Algorithmic Decision Theory and Smart Cities

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Algorithmic Decision Theory

- Today's decision makers in fields ranging from engineering to medicine to homeland security have available to them:
  - Remarkable new technologies
  - Huge amounts of information
  - Ability to share information at unprecedented speeds and quantities
- This is particularly true for those managing today's large, complex metropolitan areas – today's cities.

Algorithmic Decision Theory

- **These tools and resources will enable better decisions if we can surmount concomitant challenges:**
  - The massive amounts of data available are often incomplete or unreliable or distributed and there is great uncertainty in them

Algorithmic Decision Theory

- **These tools and resources will enable better decisions if we can surmount concomitant challenges:**
  - Interoperating/distributed decision makers and decision-making devices need to be coordinated
  - Many sources of data need to be fused into a good decision, often in a remarkably short time

Algorithmic Decision Theory

- **These tools and resources will enable better decisions if we can surmount concomitant challenges:**
  - Decisions must be made in dynamic environments based on partial information
  - There is heightened risk due to extreme consequences of poor decisions
  - Decision makers must understand complex, multi-disciplinary problems

Algorithmic Decision Theory

- In the face of these new opportunities and challenges, ADT aims to exploit algorithmic methods to improve the performance of decision makers (human or automated).
- Long tradition of algorithmic methods in logistics and planning dating at least to World War II.
- But: algorithms to speed up and improve (real-time) decision making in urban areas are much less common.

Pearl Harbor

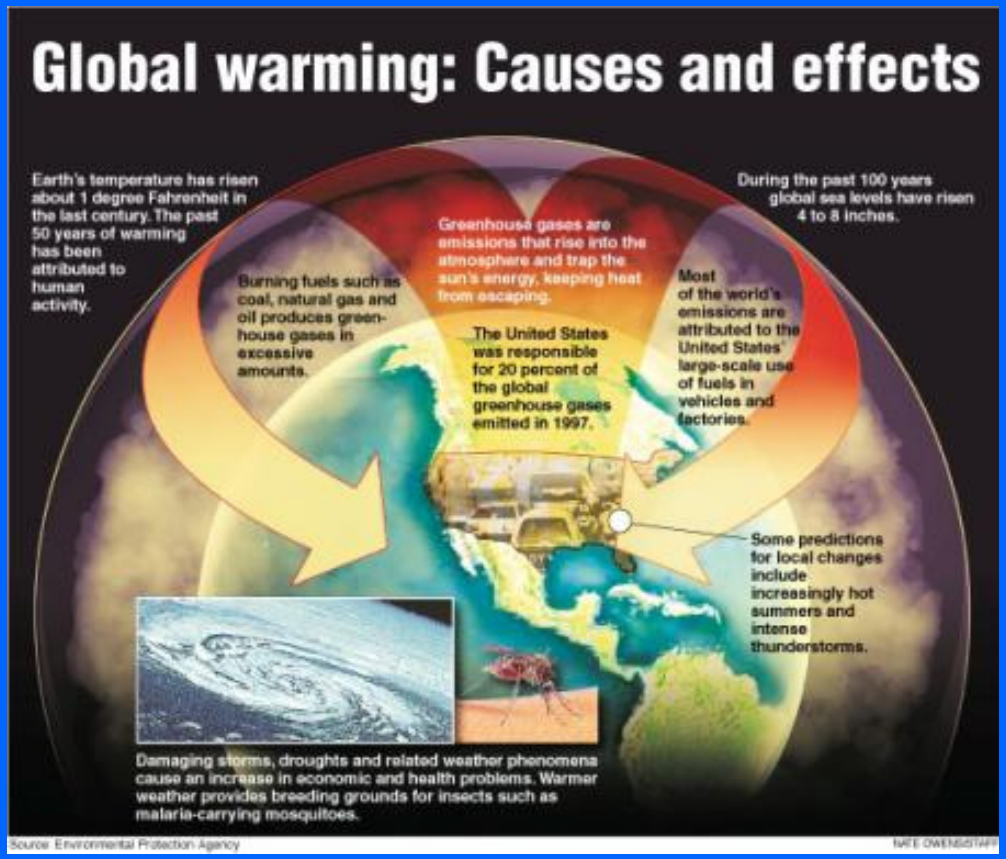
Outline

1. Climate Change
2. Handling Large Health Emergencies
3. ADT and Smart Grid

Example 1: Climate Change: (Emphasis on Health Effects)

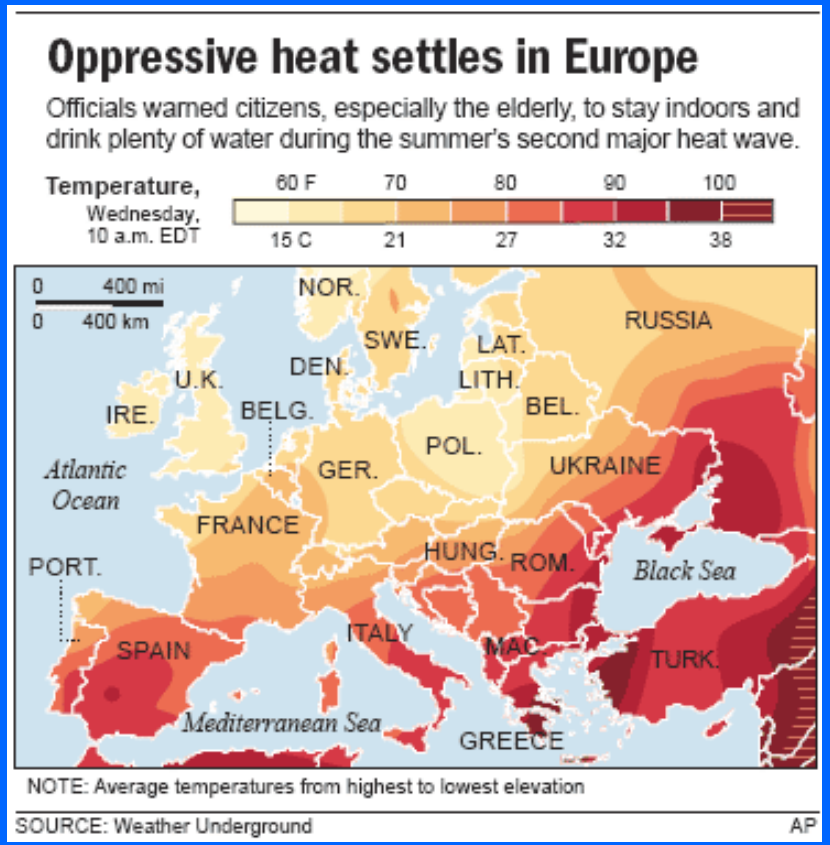
Climate and Health

- Concerns about global warming.
- Resulting impact on health
  - –Of people
  - –Of animals
  - –Of plants
  - –Of ecosystems



Climate and Health

- Some early warning signs:
  - –1995 extreme heat event in Chicago
    - ➢514 heat-related deaths
    - ➢3300 excess emergency admissions
  - –2003 heat wave in Europe
    - ➢35,000 deaths
  - –Food spoilage on Antarctica expeditions
    - ➢Not cold enough to store food in the ice



Climate and Health

- Some early warning signs:
  - Malaria in the African Highlands
  - Dengue epidemics
  - Floods, hurricanes

Extreme Events due to Global Warming

- We anticipate an increase in number and severity of extreme events due to global warming.
- More heat waves.
- More floods, hurricanes.

Extreme Events due to Global Warming: More Hurricanes

Hurricane Irene hits NYC – August 2011

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Hurricane Irene hits NYC – August 2011

- To plan for the future, NYC has a climate change initiative.
- Using mathematical modeling, simulation, and algorithmic tools of risk assessment to plan for the future
- Plan for more extreme events
- Plan for rising sea levels

Extreme Events due to Global Warming: More Hurricanes

- NYC climate change initiative is using mathematical modeling, simulation, and algorithmic tools of risk assessment to plan for the future:
  - What subways will be flooded?

Extreme Events due to Global Warming: More Hurricanes

- NYC climate change initiative is using mathematical modeling, simulation, and algorithmic methods of risk assessment to plan for the future:
  - What power plants or other facilities on shore areas will be flooded?

Extreme Events due to Global Warming: More Hurricanes

- NYC climate change initiative is using mathematical modeling, simulation, and algorithmic methods of risk assessment to plan for the future:
  - How can we get early warning to citizens that they need to evacuate?

Special Health Concern: Extreme Heat Events

- Subject of a DIMACS project.
- Result in increased incidence of heat stroke, dehydration, cardiac stress, respiratory distress
- Hyperthermia in elderly patients can lead to cardiac arrest.
- Effects not independent: Individuals under stress due to climate may be more susceptible to infectious diseases

DIMACS Project on Climate & Health: Problem 1: Evacuations during Extreme Heat Events

- One response to such events: evacuation of most vulnerable individuals to climate controlled environments.
- Modeling challenges:
  - Where to locate the evacuation centers?
  - Whom to send where?
  - Goals include minimizing travel time, keeping facilities to their maximum capacity, etc.
  - All involve tools of Operations Research: location theory, assignment problem, etc.
  - Long-term goal in smart cities: Utilize real-time information to update plans

Problem 2: Rolling Blackouts during Extreme Heat Events

- A side effect of such events: Extremes in energy use lead to need for rolling blackouts.
- Modeling challenges:
  - –Understanding health impacts of blackouts and bringing them into models
  - –Design efficient rolling blackouts while minimizing impact on health
    - ➢Lack of air conditioning
    - ➢Elevators no work: vulnerable people
    - ➢over-exertion
    - ➢Food spoilage
  - –Minimizing impact on the most vulnerable populations

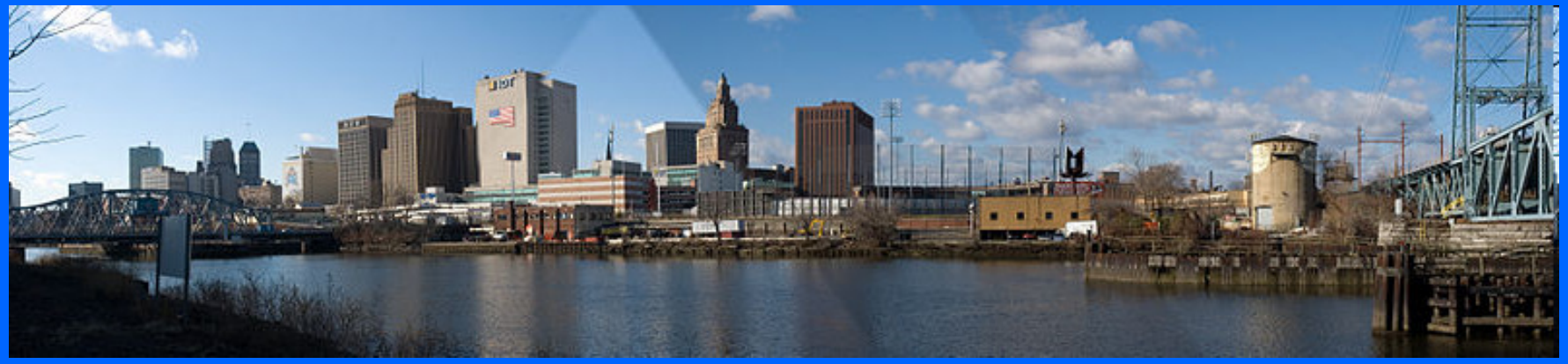
- ADT challenge: Utilize “smart grid” to update plans

Problem 3: Emergency Rescue Vehicle Routing to Avoid Rising Flood Waters

- Emergency rescue vehicle routing to avoid rising flood waters while still minimizing delay in provision of medical attention and still getting afflicted people to available hospital facilities

Optimal Locations for Shelters in Extreme Heat Events

- Work based in Newark, NJ – collaboration with Newark city agencies.
- Data includes locations of potential shelters, travel distance from each city block to potential shelters, and population size and demographic distribution on each city block.
- Determined "at risk" age groups and their likely levels of healthcare needed to avoid serious problems



Optimal Locations for Shelters in Extreme Heat Events

- ***Computing optimal routing plans for at-risk population to minimize adverse health outcomes and travel time***
- Using techniques of probabilistic mixed integer programming and aspects of location theory constrained by shelter capacity (based on predictions of duration, onset time, and severity of heat events)
- ***Smart cities: routing plans used quickly; get information to people quickly***
- ***Future: plans quickly modifiable given ADT-generated data from evacuation centers, traffic management, etc.***
- (Far from what happens in real evacuations today.)

Example 2: Handling Large Health Emergencies

Gaming Future Health Emergencies

- One way to prepare for future health crises is to "game" them.
- Modelers can help to:
  - Develop games
  - Play in games
  - Analyze the results of games

- Real-time information can make responses to health emergencies more effective and ways to do this need to be brought into our gaming.

Developing Games

- This is a hot area in computer science as many “exercises” can be “virtual”
- It involves
  - Computer game design
  - Immersive games (MIT epi game)
  - Artificial intelligence
  - Machine learning
  - “Virtual reality”
  - Theories of influence and persuasion from behavioral science

TOPOFF 3

- TOPOFF 3 was an exercise held in April 2005 in New Jersey (and elsewhere)
- Goal: ***provide federal, state, and local agencies a chance to exercise a coordinated response to a large-scale bioterrorist attack.***
- Some university faculty were invited to be official observers.
- We helped with "after-action reports" and made recommendations.
- ***Message: "smart" approaches would make both the exercise better and the outcome in a real emergency better.***

TOPOFF 3

- Scenario: simulated biological attack.
- Vehicle-based biological agent.
- Vehicle left in parking lot at Kean University in New Jersey.
- Agent later identified as pneumonic plague.

TOPOFF 3

- Local hospitals involved – patients streaming in.
- All NJ counties became ***Points of Dispensing (PODS)*** for antibiotics.
- One POD was at the Rutgers Athletic Center.

TOPOFF 3: General Observations

- Totally scripted or playbook exercise.
- Lacked random introduction of surprise or contradictory information.
  - ***Would ADT-generated models have helped the designers here?***
- No flexibility for game controller to change agenda – even after the identity of the biological agent was disclosed a week before the event started.

TOPOFF 3: General Observations

- Very quick identification of the agent as plague – less than 24 hours.
- ***No attempt to use array of databases to help in identification of the agent. In smart cities, this would be done.***
  - –Note: Pneumonic plague takes 2-3 days before symptoms appear
- No "chaos" of responding to an unknown biological agent.

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