Data Mining in Widespread Video and Other Sensors

MOUNTAIN STATE INFORMATION SYSTEMS, INC.

MISSION MOUNTAIN TECHNOLOGY ASSOCIATES

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Systems & Software Technology Conference

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PREFACE

- SSTC Conference Challenge:
  - "What are these new game changing technologies going to be?"
  - *… look into the future*
- Our Objectives:
  - Ask "*What if?*"
  - Facilitate dialogue regarding potential risks
  - Raise awareness
  - No definitive answers

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PRESENTATION OUTLINE

- Introduction (Why are we here?)
- Objectives
- General Applications (Threats, Positive Uses)
- Scenario #1
- Scenario #2
- Full Body Biometrics
- So What? Where do we go from here?

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INTRODUCTION

- What are the new risks in the exploitation of available data sources, given current/emerging technologies, and someone with a hostile intent?
  - Public (e.g. web cams, air traffic data, weather stations, others)
  - Private – behind firewalls (security cameras in stores, airports, etc.)
- What are the new business opportunities for someone with a non-hostile intent?

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EXAMPLE SCENARIOS

- Non-hostile applications
  - "Big Brother" Auto Insurance
  - Coordinate resources during an "Amber Alert"
- Threats
  - Use public sensor data to plan / execute a terrorist attack, or coordinate a robbery
  - Use public sensor data to search for missing children – for human trafficking

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PRESENTATION OBJECTIVES

From Initial Abstract

1. Summarize applicable technologies
2. Review statistics
3. Discuss firewall vulnerabilities
4. Explore applications enabled by access to data from a variety of sensors

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#1: APPLICABLE TECHNOLOGIES

- Data mining, Feature extraction & Pattern recognition
  - ***(text)*** Content analysis, conflation
  - ***(imagery)*** Segmentation, template matching
  - ***(video)*** Object-based methods – HTM [Hawkins]
- Change detection
  - Image differencing, change vector analysis, correlation change image
- Artificial intelligence
  - Machine learning, genetic algorithms / evolutionary programming, neural networks, support vector machines
  - Low power, noise tolerant hardware (NeuroGrid [Boahen])

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#1: APPLICABLE TECHNOLOGIES

- Data correlation & Data fusion
  - Normalized Cross Correlation (NCC), Fast Fourier Transform (FFT), Mutual Information [Cole-Rhodes]
- Data compression
  - Discrete Cosine Transform (DCT), Wavelets, MPEG4
- Real-time data processing
  - CloudShield “deep packet inspection”
  - IBM InfoSphere Streams

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#2: STATISTICS

- Current number of web cams and other sensors:
  - Not easily obtained – unknown –
- Annual Growth Rate
  - Again unknown – exponential?
- Type
  - Streaming video
  - Still-frame web cams
  - Air traffic data
  - Weather stations
- Mode
  - Real-time - Really real-time? Or varying latency?
  - On line data archive

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#3: FIREWALL VULNERABILITIES

Compromising Sensors on Private Networks

Many Methods

- Automated password attack
- Phishing
  - Kneber botnet
- Security lapses
  - Predator UAV hack via SkyGrabber software
- Bottom Line: We need to presume that any system may be vulnerable to compromise

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#4: THREATS AND APPLICATIONS

The previous 3 objectives set the stage for the rest of the briefing

There are hostile threats and opportunistic applications enabled by access to data from a variety of sensors

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THREATS / OPPORTUNISTIC APPLICATIONS

COMMON TASKS

- Evaluation (scoping)
  - Identifying the data sources
  - Accessing the data
  - Extracting information / Processing data
  - Acting on the information
- Countering potential threats / opportunistic applications
  - Known vs. unknown
  - Today's briefing purpose: Raising awareness, not proposing a full set of solutions

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IDENTIFYING THE DATA SOURCE

- What type & where are the sensors?
  - "Where" = both IP address & Lat / Long
  - Summarized on web sites
  - Automated "spider"
- Is the data quality (e.g. resolution of a web cam) adequate for the application?
  - Perhaps not today, but constantly improving
- Is the data rate adequate?
  - Can the data support the application?

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ACCESSING THE DATA

- Publicly accessible vs. those behind firewall
- Connecting
  - Bandwidth & number of simultaneous connections
  - Storing and/or processing
  - Disk space, processing speed
  - Will our connection be detected? Covert connection required?
- Real-time threats vs. storing data for weeks (or mining archive data) and then acting on it
  - Real-time threat – no need to store data

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EXTRACTING INFORMATION

- Automated vs. Manual
  - E.g., Coordinating a robbery or preplanning a terrorist attack, manual monitoring of web cams may be adequate
  - For facial recognition (e.g., supporting an “Amber Alert”), automation would be critical
- Automated Feature Extraction:
  - What features do we need?
  - What methods do we use?
  - How quickly do we need an answer?

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EXTRACTING INFORMATION

- Automated Feature Extraction
  - Object Detection
    - *Change detection, segmentation*
  - Preliminary Classification (? Of interest / Ignore ?)
    - *Template matching, clustering*
  - Tracking
    - *MPEG-4 object-based compression (I, B frame)*
  - Detailed Classification / Identification
    - Method depends on application & metrics

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ACTING ON THE INFORMATION

Carry out the Attack

- Depends on the Application / Threat
- Timeliness of the Data
  - "Take into Custody" the target person
    - You must be prepared to act FAST
  - Some scenarios do not require "instantaneous" action
    - "Big Brother Auto Insurance"
    - Can do analysis at your leisure

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COUNTERING THREATS / OPPORTUNISTIC APPLICATIONS

- Threats identified in advance
  - Prevent the threat before it is started
  - Stop the attack in real-time once it has started
- Identifying unknown threats
  - Can previously unknown threats - attempts to exploit data sources - be detected?

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EXAMPLE SCENARIOS

- Non-Hostile Applications / Opportunism
- Hostile Threats

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HYPOTHETICAL OPPORTUNITIES (NON-HOSTILE)

- "Big Brother" Auto Insurance Company
  - Capture and store traffic camera data, then replay to identify fault after an accident
  - Map severe weather data to corroborate or invalidate crop damage claims
- Search for or Follow Individuals
  - Build profile of target based on photos, videos, other data
  - Software provides an alarm when individual sighted, or a report of where the individual has been – time/date stamped
  - Monitor a spouse, child, etc.

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HYPOTHETICAL THREATS (HOSTILE)

- Terrorism, Theft, Personal Vendetta
  - Traffic web cams or "site of interest" video for planning or coordinating an attack/theft
  - Monitoring known targets (ref: www.PleaseRobMe.com)
- Identity Theft / Targeted Phishing:
  - Monitor video in Dept. stores for key shoppers (e.g. Mx. Bigspender)
  - Targeted phishing the next day "your purchase at Bloomingdales was rejected… Enter account info…" → Capture credit card #
  - *Ignores question of "how do they know how to match her face and email address?"*
- How would a terrorist exploit live video feeds or real-time airport traffic data from a major US city?
  - *Let's discuss privately*

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BIG BROTHER AUTO INSURANCE

The Application:

- An auto insurance company records all available traffic video for 14 days
- Upon notification of any traffic accident, the historic video is reviewed to locate the participants
  - Can fault be proven?
  - Evidence of reckless / drunk driving or road rage?
  - Other scenarios (drivers switch after accident)?
  - Automated methods? Minimal…

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BIG BROTHER AUTO INSURANCE

Scope

- 85 traffic cameras in Manhattan
- Bandwidth required = 256 kb/sec/camera
  - Disk storage for 14 days = 3.6 TB
- Assumes full motion (> 5 frames/second)
  - Ambiguity in exactly what happened?
- Size of car in image = 15 - 150 pixels
  - Positive ID possible?
- Traffic lights, pedestrians, other pertinent details visible?

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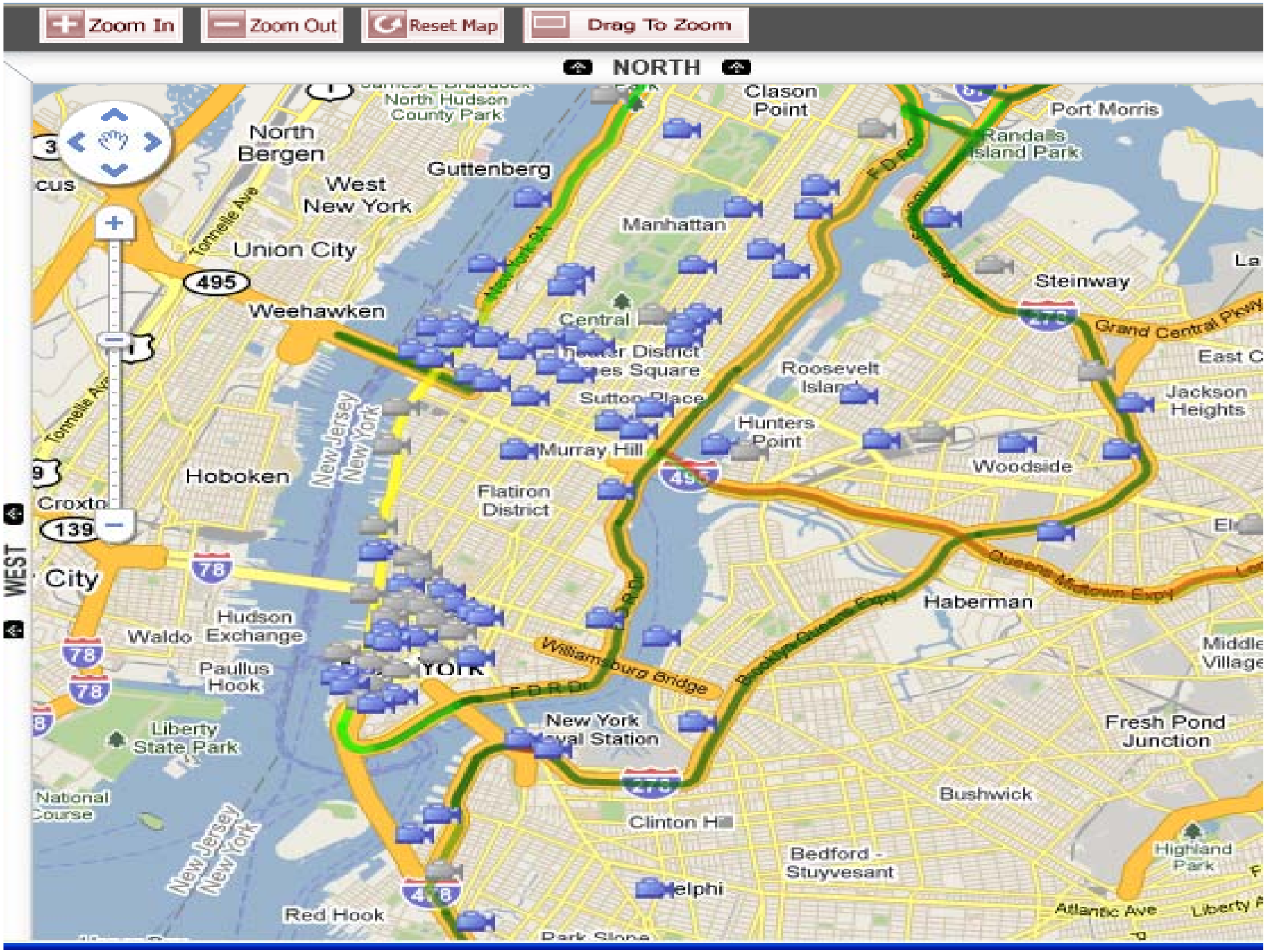
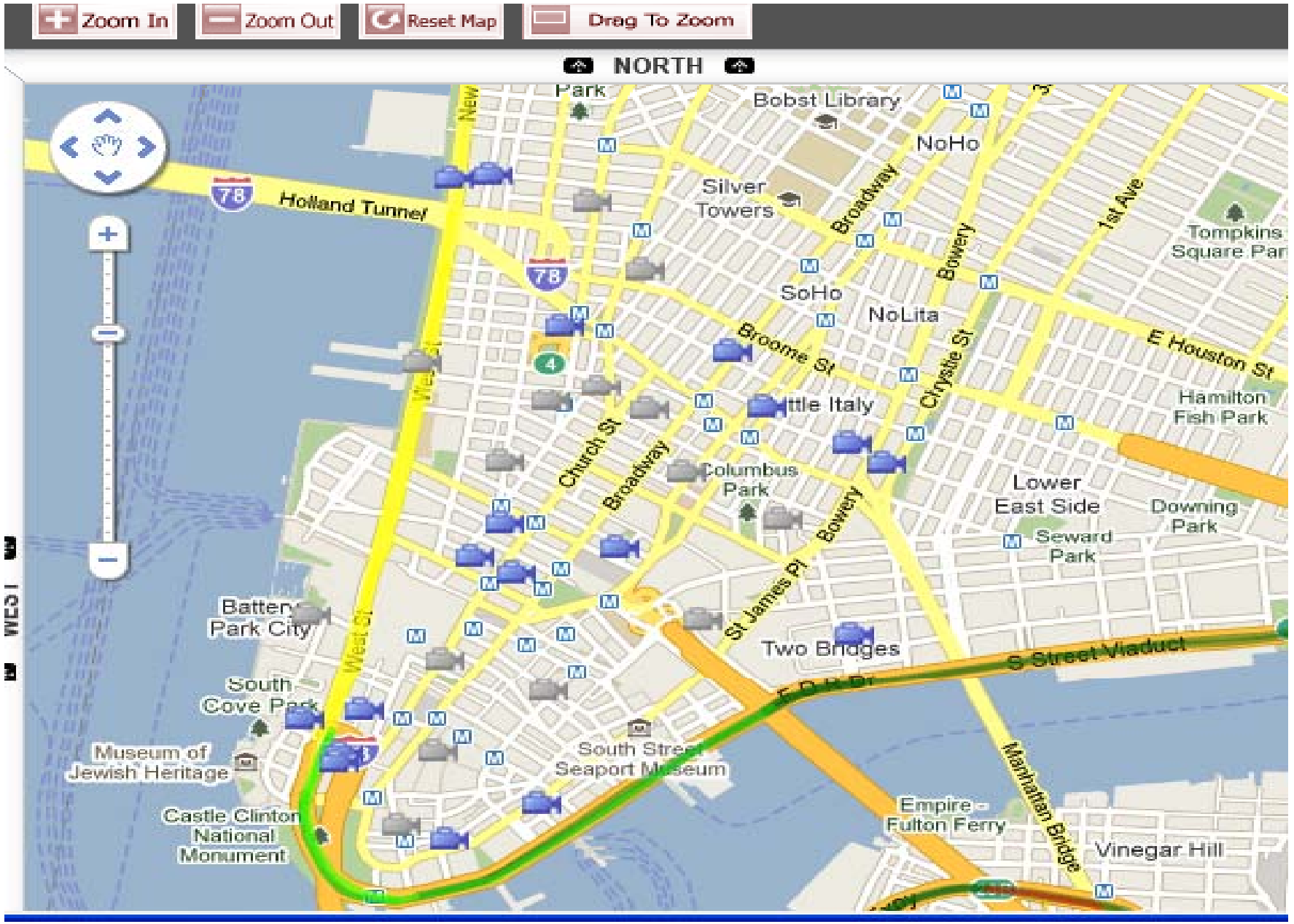
Data Sources – NYC web cams



Data Sources – NYC web cams



BIG BROTHER AUTO INSURANCE

- Data Analysis
  - Map web cams to Lat/Long
  - Locate proper time sequence in video stream, at accident site & prior inbound traffic points
  - Automated methods for identifying target of interest, accidents, risky behavior?
- Other Issues
  - Web cam coverage and resolution (HD) increasing
  - Legal to use as evidence?
  - Can insurance companies already get this data from the government without having to set up their own data center?

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Video Examples

- MD-DOT – 128 kbps

  http://www.chart.state.md.us/TravInfo/trafficCams.asp

- MD-DOT – 4 cameras

  http://www.chart.state.md.us/video/video.asp?feed=n

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SEARCH FOR INDIVIDUALS

- Applications
  - Casino security – big spenders, suspicious people
  - Amber Alert – find missing children
  - Human Trafficking – find missing children
  - Search for Terrorists / Escaped Prisoners
- Can individuals be identified in public web cams?
  - Facial identification metrics
    - Interpupillary distance, etc.
    - Do web cams provide adequate detail?
    - If not today, is it conceivable in the near future?
  - Full body biometrics
    - Body dimensions
    - Gait, other dynamic metrics

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SEARCH FOR INDIVIDUALS

Scope

- Difficulty
  - "*Amber Alert! Find this face anywhere in Manhattan*." VERY HARD
  - "*Follow my husband, ensure he takes the Jerome Avenue line, exits at 176th, goes to Murphy's for lunch*." A LITTLE EASIER
- X number of cameras in Manhattan
  - Restaurants, Department Stores, others on known routes?
- Bandwidth "required" = 256 kb/sec/camera
- Full body biometrics "requires" continuous motion (> 10 - 30 frames/second)
- Height of person in image = 15 - 150 pixels

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SEARCH FOR INDIVIDUALS

Data Analysis

- *Automated methods for identifying targets of interest*
- Build geospatial map of web cam locations (if necessary)
- Locate proper time sequence in video stream (for possible later detailed analysis)
- Not completely realistic today… Too few data sources, but web cam coverage and resolution (HD) increasing

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SEARCH FOR INDIVIDUALS

Other Issues

- Non-public data sources
- Police could build a private network of cameras on every road in/out of a city
  - Monitor for people based on stolen vehicle ID and/or facial recognition
  - Expand to capture every street, sidewalk, doorway, etc. in a city?
- Cameras to monitor every entrance to a school?
- Personal Freedom? Is this George Orwell's 1984?

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SEARCH FOR INDIVIDUALS

Video Examples

- Times Square Video

  http://www.earthcam.com/usa/newyork/timessquare/

- Times Square HD Video

  http://www.earthcam.com/usa/newyork/timessquare/?cam=lennon_hd

- Video tools from Vitamin D
  - Follow objects in motion
  - Trigger on objects / people crossing thresholds

Think about Full Body Biometrics

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FULL BODY BIOMETRICS

- Objective: Unique individual identification based on multiple views and dynamic analysis extracted from video subsets, using a multi-resolution data model compiled over time
- Applicable to other animals and objects (automobiles etc.)
- Full individual recognition based on a composite of numerous biometrics, all of which may be partially complete

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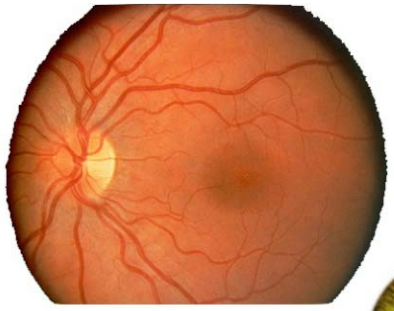
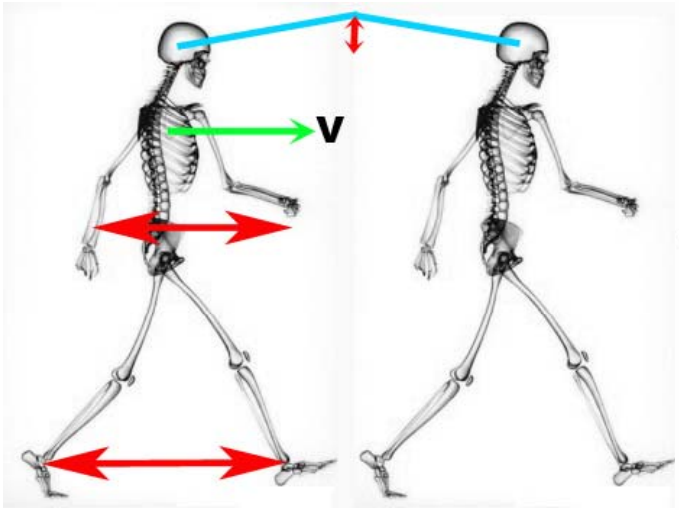
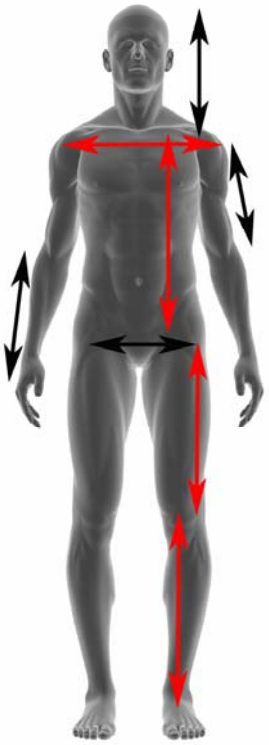
EXAMPLE METRICS



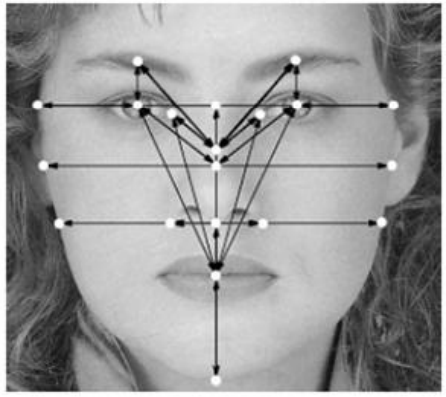
MICRO



MACRO



MID



SUPER MACRO

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DATA MODEL

- Four spatial scales
  - Micro, mid, macro, and supermacro
  - Network (Tree) data structure
  - Wavelets / Fractals for data compression
- Dynamic motion analysis integrated at macro/supermacro scales
  - Eigenvectors / Eigenvalues used to extract unique features at each scale
  - Populate predefined data models for high value targets (people on a watch list)

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METRICS AS A FUNCTION OF SCALE

Scale \ METRIC	Texture	Specular reflection	Corners	Edges	Color	Speed	Acceleration	Pose	Gait	Motility (3D, 5D, 6D)	Rigidity	Centers of mass	Traffic / Flow	Population
MICRO	*	*	*	*	*									
MID		*	*	*	*						*	*		
MACRO		*	*	*	*	*	*	*	*	*	*	*		
SUPERMACRO						*							*	*

This is in addition to classic biometrics, e.g. facial metrics, iris/retina scan, etc.

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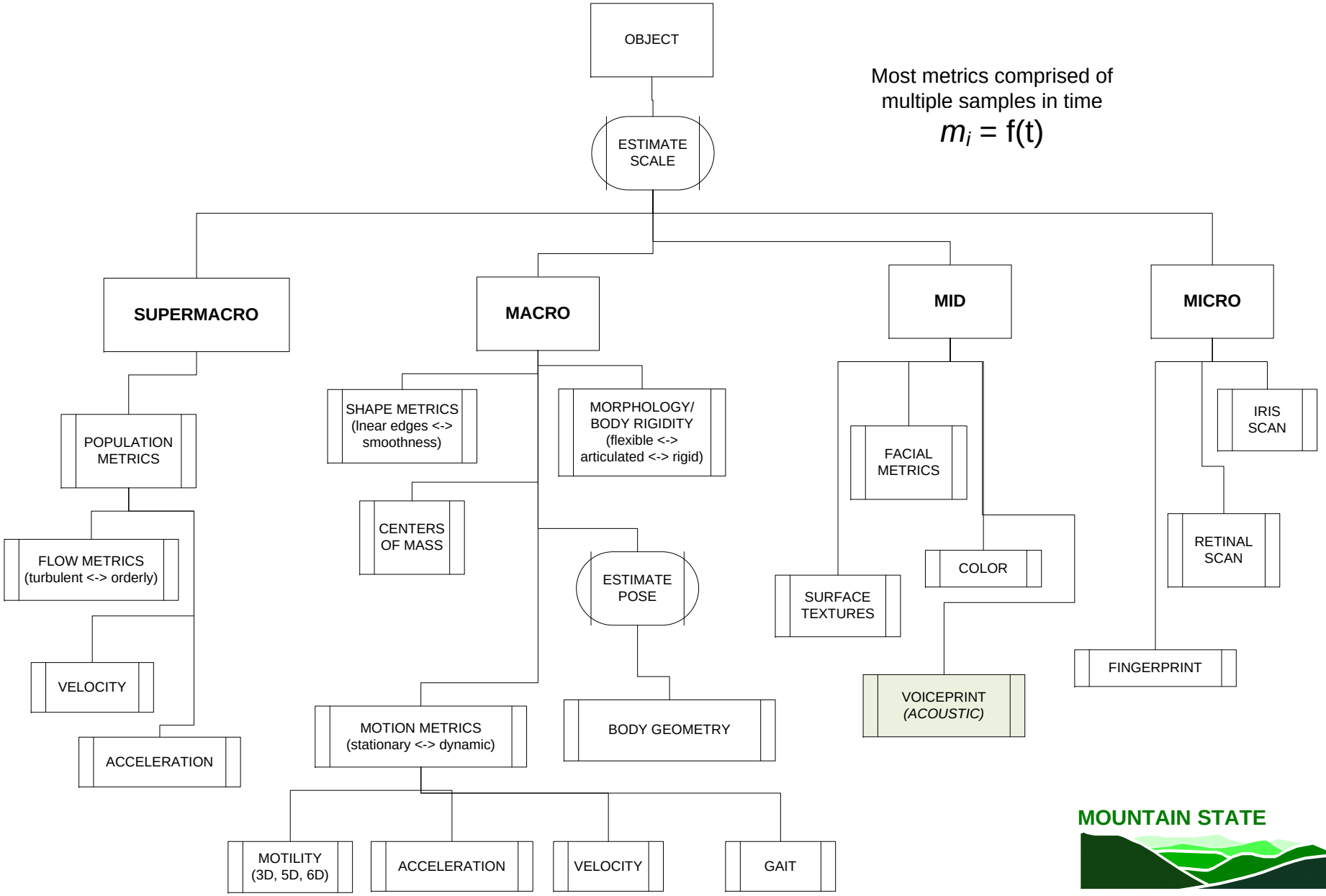
DATA MODEL



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SUMMARY

- A Glimpse into Our Vision of the Future wrt Data Mining of Video
- Scenarios: Opportunities and Threats
  - Big Brother Insurance Company
  - Search for Individuals
- Common Tasks
  - ID Data Sources
  - Access the Data
  - Extract / Process the Data
  - Act on the Information
- A lot possible today. More coming.
- Will there eventually be so many video cams that almost everything is captured? Available? Ripe for analysis?
- Will Full Body Biometrics provide an important augmentation to other methods, especially in scenarios that require covert monitoring?

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TAKEAWAY MESSAGES

- Technology is available – or nearly ready – to act on these threats/applications
- Data quality and data coverage are lacking, but gaining fast
- Technology cost is high, but dropping
- We in the tech community need to be careful about what we offer to the world, and think about risks
- Full body biometrics offers great promise
- Continuing studies need to be performed
- Continue research to serve the needs of the defense / intel communities

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- CloudShield: http://www.cloudshield.com/

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DATA SOURCES

- Object tracking video
  - Numenta
    - http://www.numenta.com
  - Vitamin D
    - http://www.vitamind.com/demo.php
  - General Electric
    - http://ge.geglobalresearch.com/technologies/imaging/

- Traffic
  - NYC:
    - http://www.earthcam.com/usa/newyork/timessquare/
    - HD: http://www.earthcam.com/usa/newyork/timessquare/?cam=lennon_hd
  - NYC: http://nyctmc.org/
  - California: http://www.video.dot.ca.gov/

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DATA SOURCES

- Air Traffic
  - http://www.passur.com/airportmonitor-locations.htm
  - NY
    - http://www4.passur.com/jfk.html
    - http://www4.passur.com/lga.html
  - CA
    - http://www4.passur.com/sna.html
    - http://www4.passur.com/bur.html
    - http://www4.passur.com/san.html

- Weather
  - www.anythingweather.com/
  - wxqa.com/stations.html
  - www.space.com/php/weatherbug/
  - www.met.utah.edu/mesowest/
  - Summary at http://www.dslreports.com/faq/13342

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