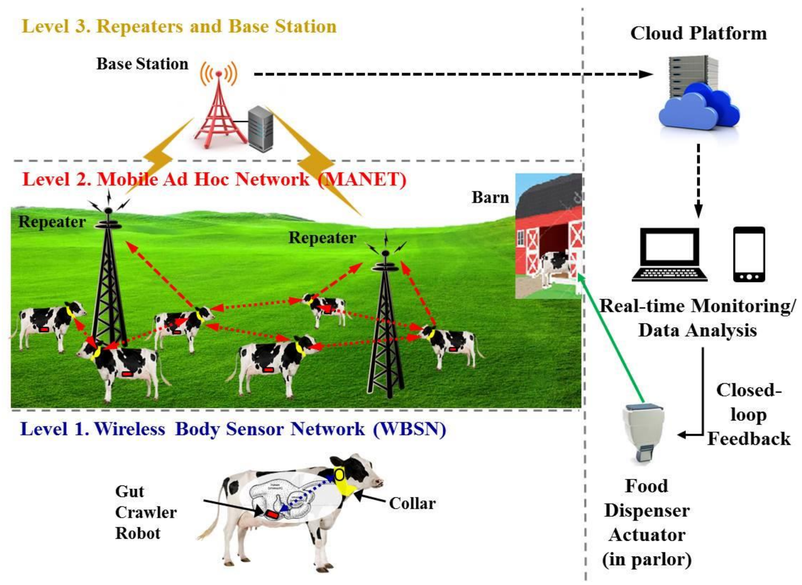
Precision Animal Agriculture – Cyber-Physical Systems

- With dairy forms now comprising 30,000-head of cattle, or more, **Precision Animal Ag** is returning the personalized, individual touch of the "family farm" to the diary industry through data analytics.
- A multi-tiered, data-centric network is proposed to monitor and actively control efficiency, safety, and quality of U.S. dairy farms at the farm, herd, and individual levels.



Cyber-Physical System (CPS) *for the U.S. dairy supply chain. Rumen and milk sensors will provide feedback to a base station that will transmit to a cloud-based data storage platform*

CPS Reference Architecture for Precision Animal Agriculture



Architecture of the proposed wireless networking infrastructure for a real-time precision animal agriculture system using cows as example animals.

The three-level network provides a high degree of configurability, rendering real-time health and behavior monitoring for numerous species.

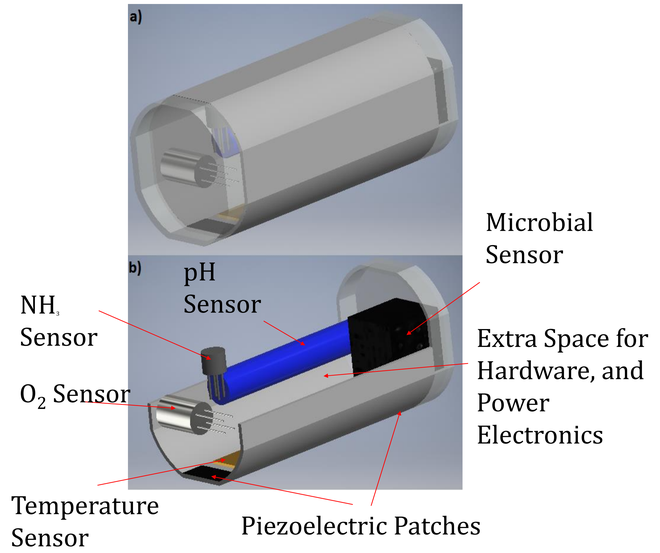
Level 1 : The Gut-Crawler robots link to collar nodes with edge analytics for reduction.

Level 2: Collars form mobile ad hoc networks for herd behavior.

Level 3: Herds relay to repeaters and the cloud for controlled actions.

Precision Animal Ag - Sensing, Estimation and Control

Unlike Precision Crop Agriculture, Precision Animal Agriculture requires identification and monitoring down to the individual animal to establish nutrition, health, and well-being. This data-centric approach starts with sensors and in a companion NRI project, we are developing in-vivo sensing and sampling packages for the RUMENS robot that will gather critically important data in real-time.



- One modular package will use COTS sensors for real-time measurement of the fermentation process inside the cow
- Another modular package will permit the capture of fluid samples at known location in the rumen.
- New generations of polymer sensors for volatile fatty acids (VFAs) are being developed for enhanced monitoring.

Estimation and Kalman Filtering

- Animal nutritionists White and Daniels will gather data from animal feed experiments on feed intake versus numerous metabolic parameters.
- Information and control theorists Sundaram and Chiu will develop advanced Kalman Filters to adapt the nutrition models to individual animals.
- CPS experts Voyles and Min will develop reconfigurable analytics engines that embody the estimation and control algorithms in a reusable form.