UCMERCED MESA LAB

From MAS-net (mobile actuator and sensor networks) to CPS (cyber-physical systems) and from HC-CPS (human-centric CPS) to CHS (cyber-human systems)

YangQuan Chen, Ph.D., Director,

MESA (Mechatronics, Embedded Systems and Automation) LAB

MEAM/EECS, School of Engineering,

University of California, Merced

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April 09, 2016. Saturday 2:20-2:40 PM

Robots and Ribs @ MESA LAB Symposium Day @ UCMerced

Welcome

- You all!
- Jinger and Greg from Dronesmith.io
  - Drone Hackathon @ Castle @ UC Merced
  - UAS4STEM

UCMERCED mechatronics.ucmerced.edu MESA LAB

Dr. YangQuan Chen, yqchen@ieee.org

Mechatronics, Embedded Systems and Automation Lab

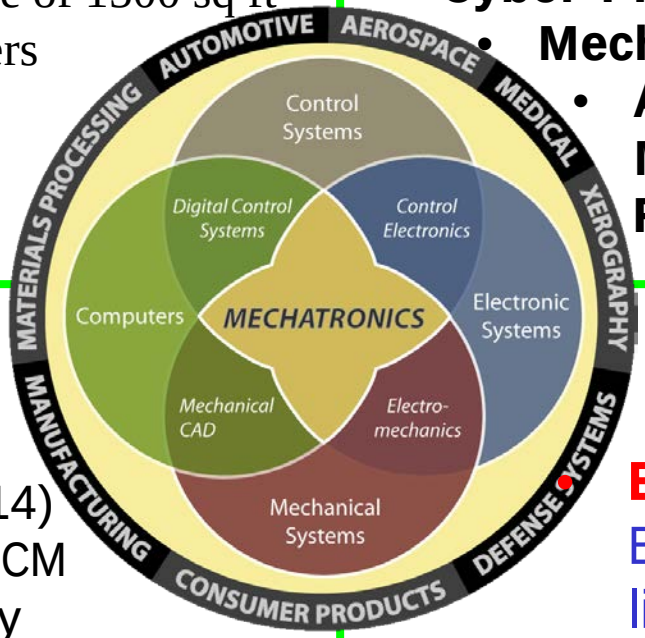
Real solutions for sustainability!

Established Aug. 2012 @ Castle of 1500 sq ft
5 Ph.D / 50+ undergrad members
12 visiting scholars || mentored
one capstone team (Sp16)

Research Areas of Excellence:

(ISI H-index=36, Google H-index=59; i10-index=316)

- Unmanned Aerial Systems & UAV-based Personal Remote Sensing (PRS)
- **Cyber-Physical Systems (CPS)**
- **Mechatronics**
- **Applied Fractional Calculus Modeling and Control of Renewable Energy Systems**



Education and Outreach Activities:

- Eng Service Learning(Sp14)
- AIAA Student Branch @UCM
- Preview Days, Bobcat Day
- "*The Drone Age*" @ Castle Air Museum
- Robots-n-Ribs| MESABox! STEM-TRACKS TEAM-E; 8 capstone teams (44 seniors) ...
- **ME142 Mechatronics (**take-home labs**)**
- **ME280 Fractional Order Mechanics**
- **ME190 Unmanned Aerial Systems**

Projects Related to San Joaquin Valley:

Energy [Solar energy, CPV, Building efficiency (HVAC lighting), smart grids integration, NG pipelines]

- **Water** (Water/soil salinity management, water sampling UAVs)
- **Precision Ag/Environment** (Crop dynamics, optimal harvest, pest ...)

MESA Lab Philosophy and Ambition

- "***We make real systems that work and others want them.***"
- **MESA Lab: Staying on top and for sustainability.**

- Nationally and internationally visible and prominent!

AMENDED IN ASSEMBLY MARCH 8, 2016

AMENDED IN SENATE SEPTEMBER 1, 2015

Senate Joint Resolution **No. 18**

News

Introduced by Senator Wolk
(Coauthor: Assembly Member Dodd)

July 16, 2015

Senate Joint Resolution No. 18—Relative to small unmanned aircraft systems.

LEGISLATIVE COUNSEL'S DIGEST

SJR 18, as amended, Wolk. Small unmanned aircraft systems.

This measure would request the President of the United States and the United States Secretary of Transportation to allow for the operation of small unmanned aircraft systems by farmers and rangeland managers pursuant to emergency rules adopted by the administration, as specified.

Fiscal committee: no.

WHEREAS, In the western United States, water is a vital and scarce resource, the availability of which has and continues to circumscribe growth, development, economic well-being, and environmental quality of life; and

WHEREAS, The wise use, conservation, development, and management of our water resources is critical to maintaining human life, health, safety, and property; and

WHEREAS, The western United States is currently experiencing serious drought conditions that are predicted to worsen; and

WHEREAS, Agricultural irrigation uses a significant amount of water, making the agricultural sector one of the most important sectors to examine when considering water conservation; and

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and in accordance with the FAA's proposed guidelines; and

WHEREAS, Small unmanned aircraft systems have been used in precision agricultural management in Japan for a decade, successfully optimizing and monitoring the management of 2.5 million acres of farmland, 40 percent of which are rice fields, without any significant reported incidents; and

WHEREAS, Several University of California campuses and the California State University system are developing precision agriculture applications with sUAS to help save water and improve crop and environmental monitoring. For example, the Mechatronics Embedded Systems and Automation Lab at the University of California, Merced, has developed numerous innovations for precision agricultural management with sUAS; and

WHEREAS, Flights of sUAS also have the capacity for detecting invasive plant species that deplete high amounts of water such as yellow star thistle, arundo, tamarisk, and cheatgrass, which serve no agricultural purpose and removal of which would help in water conservation efforts; and

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Dr. Brandon Stark to be

- http://ucop.edu/enterprise-risk-management/resources/centers-of-excellence/unmanned-aircraft-systems-safety.html
- Inaugural Director for
  - UC EHS COE for UAS Safety
- Still with us, mainly on campus.
- No “good bye”
- Building the “drone ecosystem”

UAS leadership roles

- ICUAS
  - 2016 ICUAS in DC http://www.uasconferences.com/
  - Dr. Chen will be General Chair for 2017 ICUAS, June 2017 in Miami.
- IEEE
  - TC co-chair for RAS TC ARUAV from 2012-2018.
  - http://mechatronics.ucmerced.edu/news/2016/congratulations-aruav-tc-ieee-ras-most-active-tc-award
- IEEE-UAS
  - IEEE RAS representative to sit in CTAP committee.
  - http://mechatronics.ucmerced.edu/news/2016/dr-chen-serves-ieee-usa-ctap-representing-ieee-ras

Three high impact contributions

1. **ASPRS Manual of Remote Sensing** invited contribution (4th edition) (MRS-4)
   - Brandon Stark, Brendan Smith and YangQuan Chen. (2016) "Small Unmanned Aerial Systems: Platform Selection, Insurance Issues, and TIR/SWIR Specialized Payloads" (30 pages)
2. (Wiley) **Encyclopedia of Aerospace Engineering – UAS** edited by Richard Blockley and Wei Shyy.
   - Brandon Stark and YangQuan Chen. (2016) "Remote Sensing Methodology for Unmanned Aerial Systems" (copy-edited, to appear 2016)
3. **Springer UAV Handbook** (news on 2nd Ed.)
   - Brandon Stark, Calvin Coopmans and YangQuan Chen. (2015) "*Concept Of Operations Of Small Unmanned Aerial Systems: Basis For Airworthiness Towards Personal Remote Sensing*" a chapter in Handbook of Unmanned Aerial Vehicles, Valavanis, Kimon P.; Vachtsevanos, George J (Eds.) http://www.springer.com/engineering/robotics/book/978-90-481-9708-8
   - Calvin Coopmans, Brandon Stark, Austin Jensen, YangQuan Chen, Mac McKee. (2015) "*Cyber-Physical Systems Enabled By Small Unmanned Aerial Vehicles*" a chapter in Handbook of Unmanned Aerial Vehicles, Valavanis, Kimon P.; Vachtsevanos, George J (Eds.) http://www.springer.com/engineering/robotics/book/978-90-481-9708-8

ME190 “Unmanned Aerial Systems”

- Fall 2016, 48 students (max. 72?)
- Lab in Castle Room 860 “UAS Teaching Lab”
- **Catalog Description:** “Unmanned Aerial Systems” (UAS) prepares students with essential foundational, design, integration and operational knowledge to meet emerging UAS workforce demands. Topics: UAS history, classification, applications, safety compliance; UAS components, basic aerodynamics, flight dynamics, navigation and control, payload integration, mission planning, sense-n-avoid; UAS use cases and other selected emerging topics. (4 credits with labs.)
- #UAS4STEM **taking off**

CITRIS SmartCaveDrone funded!

- http://mechatronics.ucmerced.edu/SmartCaveDrone
- Belize, Mayan Caves
  - Bo Shang
  - Garrett John

UC Multi-campus Synergy on CIDERS

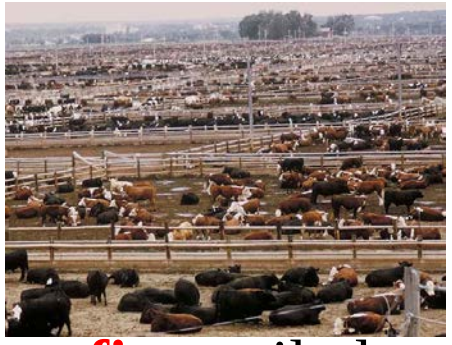
California Institute of Data-drone Engineering and Services

UCM, UCSC,UCB, UCSD, LLNL

CIDERS in Scientific data-drones: platforms, operation, and certification

UCM
UCD
UCSD

CIDERS in precision agriculture

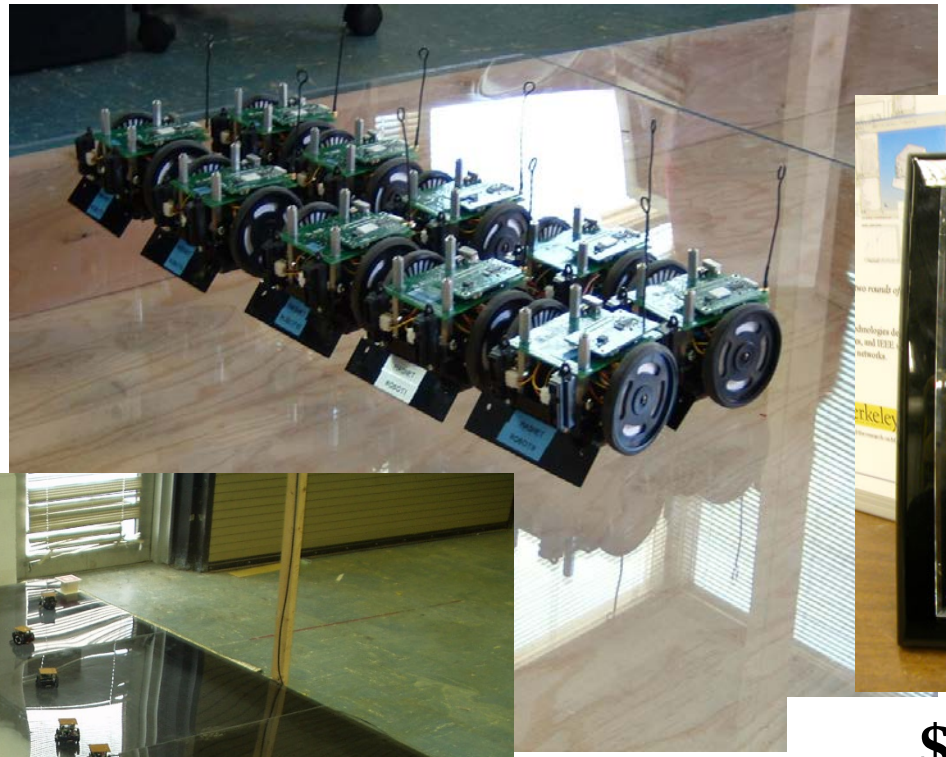


UCM
UCD
LBL
SNL
UCSD

CIDERS in environmental monitoring: water, **fire**, soil, dust, AQ …

Mote-Based Distributed Robots

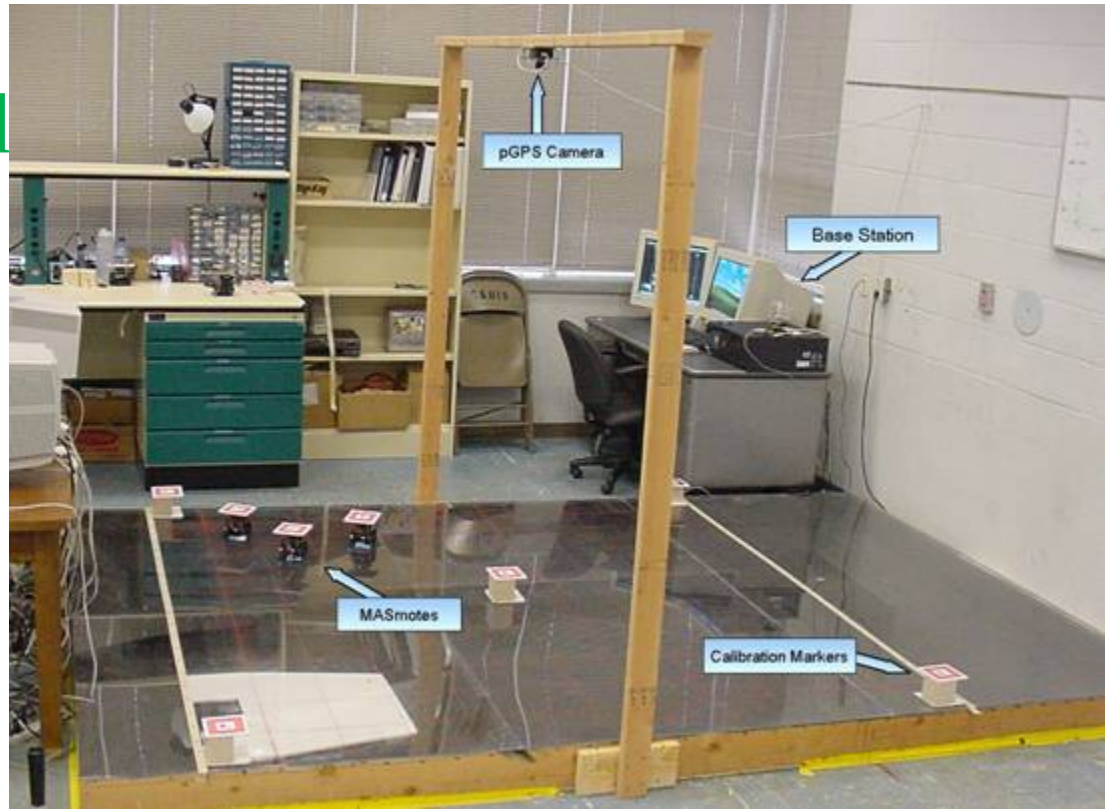
Prototype plume-tracking testbed - 2004

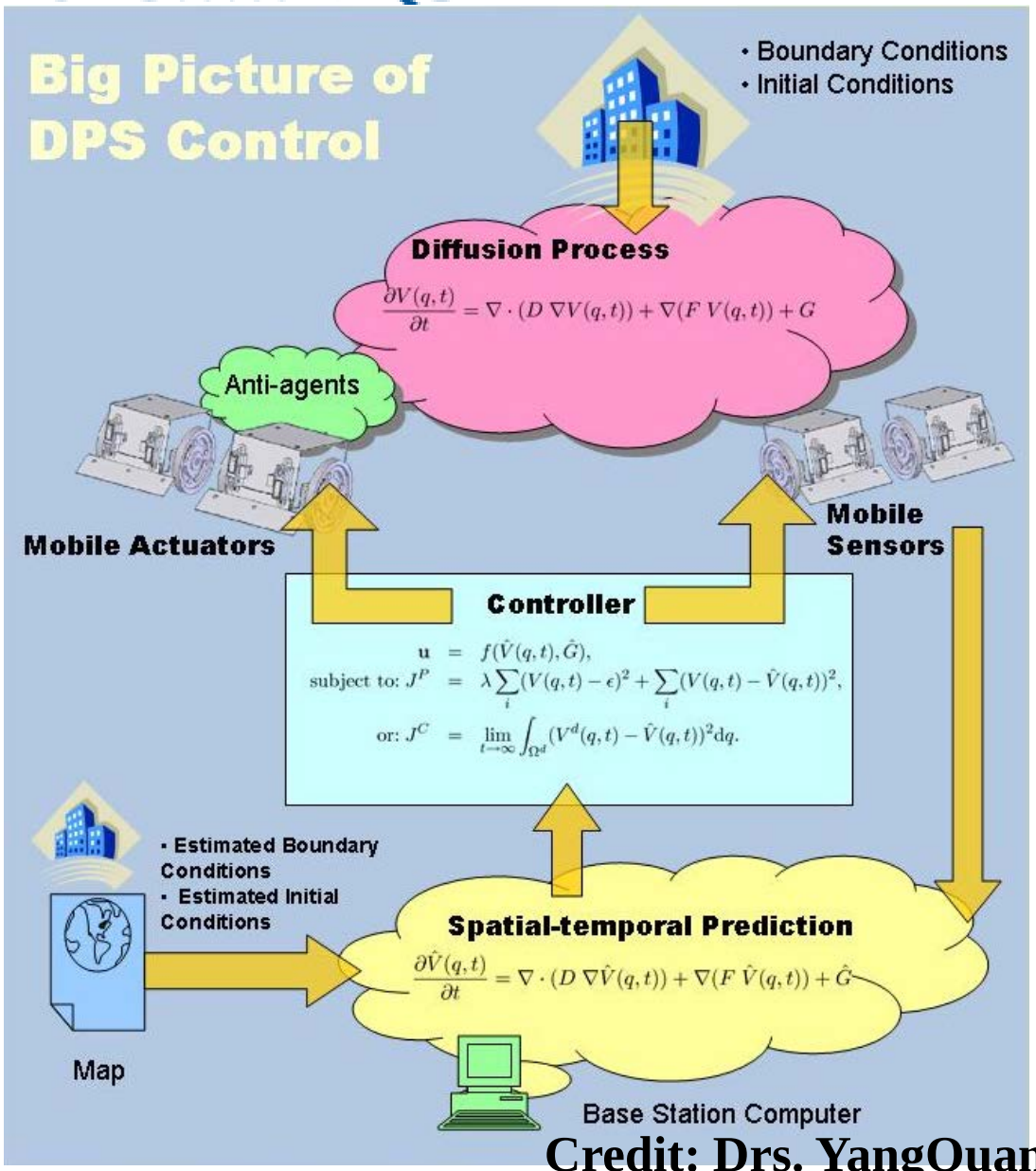


$2000 2nd Place Prize in 2005 Crossbow Smart-Dust Challenge

MAS-net

- ftp://169.236.9.29/mechatronics.ece.usu.edu/mas-net/index.htm
- Mobile Actuator and Sensor Networks (**MAS-net**), since 2002.
- An example of original research thinking/vision





DPS:
distributed parameter systems

Features:

- Domain of interest
- Sensor configuration
- Sensor effective region
- Actuator configuration
- Actuator effective region
- Mobile or static
- Communicating or not
- Collocated or not

MAS-net Project:

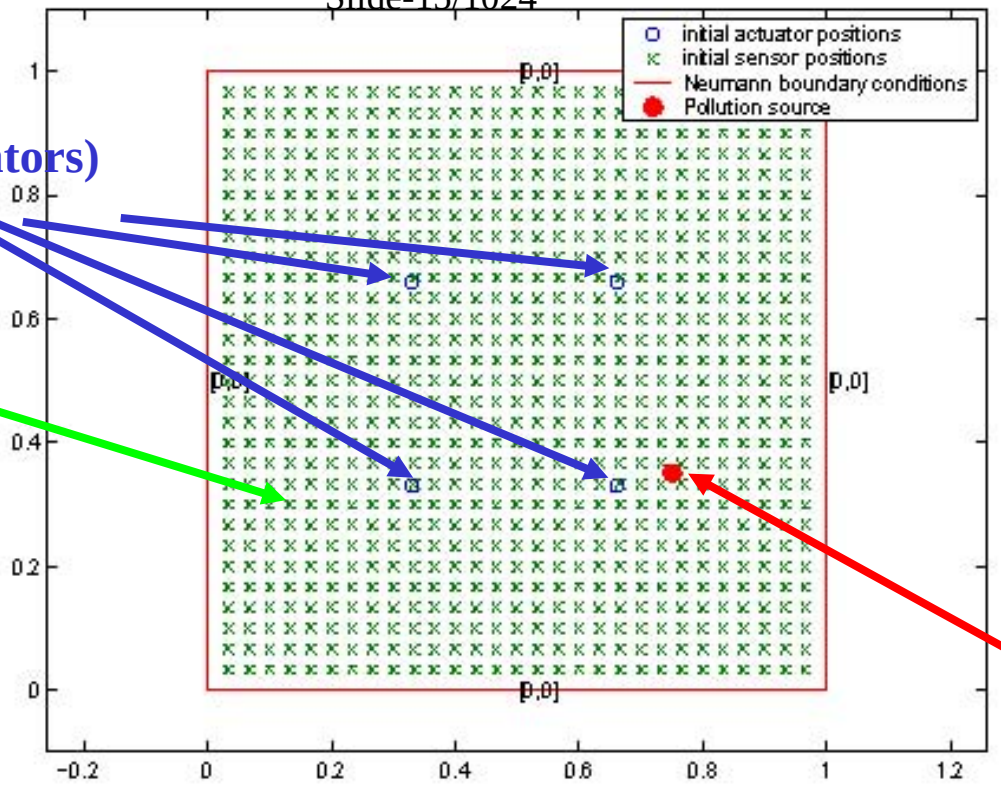
Smart Sniffing and Spraying Problem

Sensors and actuators are all mobile

Credit: Drs. YangQuan Chen and Kevin L. Moore, 2002

Mobile Robots (Actuators)

Fixed Sensors

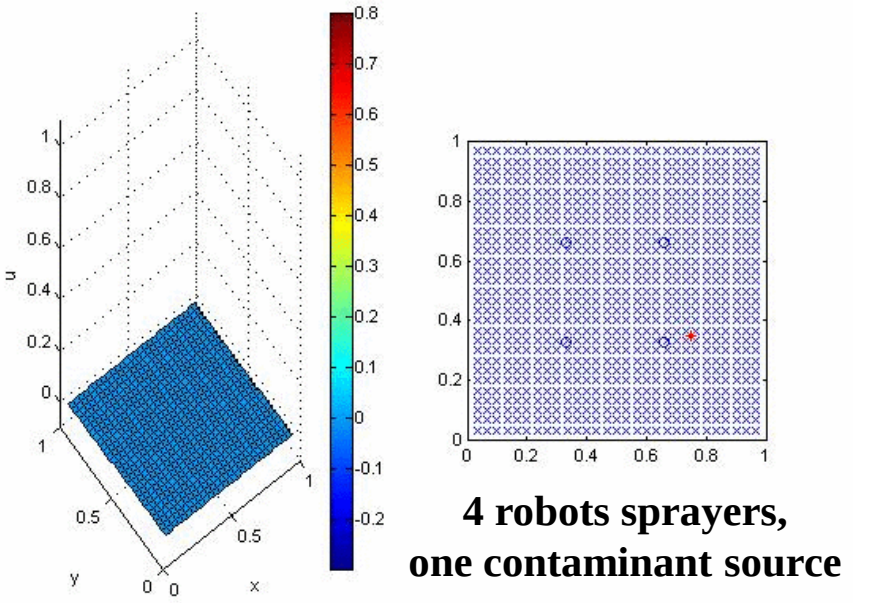


Diffusion Source

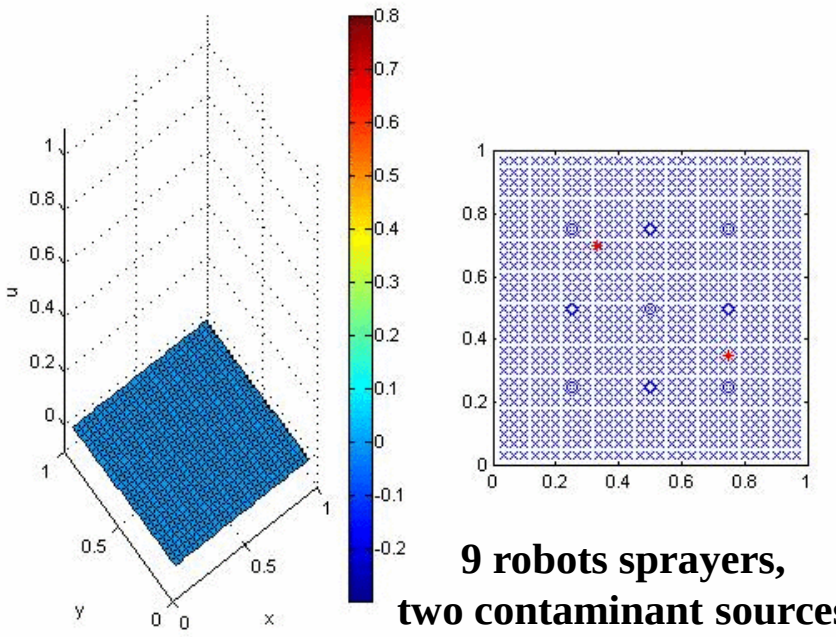
Initial layout of actuators and sensors.

Strategy:

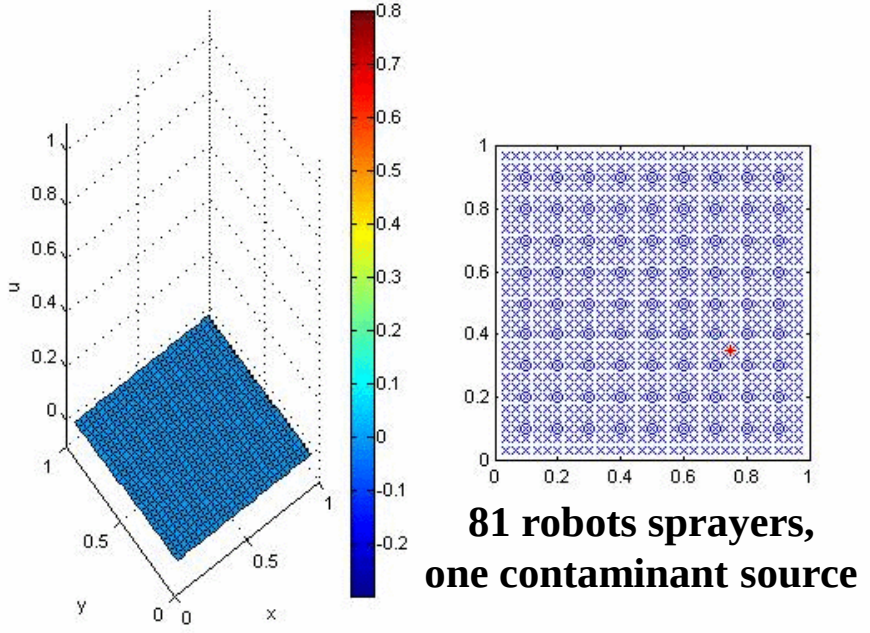
1) Form Voronoi tessellation
2) Move each robot to the mass centroid of its region
3) Spray neutralizing chemical in amount proportional to concentration in region



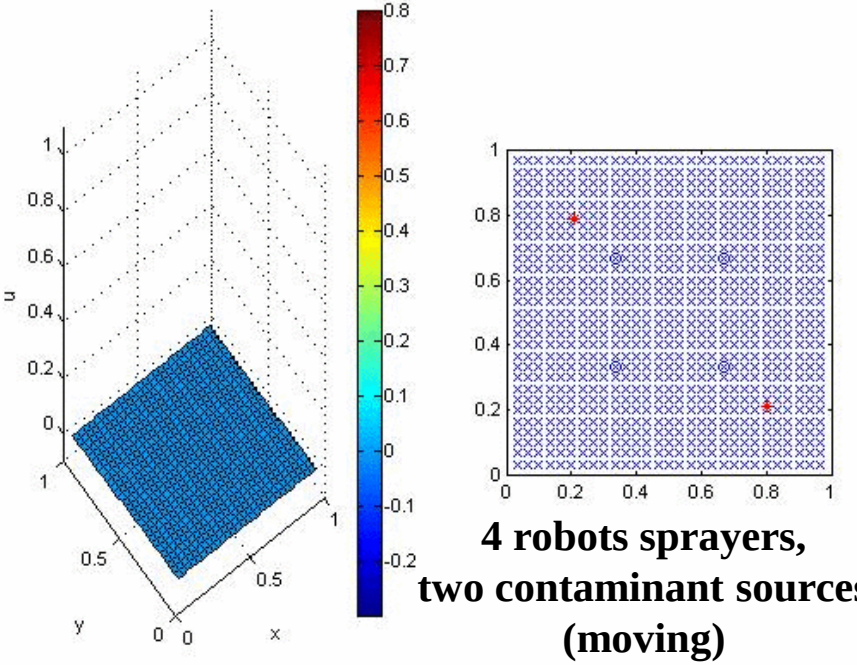
4 robots sprayers,
one contaminant source



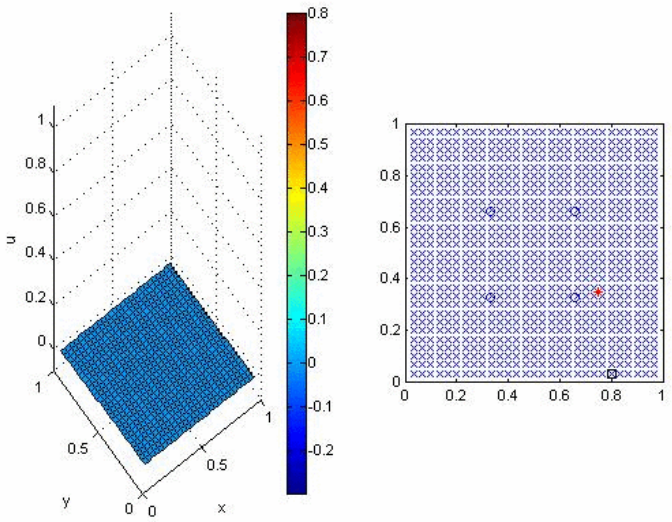
9 robots sprayers,
two contaminant sources



81 robots sprayers,
one contaminant source

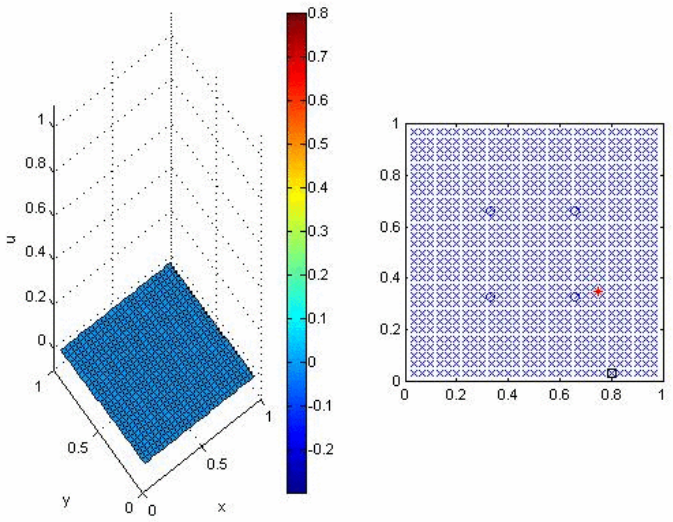


4 robots sprayers,
two contaminant sources
(moving)



4 robots sprayers,
one contaminant source, moving obstacle.

Normal potential field.



4 robots sprayers,
one contaminant source, moving obstacle.

Fractional order potential field.

Can specify the "degree of danger" of the obstacle in potential field method

WaterWatch?

Water resources, Gates, flumes

Weather, climate

demand

Water rights

Irrigation control

irrigators

Geo-Domain

human

crops

animals

etc.

UAVs

calibration

Ground sensor pods

- **Right time**
- **Right place**
- **Right amount**

www.athertonsc.qld.gov.au/ photogallery.htm

Credit: Dr. YangQuan Chen, 2005

http://www.nasa.gov/centers/goddard/news/topstory/2004/0729soilshowdown.html

My submission - “Computational” can be put in front of almost every thing

- Computational intelligence
- Computational material
- Computational neuron science
- Computational psychology
- Computational fluid dynamic
- Computational biology
- Computational chemistry
- Computational ecology
- Computational social science
- Computational virology
- ….

My submission - “Control” can be put after almost every thing

- Speed Control
- Diet Control
- Weight Control
- Emotion Control
- Arm Control
- Microclimate Control
- Machine Control
- Human Gait Control
- Blood-pressure Control
- Aging Control
- Evacuation Control/Traffic Control/Conggestion Control
- ….

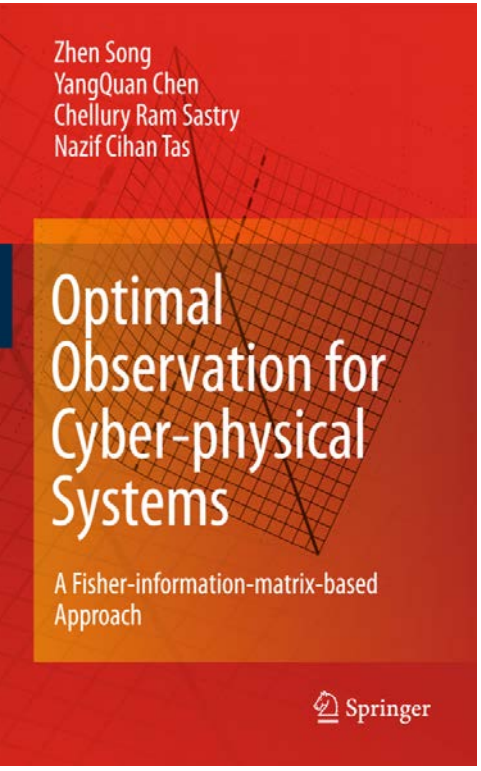
So, here comes CPS

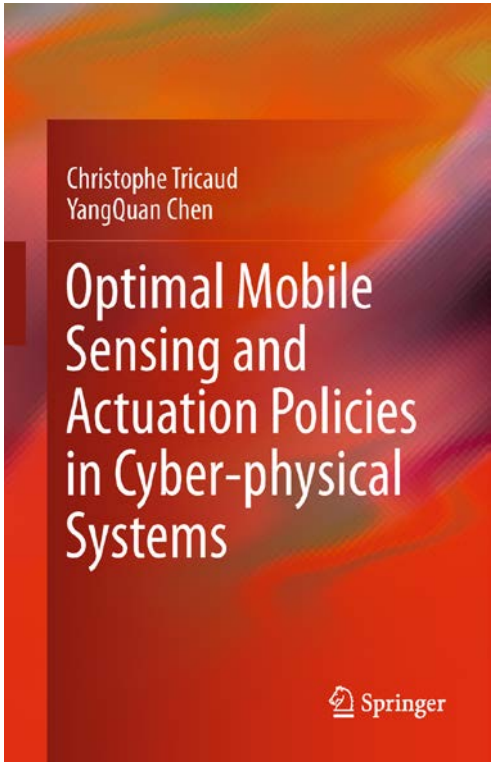
Computational Thinking + Control Thinking

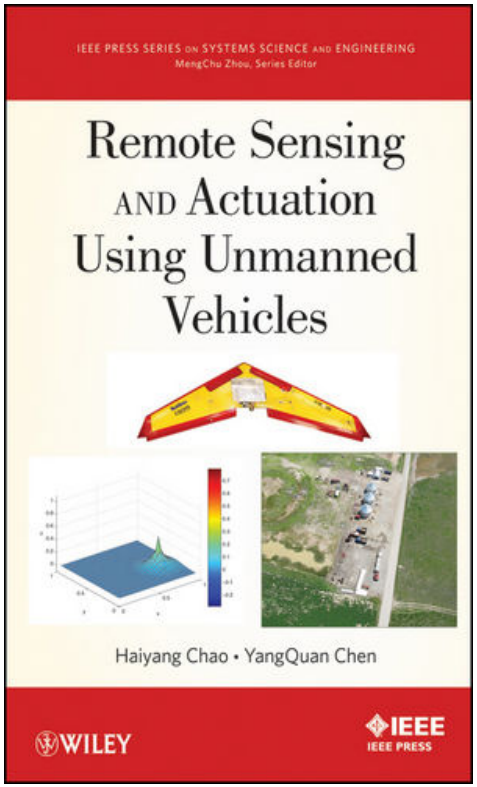
=> Cyber Physical Systems

Dr. Chen's Definition of CPS:
Computational thinking and integration of computation around the physical dynamic systems form the Cyber-Physical Systems (CPS) where sensing, decision, actuation, computation, networking, and physical processes are mixed.

Smart sensing and actuation policies







???????????

By
Brandon Stark
Brendan Smith
Tiebiao Zhao *et al*

Human-centric CPS

- http://www.ieeecss.org/e-letter/november-2008#The%20First%20International%20Symposium%20on%20Cyber%20Physical%20Systems%20%28ISCPS%29
- First International Workshop on CPS under ASME/IEEE MESA 2009.

Opportunities

- *"Drones can also take the heart rate and other physiological data from their on-the-ground operators to gauge their stress levels. The system could be trained to take over from the human operator if it decides his or her stress levels are too high or that the operator is making irrational decisions."* **May 31, 2013** Liz Goodwin

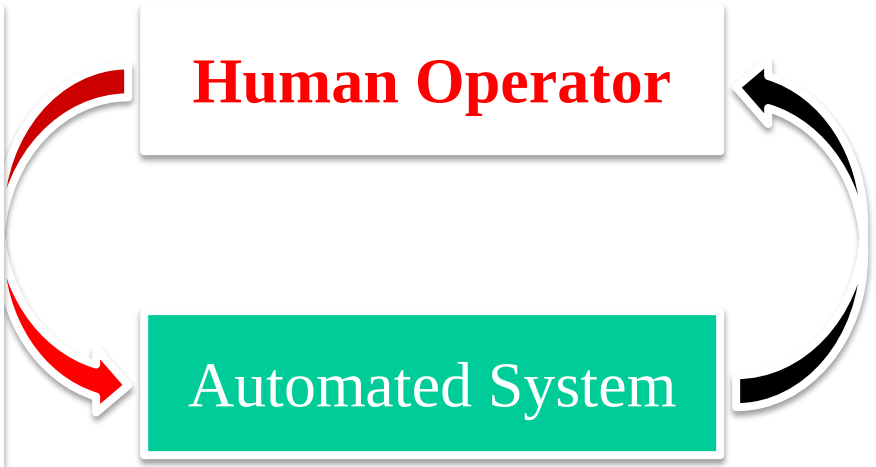
- http://news.yahoo.com/blogs/lookout/drones-enter-public-skies-2015-safe-095826982.html#more-47107

The Human-Automation Interaction Cycle

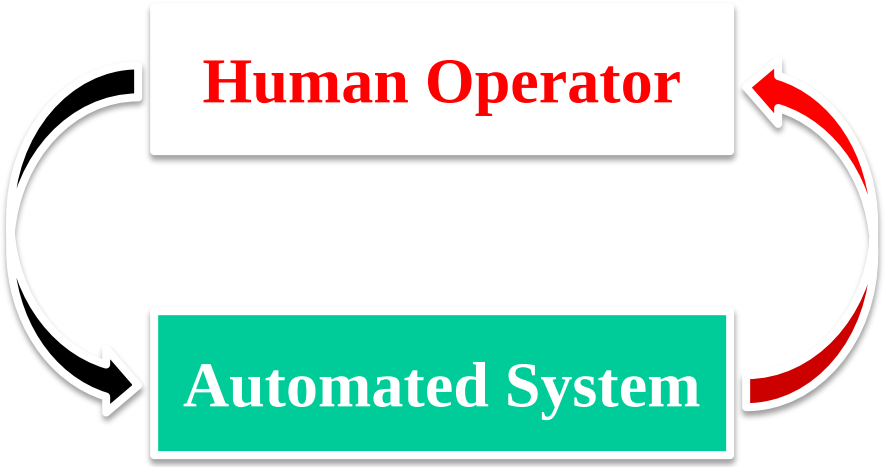
The Human-Automation Interaction Cycle

The Human Control over Automation

- Human monitors automated systems
- Human operates as the 'sensor' for correct behavior
- Safety
- Human-in-the-Loop



The Human-Automation Interaction Cycle



Automation for Human Assistance

- System monitors human
- Human health monitors for analysis
- Bio-feedback
- Emotional-feedback

Human-Automation Interaction

- Human Over Automation
  - Metrics
    - Situational Awareness
    - Cognitive Load
  - Legislative History
    - Humans act as the final safety level
- Automation Systems for Humans
  - Physiological Monitors
- State of Human Observer (SOHO)
- Next Level of Technology


STORIE IDEE E PERSONE CHE CAMBIANO IL MONDO
WIRED
EVOLUZIONE IN CORSO
HUGH HERR HA CAMBIATO LA VITA DI ATLETI COME PISTORIUS E AIMEE MULLINS
DARWIN AVEVA RAGIONE LA TECNOLOGIA INTORNO A NOI CI CAMBIERÀ
LA CASA RICARICABILE
PRODUCE ENERGIA E TI PAGA ANCHE IL MUTUO
RIVOLGERSI A MARIO CUCINELLA
SESSO
IL SIGNOR G E LA MECCANICA DEL PIACERE

What is driver's role in driverless car?

Optimal role/function assignment?

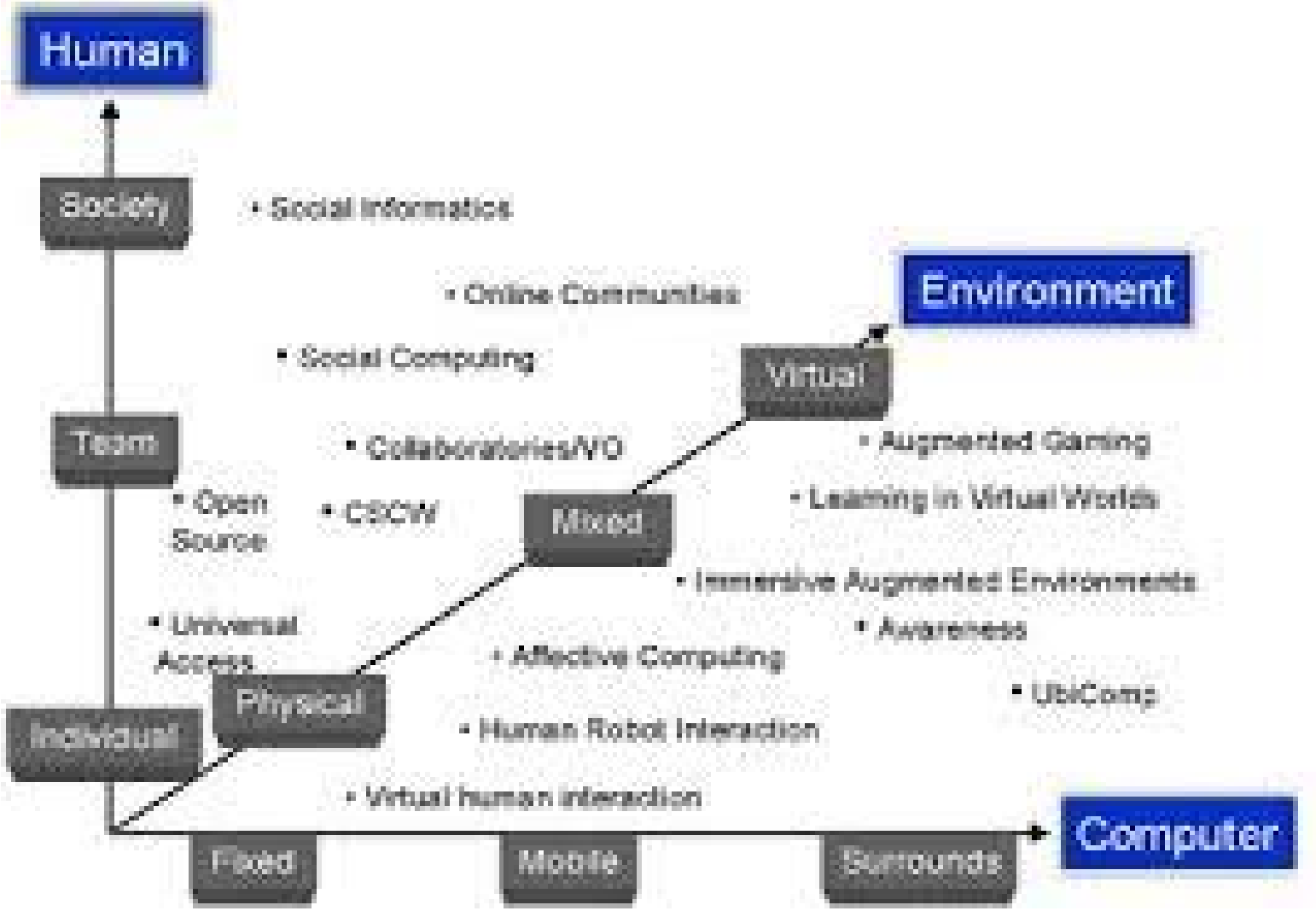
Physiology-aware; Psychology-aware

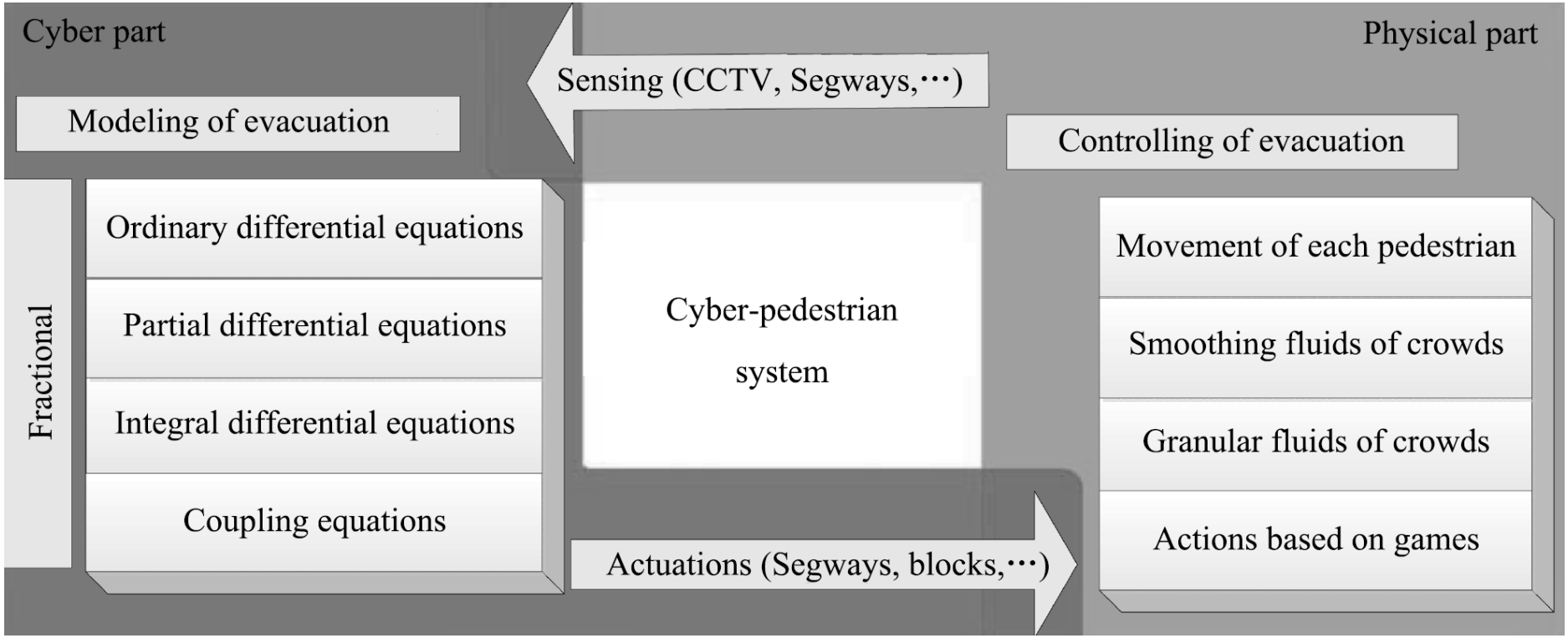
Situational Awareness

Your car reminded you: *You forgot head check when you change lane*

http://h-cps-i.sciencesconf.org/

NSF CHS (cyber-human system)





Kecai Cao, Yangquan Chen, Dan Stuart, and Dong Yue. **Cyber-physical modeling and control of crowd of pedestrians: a review and new framework**. *Automatica Sinica, IEEE/CAA Journal of*, 2(3):334–344, 2015. http://arxiv.org/abs/1506.05340.

New research monographs

- Kecai Cao, Daniel Stuart and YangQuan Chen. "*Fractional Order Crowd Dynamics: Modeling, Experiments, and Control*" (Invited book project. Volume #1 of the **De Gryuter Monograph Series "Fractional Calculus in Applied Sciences and Engineering"**, to appear summer 2017)
- Fudong Ge, YangQuan Chen and Chunhai Kou. "*Regional Analysis of Time-Fractional Order Diffusion Processes*" (275 pages, research monograph book project, contracted, **Springer London,** to appear Winter 2016 or Spring 2017) [draft book partly ready]

"cyber-human systems" 4/9/16	"cyber-physical systems" 4/9/16
• ieeeXplore: 2	• 2041
• Sciencedirect: 1	• 1318
• Google: 3750	• 450000

Dr. Chen's submission: "Cyber-Human Systems" (CHS) will be a hot topic in the next 10-20 years as human (individual, team, society/community), computer (fixed, mobile and surrounds), and environment (physical, mixed and virtual) fuse.

Cyber-Physical Systems (CPS)

- New buzzword. New NSF thematic funding thrust after ITR (info technology research)
  - MAS-net was supported by ITR DDDAS program.
    - http://mechatronics.ece.usu.edu/mas-net/
    - http://mechatronics.ece.usu.edu/mas-net/dddas
- My Definition of CPS: Computational thinking and integration of computation around the physical dynamic systems form the Cyber-Physical Systems (CPS) where sensing, decision, actuation, computation, networking, and physical processes are mixed.
- Status: 9/11/08 Google = 5180 items; ieeeXplore= 21 items; umi.com=1 item; Amazon books=0
- Status: 5/27/09: Google = **15,700** items; ieeeXplore= **44** items; umi.com=**3** item; Amazon books=**1** item
- **Fact:** CSOIS has been doing Cyber-Physical Systems research since 2002.

Déjà vu

In the next a few years …

Thank you for attending my talk!

For more information, check

http://mechatronics.ucmerced.edu/