Smart Ophthalmics©

An Exemplar of Autonomous Tele-Medicine

Enabling PHM for Human Assets

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Acknowledgements

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Keonjian Endowment:

Maria Keonjian
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<table>
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<tr>
<th>Patent number</th>
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<tr>
<td>US 6,578,966</td>
<td>“Computer-based 3D visual field test system and analysis”</td>
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<td>EP 1276411</td>
<td>“Computer-based 3d visual field test method”</td>
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<td>US 6,769,770</td>
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Several PCT, Patent, and Provisional Patent Applications filed on behalf of Caltech and University of Arizona on Smart Ophthalmics®

Ceeable Technologies: Startup Company marketing vision testing Caltech IP
Dr. Wolfgang Fink is Chief Technology Officer
Need and Industrial Relevance

• In civilian life there are many conditions that, if undetected or detected too late, may lead to (irreversible) vision impairment and even to blindness, such as:
  • Glaucoma (~76 million worldwide by 2020)
  • Macular Degeneration (~196 million worldwide by 2020)
  • Diabetic Retinopathy (~247 million worldwide by 2030).

• Military and space environments have many significant effects on the visual and ocular system that can adversely affect warfighter performance, and may lead to long-term health consequences.

• Early detection and therapeutic countermeasures will have a significant savings potential in healthcare costs to patients, health insurers, and economies at large.
Future of “Vision Testing on Earth and in Space” ???
Motivation for Smart Ophthalmics© and its Impact

- Development and deployment of low-cost but high quality mobile examination devices for rapid deployment in the theatre, space, disaster-stricken areas, third world, remote areas, and in hospitals (i.e., at the bedside).

- To provide quality and comprehensive ophthalmic healthcare to people who:
  - are geographically dispersed (e.g., populations in rural/remote areas)
  - operate/live in austere environments (e.g., theatre, space, third world, natural disaster areas)
where time, cost, and possibility of travel make access to even adequate medical care difficult if not impossible.

- As a result, significant causes of preventable vision loss, such as ocular trauma, glaucoma, and macular degeneration, may be detected early and treated in time to prevent permanent vision impairment or even blindness.

- M-Health and T-Health harbor significant savings potential in healthcare costs to patients, health insurers, and economies at large.
State-of-the-art Standalone Ophthalmic Instruments

- Ophthalmic Microscope
- Ophthalmic Slit Lamp
- Ophthalmoscope/Fundoscope
State-of-the-art Ophthalmic Instruments vs. Handheld Smartphone-based Examination Devices

State-of-the-art Standalone Ophthalmic Instruments

Ophthalmic Microscope  Ophthalmic Slit Lamp  Ophthalmoscope/Fundoscope

Examples of Miniaturized Portable Smartphone-based Ophthalmic Instruments
State-of-the-art Ophthalmic Instruments
State-of-the-art Ophthalmic Instruments

vs.

Handheld Smart-Tablet-based Examination Devices
What is *Smart Ophthalmics*©?

Bring healthcare exam to the patient rather than the patient to the exam!

Caltech Patents:
#6,578,966
#6,769,770
#7,101,044
#7,481,534
#7,762,664
#9,122,956
#9,424,489
EP #1276411

UofA Patents pending
Assisting Early Glaucoma Detection

Cup-to-Disk Ratio

http://www.fiteyes.com/home/understanding-your-test-results

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Smart Ophthalmics® Application Example #1: Fundus Imaging & Analysis
Proof of Concept
Proof of Concept
Proof of Concept
Smart Ophthalmics® Application Example #1:
Fundus Imaging & Analysis
Motivation for *Pupillometry*

- Monitoring both pupils of a person, merely with a flashlight (so-called "swinging-flashlight test"), tells first responders whether the person has suffered critical brain damage.
- Monitoring the pupil may indicate drug (ab)use, e.g., cocaine.
- Monitoring the pupillary movement in darkness has the potential to reveal whether a person is fatigued or suffering from sleep disorders (i.e., sleep apnea).
- Pupillometry is non-invasive.

*Serious* pupillometry usually requires a laboratory setup:

- Dedicated light-controlled (dark) room + dark adaptation
- Chin-head rest
“Swinging Flashlight Test”

Direct & Consensual Pupillary Reaction

RAPD: Relative Afferent Pupillary Defect

http://casemed.case.edu/clerkships/neurology/NeurLrngObjectives/Pupil.htm
Anatomic Pupillary Pathway

- Edinger-Westphal nucleus
- Pretectal nucleus
- Lateral geniculate nucleus
- Optic nerve
- Ciliary ganglion
- Efferent pathway
- Afferent pathway
- Nervus opticus
- Chiasma
- Tractus opticus
- CGL
- Area praetectalis

Fink et al., Ger J Ophthalmol 1996

http://casemed.case.edu/clerkships/neurology/NeurLrngObjectives/Pupil.htm

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Neural Modeling of Pupillary Pathway

Fink et al., Ger J Ophthalmol 1996

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Smart Ophthalmics© Application Example #2:
Pupillometry & Analysis
Perimeter (Oculus TAP 2000)  

Arrangement of Point Stimuli

CON: Examination time up to tens (40) of minutes, strenuous!
3D-Computer-automated Threshold Amsler Grid (3D-CTAG)

Testing Principle
Smart Ophthalmics© Application Example #3:
Comprehensive Visual Field Examination
Current & Future Examples:
Biofeedback-controlled Wearable Sensors

“Apparatus for Electrical Stimulation of Cell and Method of Use” (UA patent)
Website: InTelMed.arizona.edu
**Summary & Outlook**

*Smart Ophthalmics©* addresses the following major market needs:

1. *Professional medical market*, such as paramedics, medics, optometrists, and ophthalmologists

2. *Military market*, as evidenced by a recent Army SBIR Call “Adapting SmartPhones for Ocular Diagnosis”

3. *Emerging field of Mobile Health (M-Health)* and growing global markets for *Telemedicine Technologies*

4. *Enabler for PHM for Human Assets*: *all data mining, data understanding, and predictive techniques applicable*

5. *Exemplar for other Medical Applications*: *same framework*
Contact Information

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