## **Powerful But Limited:** A DARPA Perspective on Al

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## **Artificial intelligence**

Three waves of AI technology (so far)



#### The first wave is still advancing and solving hard problems

The second wave is amazingly effective, but it has fundamental limitations

New research is shaping the third wave



## Intelligence is an ability to process information

#### perceive

rich, complex and subtle information

#### learn

within an environment

#### abstract

to create new meanings

#### reason

to plan and to decide



Artificial intelligence is a programmed ability to process information



## **First-wave AI technologies**

#### Handcrafted knowledge

Engineers create sets of rules to represent knowledge in well defined domains

Al systems reason over narrowly defined problems

No learning capability and poor handling of uncertainty





**Planning tools** 



#### **Command Post of the Future**



Cybersecurity



#### **Expert systems**



## First wave stumbles on natural data

**DARPA Autonomous Vehicle Grand Challenge** 140 miles of dirt tracks in California and Nevada



**2005** # completed: 5

## # completed: 0

2004

#### The problem in 2004

Vehicles were able to follow the GPS waypoints very accurately but either missed or hallucinated obstacles ahead

#### The difference in 2005

A probabilistic algorithm interpreted the flood of incoming sensor data to learn the terrain and map out an optimal driving surface



## **Second-wave AI technologies**

#### Handcrafted knowledge

Engineers create sets of rules to represent knowledge in well defined domains

Al systems reason over narrowly defined problems

No learning capability and poor handling of uncertainty



#### Statistical learning

Engineers create statistical models for specific problem domains and train them on big data

AI systems have nuanced classification and prediction capabilities

No contextual capability and minimal reasoning ability





Apple Siri

Google

Text analysis



Image recognition

Farfade, Saberian, and Li 2015



AlphaGo



## Key enablers of second-wave AI





Many applications and big markets





## **Today's artificial intelligence is powerful...**





## ...but limited



Construction worker in orange safety vest is working on road



A young boy is holding a baseball bat

Andrej Karpathy, Li Fei-Fei



TayTweets @TayandYou					¢	2+ Follow
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## Internet trolls cause the AI bot, Tay, to act offensively



## **Future third-wave AI technologies**

#### Handcrafted knowledge

Engineers create sets of rules to represent knowledge in well defined domains

Al systems reason over narrowly defined problems

No learning capability and poor handling of uncertainty



#### Statistical learning

Engineers create statistical models for specific problem domains and train them on big data

AI systems have nuanced classification and prediction capabilities

No contextual capability and minimal reasoning ability



#### **Contextual adaptation**

Engineers create systems that construct explanatory models for classes of realworld phenomena

AI systems learn and reason as they encounter new tasks and situations

Natural communication among machines and people





## **Develop explainable AI**



why/why notI know when it will succeed/fail



# Uncover causal relationships among 1,000,000s of scientific observations



Early result: An automatically generated web of influences from 1000 research papers



## Some third-wave AI technologies

Human-machine symbiosis

#### Automatic whole-system causal models

Continuous learning

Embedded machine learning

Explainable AI

## **DARPA** R&D investments in foundational technology and applications



