CPS: Breakthrough Understanding Ultrafast Instabilities in a Global Cyber-Physical System

Award #1522693

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Challenge:

Future real-world CPS will be 'messy':

- Large: # of sensors, actuators 1→10^{3,4,5,....}
- heterogeneous: many types of sensors, actuators, devices, algorithms, humans
- competitive: free market, Amazon vs. Uber; limited resources → large economic game
- adaptive, dynamical: no 'steady state'
- large fluctuations: complex system
- decentralized: Amazon, Uber, Google
- complex feedbacks: human, machine, software
- · incomplete information: privacy, competition
- · imperfect information: latency, fake news
- fast: software and hardware operates faster than human reaction times
- attacks: cyberwarfare, crime, extremism, system manipulation with fake news etc.
 Instead of worrying about optimization etc., the crucial concerns for regulators, governments, society, users will be:

What might go wrong? When? How bad? What should be done about it?





Solution: Our theoretical solution (see schematic below) is unique in its analytical, many-body, scalable nature & is grounded by controlled human-machine laboratory experiments

Project Outcomes:

Approx. <u>30 publications</u>, including in *Science, Nature & Phys. Rev. Letters.* Huge <u>media attention</u>, e.g. New York Times, BBC, CNN, PBS, The Guardian. Prestigious APS 2018 Burton Award. <u>Invited by U.S. agencies at Federal &</u> <u>State level, e.g. briefings to State</u> <u>Department and FBI.</u> Importance of research discussed in 2019 <u>Congressional Hearing(s)</u> Follow-on project judged as not competitive

ecology of heterogeneous <u>machine</u> sensors/actuators

future CPS = machine behavior + human behavior

ecology of heterogeneous <u>human</u> sensors/actuators



Extremes observed in human-machine CPS systems raise serious concerns about implicit risk, safety & security of CPS that operate in everyday world

Real-world CPS

fluctuations (i.e.

experiment at

Technological

1809.05142v2

Applied Energy

25 Sep 2018

University)

arXiv:

and

al.

Nanyang

dynamics show large

extreme behaviors)

Energy conservation





Volume 237, 1 March 2019, Pages 810-821 Berkeley group Konstantakopoulos et

(d) Desk light device status pattern Patterns among all targeted resources. The on pulses point to instances that the thresholding system indicates activity in the device.



Our theory of extremes: Mathematical & empirical verification & validation



CPS, can be fulfilled using our theory (e.g. crowd anticrowd)