Integration of Thin Flexible Autonomous Microsystems for Vision Correction

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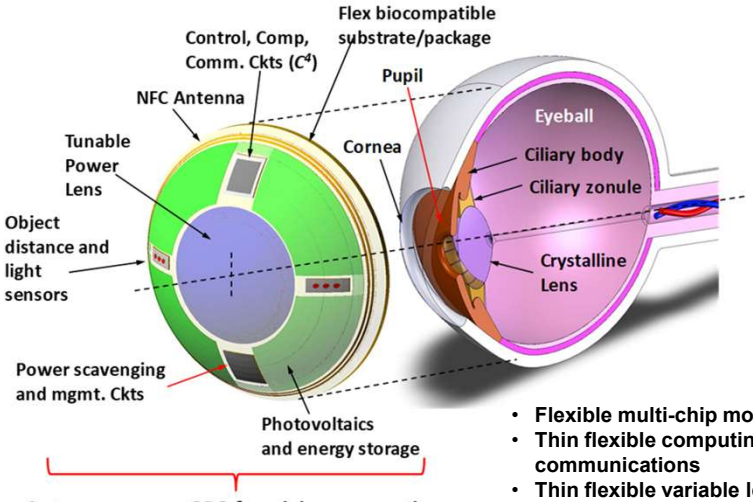
GOALS

- Many μ-CPS require continuous operation in isolated or unreachable environments while subject to severe resource constraints.
- These μ-CPS must autonomously maintain operations using energy scavenging and intelligent decision-making that maximizes operation life.
- Resource constrained μ-CPS are pervasive to wearable and implantable systems for health monitoring and corrective devices

- ***Goals*** for this project focus on hardware and software implementation of energy-scavenging vision-corrective smart contact lenses for restoration of accommodation in presbyopia patients (~90% of aging adults)

AUTONOMOUS VISION CORRECTION CYBER-PHYSICAL MICROSYSTEM

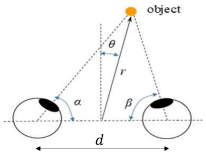


- Flexible multi-chip module
- Thin flexible computing and communications
- Thin flexible variable lens
- Flexible power scavenging

Autonomous VC-μ-CPS Subsystems

- Ultra-thin system incorporates micro-power:
  - Distance to object range sensor (***D***)
  - Tunable power lens (P_l)
  - Computation of corrective power $P_l = f(D)$
  - Intelligent energy management using solar cells and inductive power scavenging
  - Thin film energy storage
  - Wireless communications interface
- All fabricated on a flexible curved substrate

Passive Distance Ranging Via Eye Vergence Point Detection



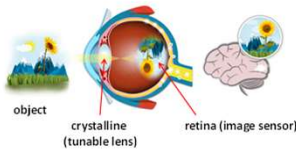
$$r = \frac{d}{(cot(\alpha) + cot(\beta))}$$

$$\theta = \frac{(\beta - \alpha)}{2}$$

- No need for radiation emission echo → low power
- Insensitive to presence of windows or spurious reflections
- Object range and bearing angles determined by inter-pupillary distance and the eye angles
- Similar method utilized by visual system

HOW DOES IT WORK ?

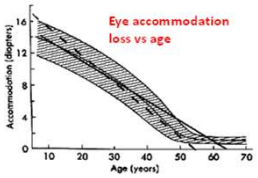
The Human Eye as a Lens-Camera System



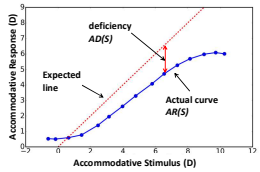
- Eye lens is a tunable lens as image distance is fixed thus providing accommodation
- When eye does not focus image on retina it produces vision errors

- When the eye lens is distorted or not working normally it produces refractive errors (RE) in vision

- Three types refractive errors
  - ✓ Myopia (near sightedness)
  - ✓ Hyperopia (far sightedness)
  - ✓ Presbyopia (age related loss of lens accommodation)
  - ✓ Presbyopia affect 90% of world population over 45 yrs old (~1.5 billion people)

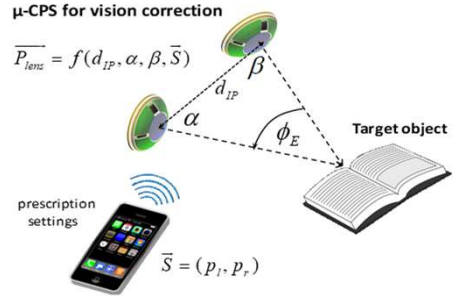


Smart contacts must provide Accommodative Deficiency *AD(S)*



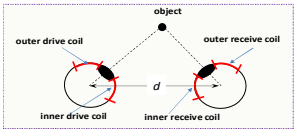
μ-CPS measure object distance and adaptively adjust lens power to provide the accommodation deficiency ADs

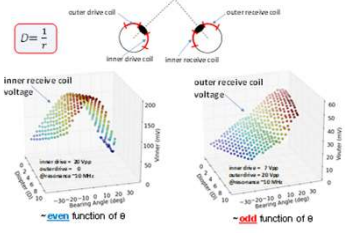
μ-CPS for vision correction



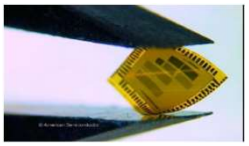
The Quad-Scleral Coil Approach

- No external coils
- All coils are on contacts
- Two source coils on one eye
- Two receiver coils on other eye
- Two half-circle coils per eye
- Angles between half coils is 2γ
- Determine range and bearing angle from these measurements
- pupillary distance = d = 60 mm

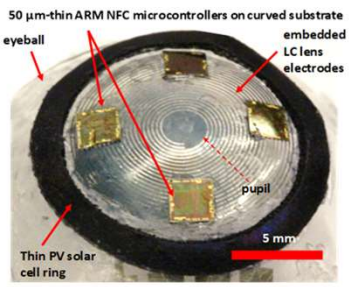




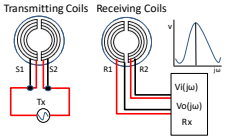
PRELIMINARY RESULTS



Flexible NFC and microcontroller chip. This chip has an 8 MHz Cortex-M0 that can be programmed for adaptive optics calculations and LC lens driving.



Example microassembly and integration of thin microsystems on flexible curved transparent substrate



SUMMARY

- Project addresses autonomous resource constrained μ-CPS for critical applications in isolated environments such as needed in wearables and implantable health care devices
- Specific implementation of thin smart corrective vision μ-CPS for accommodation restoration of presbyopia patients
- Autonomous software and hardware systems will be developed