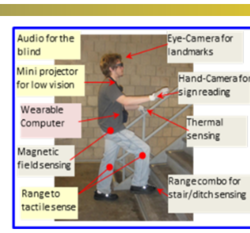
Human-Machine Perception and Assistive Technology

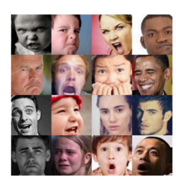
人机感知和辅助技术研究

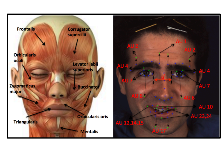
Dr. Zhigang Zhu (朱志刚)
Herbert G. Kayser Chair Professor of Computer Science
City College Visual Computing Laboratory (CcvcL)
Grove School of Engineering
City College of New York and
CUNY Graduate Center
http://www-cs.engr.ccny.cuny.edu/~zhu/

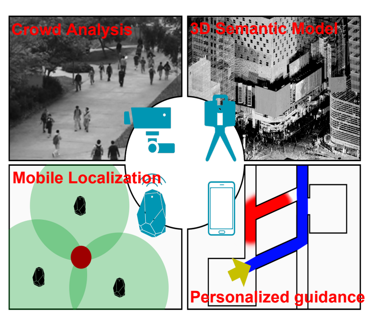
City College Visual Computing Lab

- Assistive Technologies
  - Assistive Navigation and Smart Living
  - Sponsors: NSF, VentureWell, NYSID
- Deep Learning
  - Facial/Brain Computing and Crowd Analysis
  - Sponsors: NSF, DHS
- Multimodal Sensing
  - Surveillance and Security
  - Sponsors: AFRL, AFOSR, ARO, DHS, NSF
- Smart Transportation Hub
  - Transportation, Security and Services
  - Sponsors: DHS, NSF



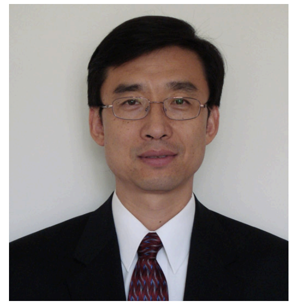






Bio-Sketch 作者簡介 [0]

清華十載學業成，麻州三年再進修；
基督愛心為榜樣，教書育人在紐約。
計算視覺是本行，交通監測並導航；
多種傳感幫視障，人機智能跨學科。
科研盡心又盡力，師生融洽同切磋；
青出於藍勝於藍，桃李滿園心歡然。



Ten-years at Tsinghua shaped the **content**, Three-years at UMass provided the **context**.
Personal faith stirs up my **compassion**, and City College is the place for my **contributions**.
Computing vision is my major, which applies to transportation, security and navigation.
Multimodal research helps people in need, which includes human & machine intelligence.
Cutting edge research needs the best efforts, so students and professors work in harmony.
My wish is that students are better prepared, and are more willing to contribute to society.

Abstract 摘 要

視覺甚精細，人腦更神奇；其一若有障，生活成問題。
科研要聯合，輔助需科技；多方來資助，用戶亦參與。
高校做研究，啟發新創意；培養有用才，工作有意義。

創新最前沿，機腦並生理；感知加計算，移動聯雲際。
幻境與遊戲，皆能更有益；不拘舊觀念，感知互代替。
交通在改進，智能又可及；導航到戶內，深度來學習。

雙目加智能，單目可測距；全向有優勢，三維更迅捷。
設計全身目，嘗試群幫眼；肌電能辨聲，舌頭看圖案。
機器讀人臉，盲者識表情；人腦之奧妙，或許可探知？

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Abstract

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Human vision is truly delicate, and the human brain is more amazing;
If either of them has problems, daily lives are very challenging.
Assistive living requires emerging technology, which needs collaborating;
Funding support is important, but more critical is user engaging.
The goals of research at higher education are not only to inspire novelty;
But also to train the next generation workforce, to do good to society.

Emerging Frontier in Research & Innovation (EFRI), includes M3 Control;
Multimodal perception is key, and mobile/cloud computing is the backbone.
Both virtual reality and gaming can be more positive and beneficial;
If not limited by conventional wisdom, alternative perception can be done!
Public transportation needs to be improved, to be both smart and accessible.
Location-based services go indoors, deep learning can also be here found.

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Outline

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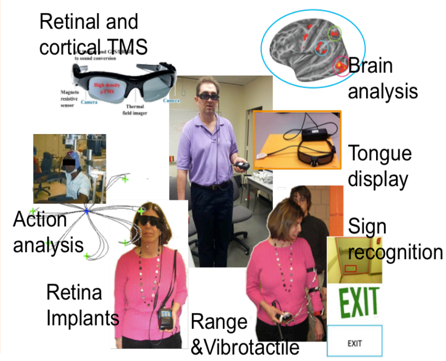
1. Introduction: Assistive Technology
2. State of the Art: Human-Machine Vision
3. Machine Vision Techniques
4. Alternative Perception Techniques
5. Facial Computing and Deep Learning
6. Platforms and Applications
7. Education and Training
8. A Summary

1. Introduction: Assistive Technology
引言：替代和輔助技術

世界人口七十億，接近三億有視障；[1]
自閉拖累千萬家，行動交流遇困難。[2]
還有其他殘障者，輔助技術來幫忙；
導航讀臉找地方，多種技術都用上。
城市學院視覺組，聯合媒體腦科學；[3, 4, 5]
機械生理佐理工，五個方面齊聯合。[6, 7]
研究創造最前沿，本文介紹幾方面；[8]
尚離期望有差距，但求啟發同向前。



Among the 7 billion people worldwide, nearly 300 million are visually impaired.
One in 70 is on ASD, & they're facing challenges in both mobility and communication.
For BVI, ASD and other disabled, assistive technologies can offer great helps:
In navigation, in face recognition and in finding places, emerging technologies are in need.
City College Visual Computing Lab, is jointed by Media and Neuroscience Labs.
Plus Mechanical and Biophysics at Georgia Tech, five disciplines are working on this EFRI.
Within the topic Man Machine and Motor Control, we can only discuss a few projects.
Even though there is a long way to go, we hope to provide some inspiration to peers.

2. State-of-the-Art: Human-Machine Vision
當前進展:跨學科人機視覺研究

人眼功能甚精細，大腦運作更奧秘；
千万精英齊努力，成果頻出需繼續。
視覺導航跨領域，電腦人腦並生理；
眼見腦算後行動，輔助視障靠合力。
政府民間均資助，師生用戶同參與；[8-11]
國際論壇細研討，各行專家有高見。[12]
替代視覺途經多，物理數字和醫學；[13]
耳舌身手皆可用，更有理解並移植。[14, 15]

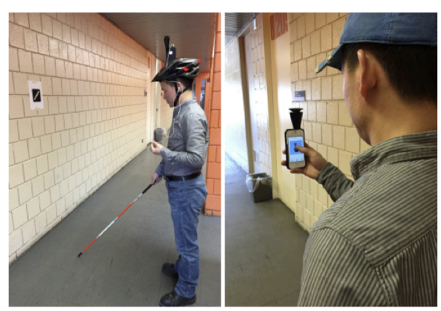
The functions of human vision are so amazing, yet the human brain is really a mystery.
Ten thousand researchers put their talents on them, fruitful yet still below expectation.
Vision navigation is cross-disciplinary, including computing, neuroscience and physiology.
See, think and action are in one, assistive vision needs research collaboration.
Funding support is important for research, and user engagement is even more critical.
International forums are inspiring, with insights of experts from various fields.
Alternative perception has multiple approaches, in physical, digital and medical.
Ear, tongue, hand and body can all be used, let alone to say machine vision and implants.

3.Machine Vision Techniques
機器視覺技術

- 3.1. Vision-based indoor navigation
  - 室內導航視覺種種
- 3.2. Smart sampling for binocular vision
  - 雙目視覺智能採樣
- 3.3. Mobile vision with single images
  - 手機單目三維視覺

3.1. Vision-based indoor navigation
室內導航視覺種種

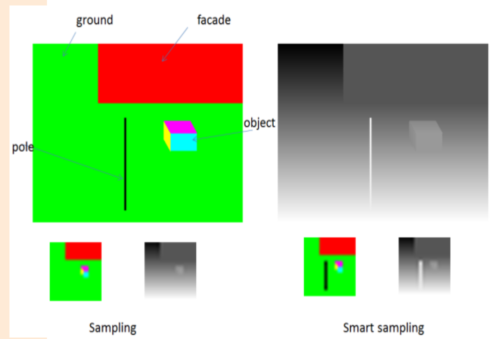
戶外衛星可導航，室內仍需新技術；
電磁信號可他用，視覺技術亦誘人。
智能手機觀全向，圖像檢索定方位。 [16]
移動三維更快捷，建模定位已實時。 [17, 18]
單項技術總有限，多種融合更完善；[18-20]
地圖預讀先規劃，智能手機聯雲端。
傳感技術是關鍵，移動計算為前端；
雲端處理在後台，新興技術益處多。



Outdoor navigation can readily use GPS, but indoor navigation still need new technologies.
Wi-Fi, magnetic, etc. have been used, but vision techniques are still the most attractive.
Panoramic vision can be used with a mobile phone, localization done w/ image retrieval.
Mobile 3D vision is more effective, modeling & positioning are in one and in real-time.
There're always limitations in single techniques, so multisensor fusion shall do better.
Planning and mapping can be undertaken before you go, by simply using a floor plan.
Multimodal sensor techniques are the key, and mobile computing is the front-end.
Cloud computing do the more sophisticated, and emerging technologies benefit all.

3.2. Smart sampling of binocular vision
雙目視覺智能採樣

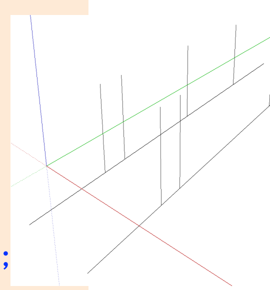
雙目視覺成果多，室內戶外均見效；
感知思維一窗口，研究認知有價值。
室內簡潔少圖案，立體匹配有難處；
不知人眼如何做，莫非基於內容塊？
圖像分為自然塊，按塊匹配得參數；[21, 22]
視場處處有測量，靈巧採樣數據精。 [23]
優先提示近距物，動畫目標或醒目；
網膜移植若有效，精簡數據是關鍵。 [24]

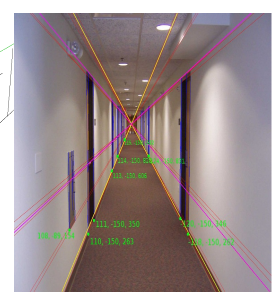


Research in binocular vision is the most popular all times, and it can be used both in & out.
It also serves as a window to understanding human perception, thus having hi-sci values.
Unfortunately many indoor scenes are textureless, which troubles stereo correspondences.
Researchers are always wondering how humans do the job: maybe we are using contents?
If an image can be segmented into natural patches, then matching can be made easier.
Even better is to provide 3D measures everywhere, thus providing basis for smart sampling.
Priority can be given to the closest, and animated obstacles can also be very helpful.
We believe smart data selection is the key, for an effective low-res retinal implants.

3.3. Mobile vision with single images
手機單目三維視覺

紅外測量距離短，雙目視覺匹配難；
人眼單目可測距，緣何不讓機器做？
智能手機拍照易，計算功能也超強；
室內城區均有效，距離光照均無憂。
走廊街道最適用，平行線末有滅點；
估計方向距離遠，實時計算沒問題。
感知組織來初試，霍夫級聯載手機; [25, 26]；
找出通道並入口，視覺導航定有用！





RGB-D camera uses IR for a short distance, & binocular vision has challenges in matching.
A human being can estimate distances with a single eye, why not a machine too?
Cameras are a default in smartphones, whose computing power is also stunning.
It works in both indoors and outdoors, without the worries of distance and illumination.
The best scenarios are corridors and streets, where VPs can be found for parallel lines.
Both orientation and large distances can be obtained, & real-time computing is also for sure.
Perceptual organization is the key principle, and HT and J-Linkage have been tried.
Both corridors and doorways can be detected, which are very useful for indoor navigation.

4. Alternative Perception Techniques
替代感知技術

- 4.1. Whole-body haptic eyes
  - 全身目的嘗試
- 4.2. Crowd-sourcing human vision sensors
  - 群幫眼導航初試
- 4.3. Tongue-eye and Electromyography (EMG)-ear
  - 舌頭看和肌電圖聽

4.1. Whole-body haptic eyes
全身目的嘗試

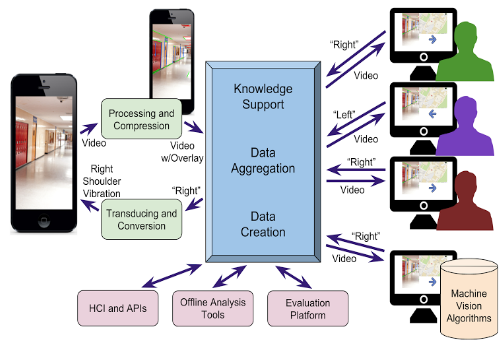
全身是目載聖經，皮膚能看見小說；[27, 28]
曾用皮膚讀圖像，舌頭胸背全試過。 [14]
顏色亮度難膚讀，為何不試讀距離？
全身沉浸距離場，振動強弱可表達。 [29]
虛擬世界來模擬，全身感元上千個；
用在人身是否行？振動皮膚或干擾。 [30]
設計模塊皮膚眼，裝在各處做試驗；
用戶喜歡學生樂，初步實驗有成效！ [31]

Whole-body eyes are recorded in Revelation, and skin reading is also described in sci-fi.
In the real-world researchers indeed tried haptic reading, with chest, back and even tongue.
Reading brightness is rather confusing, why not trying depths and ranging?
If users can be emerged into a field of distances, with haptic strengths to give the feeling!
Simulated in virtual environments, and over thousand haptic cells can be on a body;
But it would be a problem with a real person since vibrations will be interfering.
Thus we designed modular haptic eyes with BLE connections, and put them on body to test.
Both numbers and locations can be optimized, which is enjoyable for students and users.

4.2. Crowd-sourcing human sensors

群幫眼導航初試

機器視覺進展多，導航避障讀路標；
無人駕駛靠感知，穿在身上尚待時。
老少網友遍全球，二十四時在線上；
群幫已成新時尚，何不用其助導航？
用戶視頻傳網上，網友眾目來群幫；[32，33]
數據過濾是關鍵，實時指示步步行。
用戶安全過馬路，網友免費遊世界；
各類數據可收集，人機研究有價值。

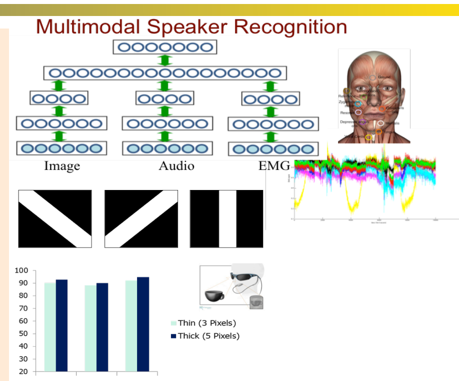


Rapid advances've been made in machine vision, for navigation, obstacles and landmarks.
Driverless cars rely on sensors but they are still not ready to be worn on a human body.
Around the globe millions of web surfers are online 24/7, both old and young;
We witnessed the emerging crowdsourcing applications: Why not for assisted navigation?
Users only need to broadcast their cam video online, so crowd eyes can help;
But data filtering and aggregation are a must, and real-time directions are essential.
We envision that users can cross streets safely, and crowd can tour the world for free;
Further multimedia Big Data can be collected, for research in man-machine intelligence.

4.3. Tongue eye and EMG ear

舌頭看和肌電圖聽

網膜移植有產品，舌頭看圖也嘗試；[14, 15]
辨音可用肌電圖，腦波或知人心情。
耳目有障困難多，交通受阻交流少；
替代感知有應用，或可更深識人腦。[8]
肌電信號來辨音，深度學習做比較；
一字識得講話者，效果堪比用語音。[34]
舌頭看圖初測試，識別圖案待商榷；[35]
或可巧用指方向，空出手耳做其它。



Products for retinal implants are already there, and tongue-reading is also in trials;
EMG can be used for speaker identification, and EEG might read human mind.
Impairment in vision and hearing are challenging, in both mobility and communication.
Alternative perception is one of the approaches, which can also help understand brain.
EMG has been tried to identify speakers, using a deep belief network.
Speaker ID can be obtained with a single word, comparable to using acoustic signals.
We also tested figure-reading with tongue, and found that this was very confusing;
However it can readily tell directions, which'd be used for hand- & ear-free navigation

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5. Facial Computing and Deep Learning
面部識別和深度學習

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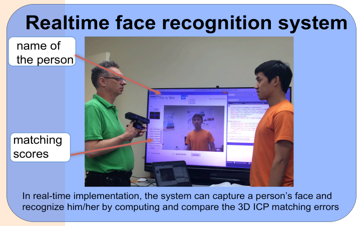
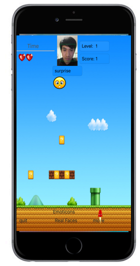
喜怒哀樂寫臉上，面部識別很重要；
無奈視障不能見，自閉患者亦作難。 [36, 37]
深度學習識表情，網上收集眾臉譜；[38]
卷積網絡為引擎，設計遊戲採數據。 [39]
多種模式來集成，實戰表情列前茅；[40]
人機智能相結合，多核學習最給力。
表情單元是核心，學習轉移省訓練；
興趣編碼顯效果，時空集成更提升。 [41, 42]





Human emotions are written on faces, therefore facial recognition is vital for social lives.
Unfortunately BVIs cannot see, and ASD friends also have challenges.
We studied facial computing via deep learning, & a dataset from Web is the 1st step.
CNNs are designed as the facial engine, and real-world data are collected via gaming.
Multimodal ST features are integrated, to achieve the top 5 performance among 60.
Both learned and hand-crafted features are used, and multi-kernel SVM is most effective.
Action Units are the core, and learning transfer improves learning efficiency.
Attention-coding is very effective, and LSTM net further improves the performance.

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6. Platforms and Applications
平台和應用

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- 6.1.GIVE-ME VISION: a platform
  - Gamification In Virtual Environment for Multimodal Evaluation
  - 虛擬技術助人遊戲技術
- 6.2. SAT-Hub: an Application
  - Smart and Accessible Transportation Hub
  - 智能可及交通樞紐

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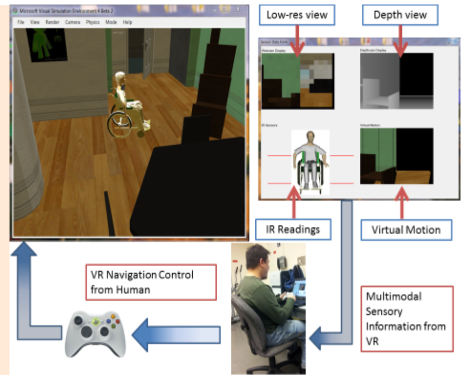
6.1. GIVE-ME VISION: a platform
虛擬技術助人遊戲技術

遊戲有害也有益，虛擬現實更迷人；
兩者聯合輔視障，賜我光明先模擬。 [43, 44]
仿真各類傳感器，研究開發成本低；
虛擬現實做訓練，用戶有趣無危險。
關鍵技術要逼真，最好直接移現實；
初步測試來驗證，虛擬遊戲有成效。
其一模擬舌頭看，其二模擬群幫眼；[35; 33]
其三模擬全身目，其樂融融育博士。 [31, 44]



Gaming can be good or harmful, and virtual reality (VR) are more attractive and lustful.
Both can be better used for assistive vision, GIVE-ME VISION can be the first good step.
Various sensors can be simulated, facilitating both rapid prototyping and low costing.
Navigation training in VR can both be entertaining and provide peace of mind.
The key is VR deigns shall be close to reality, better directly mapped to real experience.
Some initial tests have been carried out, showing GIVE-ME platform is effective.
Tongue-seeing is simulated first, crowd-sourcing comes the second;
Followed by the test of whole-body eyes, and the PhD graduate enjoyed it day and night!

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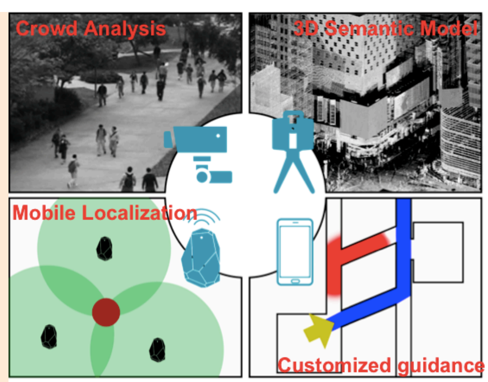
6.2. SAT-Hub: an application
智能可及交通樞紐

公共交通便都市，信息技術更添色；
可惜殘障遇挑戰，數字分化更明顯。
交通智能又可及，城市若歌雙聯合；[45,46]
安全交通兼服務，集成一體利全民。
數字模型識環境，人群分析知動態；
多種傳感定方位，戶內室外均便行。
聯手政府和公司，服務機構亦加入；
用戶積極來參與，智能城市遍全球。 [46]



Publication transportation is vital in a big city, and IT really changes the landscape of ITS.
However this creates more challenges for disabled, making digital divide even more obvious.
Smart and Accessible Transportation Hub, is a collaboration between CUNY & Rutgers.
Security, Transportation and Services, three are in one to serve all citizens.
Digital 3D modeling is for the environment, crowd analysis is for the pedestrians.
Multi-sensors are used for localization, customized guidance is provided both in & out.
Partnerships are among government, industry & academia, service institutions are also in.
User engagement is an indispensible part, and Smart Cities apply to anywhere in the world.

7. Education and Training
教育和培訓

- 7.1. Capstone Project Design on Assistive Tech
  - 輔助技術本科實習
- 7.2. REM：Research Experience and Mentoring
  - 研究經歷指導

7.1. Capstone/Senior Design on AT
輔助技術本科實習

本科聯合實戰課，成功運作已六載；
電子計算和工程，培養學生逾百人。 [47]
啟於技術幫視障，智能居住漸顧及；
聽力運動健忘症，老人自閉全可幫。
始於用戶真需要，學於實踐有動力；
聯合各方助殘障，教育公益兩不誤。 [48-51]
城市學生富創造，技術創新加科研；
屢次獲得創業獎，研究文章亦頻出。 [47; 52-54; 17, 29, 55]

The joint Cs/CpE/EE Senior Design course, has been running for six years.
The theme is Assistive Technology (AT), over 120 students have graduated.
It all started with assistive vision, and then smart living was also included.
Further AT covers challenges in hearing, motion and memory, ASD and elderly are also on.
Each project starts with users' real need, & students are motivated via learning by doing.
Collaborating with multiple institutions, for both education and social services.
Students at City are truly creative, in technology, entrepreneurship and research.
A number of grand prizes have been won, and UG students can also publish papers!

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7.2. Research Experience and Mentoring

REM：研究經歷指導

研究指導新嘗試，少數群體得幫助；
四年培訓愈七十，各種層次成果出。[56-57, 37,39]
高中老師加學生，社區教授也培訓；
大學各級來精選，博士學生做指導。
暑期十周密培訓，日日小組細研討；
每周大組做報告，來春全國年會秀。[58]
學員輔導同長進，高中老師開新課；[54]
社區學生轉本科，高中學生上名校。

REM was a pilot program at NSF EFRI, and it focuses on underrepresented groups.
The CCNY REM has graduated over 70 RPs, and achievements are visible in various levels.
RPs included high schoolers, HS teachers, college students &community college professors.
Formal interviewed were carried out, and PhD students learned to be better mentors.
Ten weeks were spent in a team environment, with daily interaction and discussions.
Weekly presentations are required in all-meetings, and most PRs also attended ERN.
RPs and mentors were both advanced, and HS teachers started to offer new courses.
CC students transferred to senior colleges, & HS students attended prestigious colleges.

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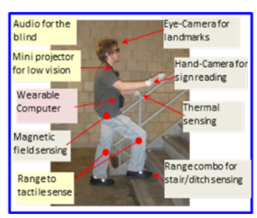
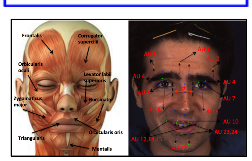
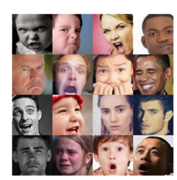
8. A Summary 小結

雙目加智能，單目可測距；
全向有優勢，三維更迅捷。
設計全身目，嘗試群幫眼；
肌電能辨聲，舌頭看圖案。
機器讀人臉，盲者識表情；
人腦之奧妙，或許可探知？







Binocular vision is made smart, and monocular vision can better estimate distances;
Omnidirectional vision sees everything, and 3D vision is more direct and effective.
Whole-body eyes have been designed, and crowd-sourcing human sensors are tried;
EMG can be used to recognize speakers, even tongues may be able to read images.
Smart machines read facial expressions, so the blind can see emotion of others;
The mystery of the human brain, may be further explored.

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CcvcL Research Grants (Total >$5.5M) Prof. Zhigang Zhu, CS/CCNY

- AFRL, AFOSR, ARO and DARPA
  - Exploitation and Fusion for DoD missions
  - Multimodal Sensing for ISR applications
- DHS SRT and NSF S&CC
  - DHS SRT Crowd Analysis (2015), and 3D+Crowd+Service (2016)
  - NSF Smart and Connected Community (2017)
- NSF EFRI (Emerging Frontiers in Research and Innovations)
  - Man, Machine and Motor Control (M3C) for Visually Impaired, $2M
  - NSF Research Experience and Mentoring (REM), $420K
- NSF I-Corps (Innovation Corporation) and SBIR
  - Transforming 2D Video into an Interactive 3D Viewing Experience
  - Vista Wearable, Inc. (startup by three students)
- Industrial and Local Supports
  - Smart Offices, Urban & Homeland Security
  - 3D Visualization and Modeling
- VentureWell (formerly NCIIA)
  - Novel Ideas for Vital Applications
  - Course and Program Development (Senior Design)

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