

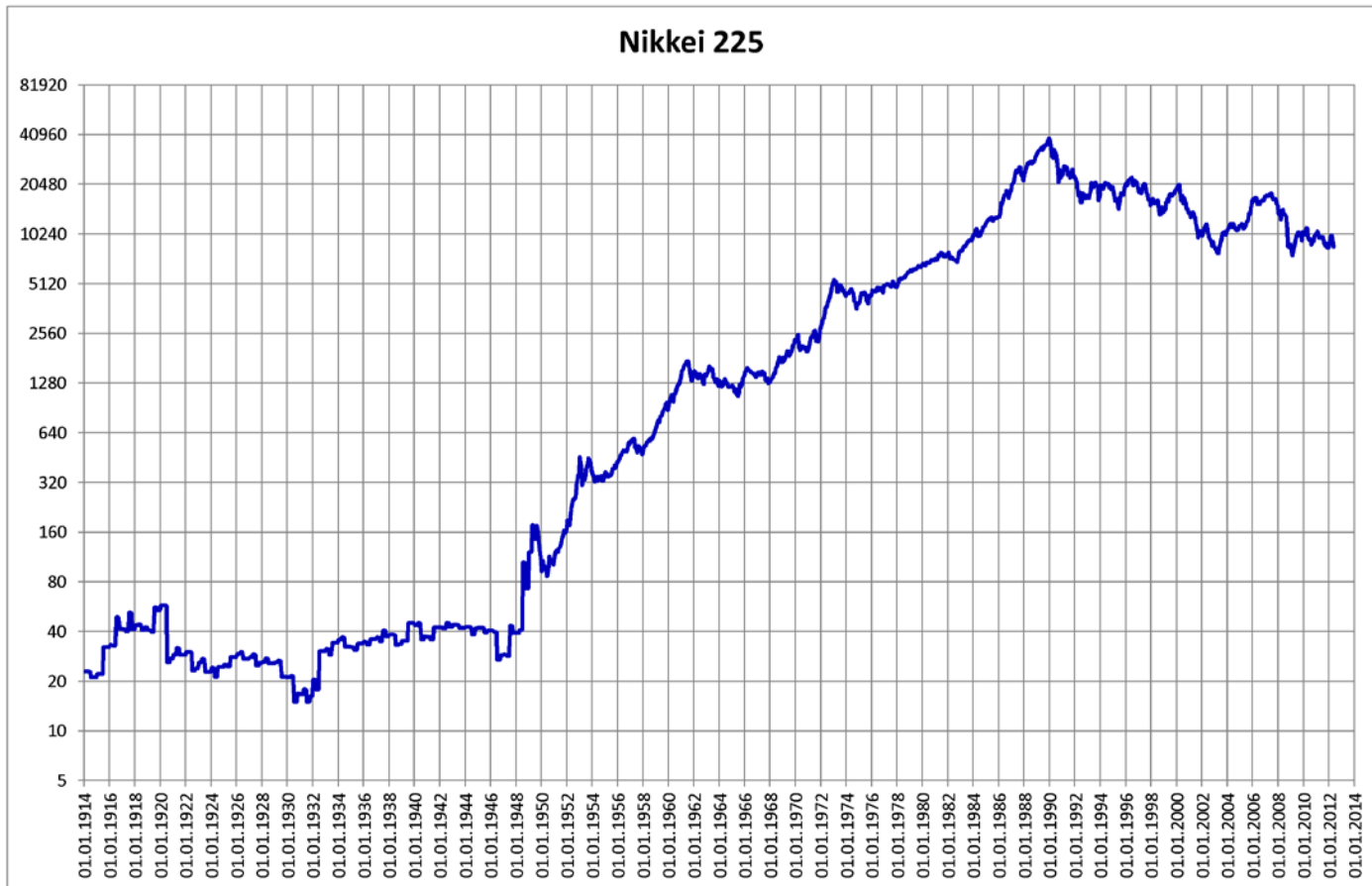
# Can Robotics Create Another Miracle?

Gill Pratt

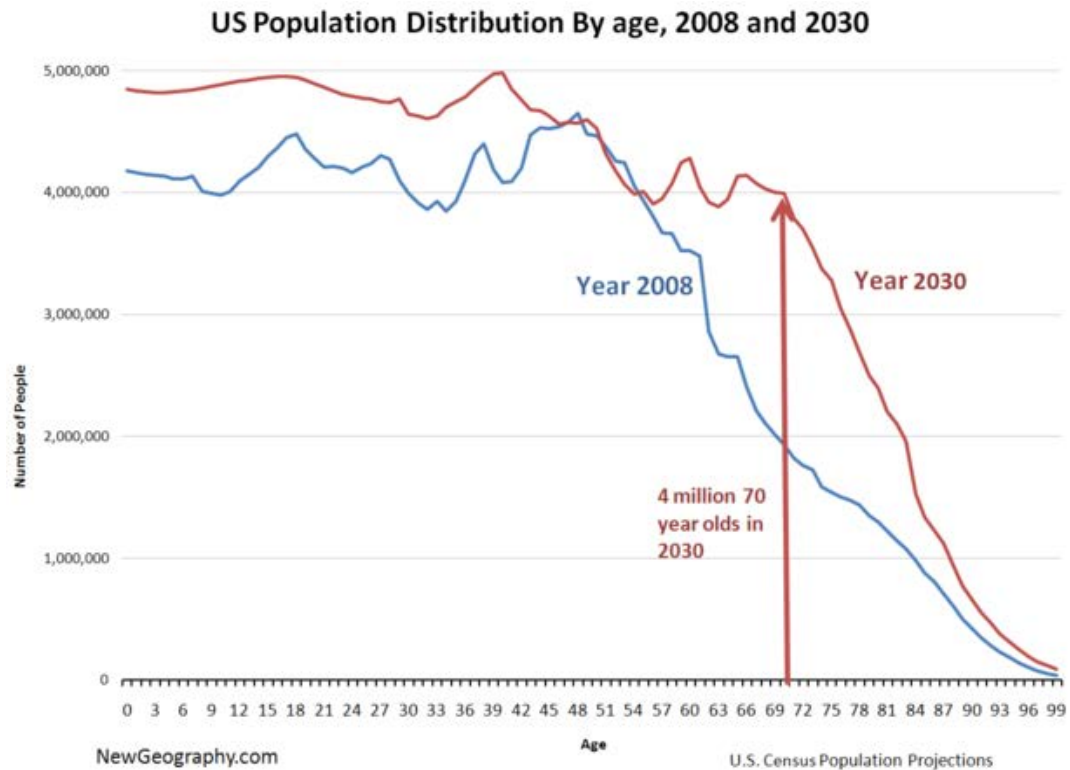
CEO, Toyota Research Institute

July 14, 2016

# Nikkei 225, 1914-2014, Log Scale

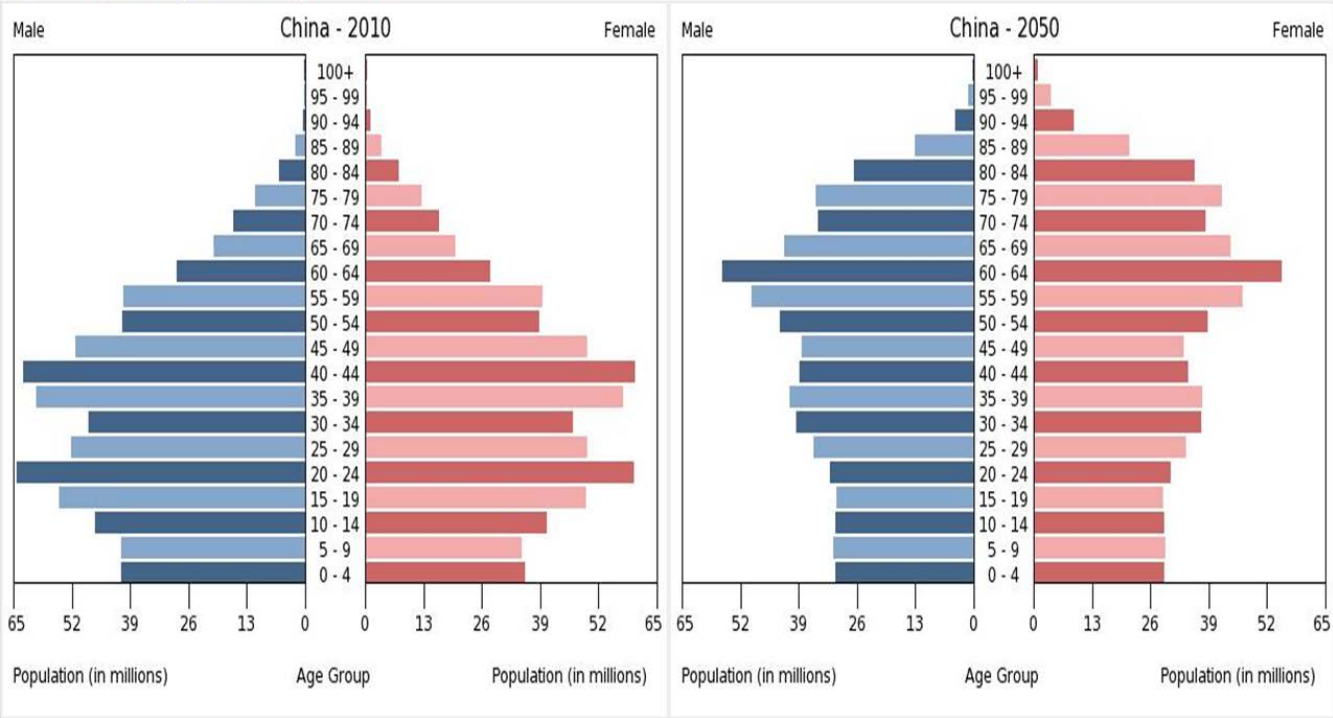


# Aging Society, US

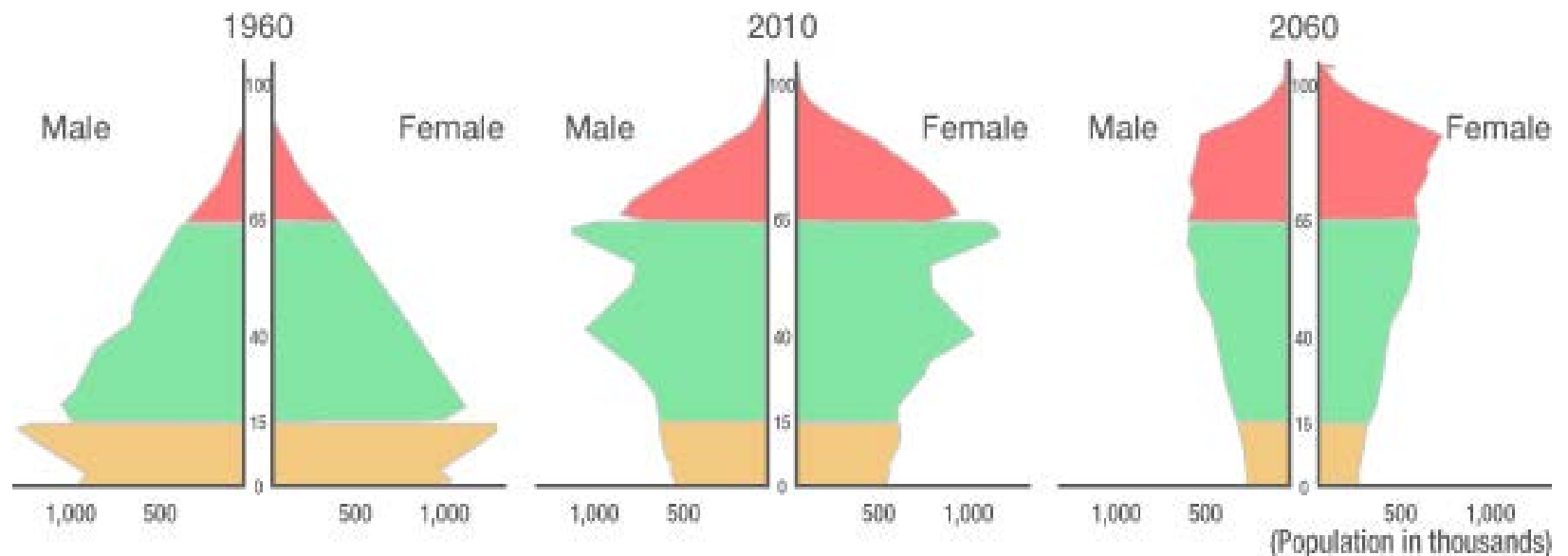


# Aging Society, China

Population Pyramid Graph - Custom Region - China



## Japan's Changing Population Pyramid (population by age)



Sources: (For 1960 and 2010) Statistics Bureau (Ministry of Internal Affairs and Communications), *Population Census of Japan*; (for 2060 projection) National Institute of Population and Social Security Research, *Population Projections for Japan* (January 2012), based on medium-variant fertility and mortality assumptions.

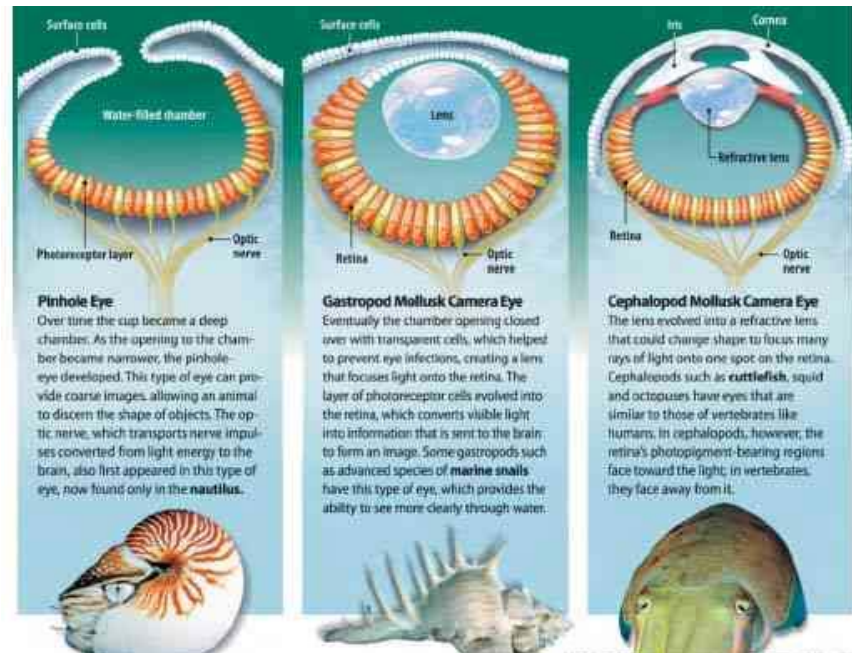
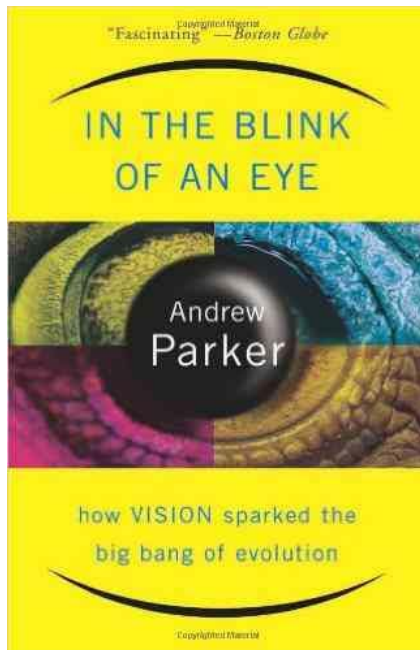
Can This Challenge be an  
Opportunity in Disguise?

*Journal of Economic Perspectives—Volume 29, Number 3—Summer 2015—Pages 51–60*

## **Is a Cambrian Explosion Coming for Robotics?**

Gill A. Pratt

# The Cambrian Explosion and Vision (About 450 Million Years Ago)





# Exponential Growth

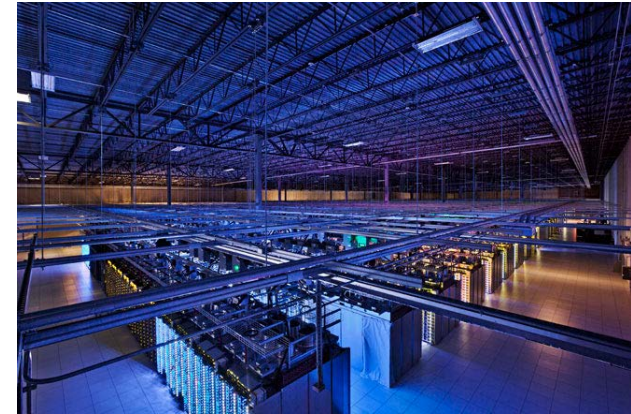
# Hyper-Exponential Growth

# Today's Technological Factors in Robotics

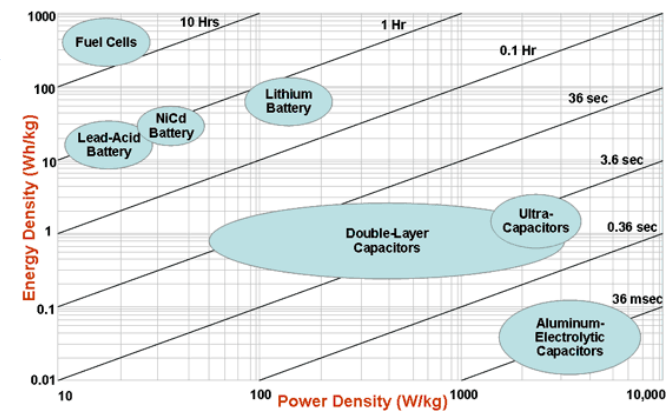
- The Billions of Devices/Year cell phone industry has created:
  - Inexpensive High Performance **Wireless Communications**
  - Inexpensive Low Power High Performance **Computing**
  - Inexpensive High Performance **Cameras and other Sensors**
  - Inexpensive High Performance **Displays**
  - Inexpensive Dense **Data Storage** on Device and Cloud
  - Inexpensive High Performance **Batteries**
  - Inexpensive High Efficiency **Power Electronics**
- Hybrid and Electric Vehicles have lead to High Performance Batteries and **Electric motor drive technology**
- Social Media Big Data, Cloud Computing, and Deep Learning has enabled **Machine Perception** to Reach Human Levels of Performance
  - **Visual Object Recognition**
  - **Speech Understanding**

# Cloud Robotics + Robotics Beyond the Cloud

- World's data storage now measured in Zetabytes ( $10^{21}$  Bytes)
  - By Comparison – Number of Synapses in Human Brain:  $\sim 10^{14}$
  - About 10 billion images have been uploaded
- World's computing capacity approaching 1 Zeta OPS
  - Google is one of world's largest consumers and manufacturers of computers
  - Highest performance video games now do 80% of their computing on the cloud
- High speed wireless connection to the internet becoming ubiquitous
  - Example Product: Google Chromecast (\$35)
- Batteries have low energy density (approx. 1/10 fossil fuels)
  - SWaP is at a premium in mobile devices
- Hard part of robotics is between the ears (of the robot)
  - Many problems get easier with lots of data + processing
    - Example: Use of maps for autonomous driving
    - Example: Visual object perception
- **Big Idea : Put the robot brain on the cloud**
  - Side benefit – all robots learn from each robot's experience
- **RESULT: Hyper-Exponential Growth**



A server room in Council Bluffs, Iowa.  
Photo: Google/Connie Zhou



Source US Defence Logistics Agency