

Modeling the Theoretical Performance Limits of Biometrics

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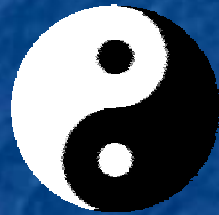
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Biometric Performance Modeling

"All models are wrong; some are useful"

- George E. P. Box

The
Science
of
Biometrics



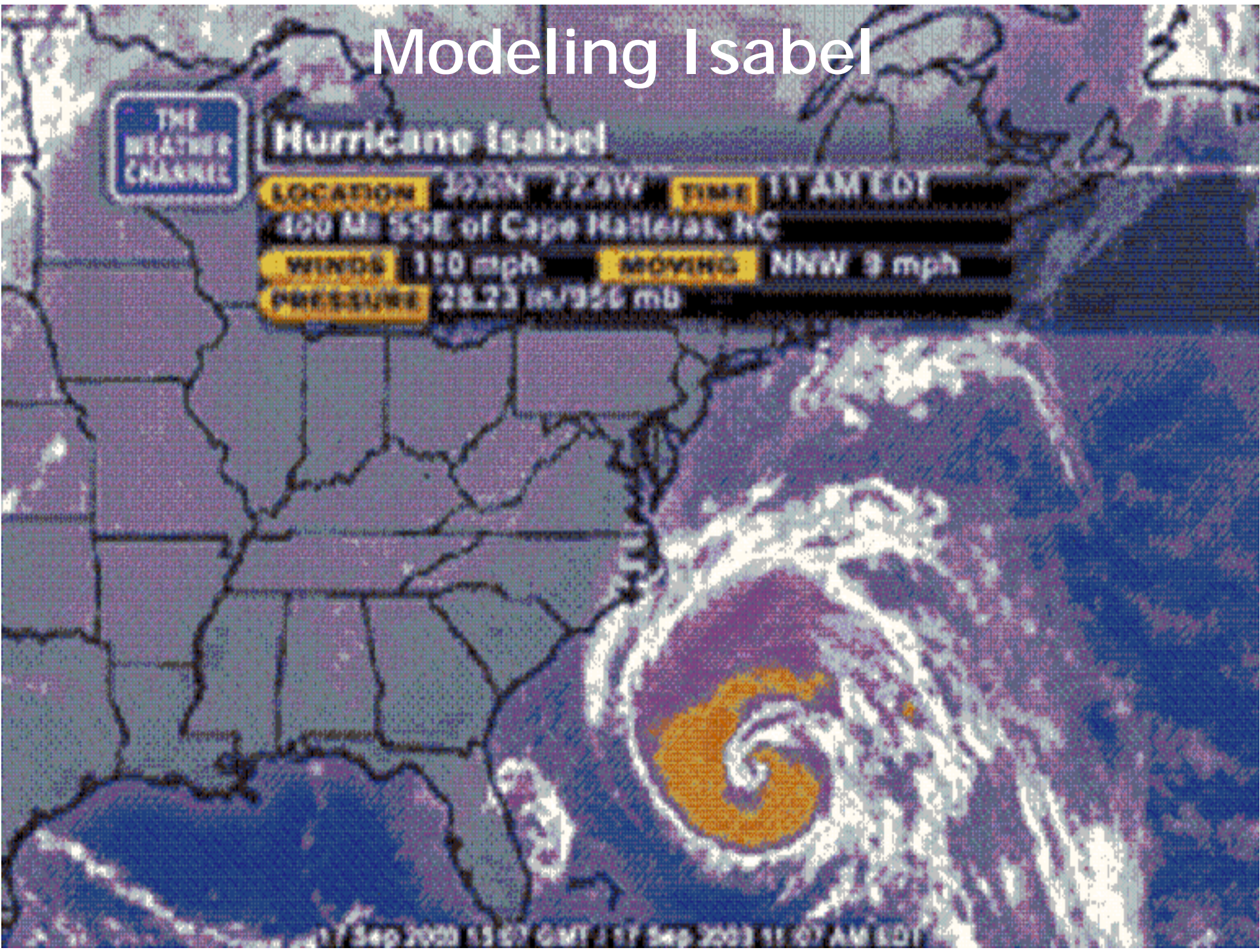
*The
Art
of
Biometrics*

Modeling Isabel

THE WEATHER CHANNEL

Hurricane Isabel

LOCATION 22.2°N 124°W TIME 11 AM EDT
100 MI SSE of Cape Hatteras, NC
WINDS 110 mph MOVING NNW 3 mph
PRESSURE 28.23 in/956 mb



17 Sep 2003 11:07 AM EDT

Why Model Biometric Performance?

- Identify key research areas for improvement
- Optimize large-scale systems
- Understand relevance of empirical studies
- Develop Scientifically Rigorous Analysis
- Identify main Factors affecting performance
- Identify primary Features for extraction
- Identify potential of New Biometrics

What are the components of Biometric Performance, $P_{dc} = f(E, Pop)$; $P_{cp} = f(E, Pop)$

Understand, Quantify and Optimize

Decision Confidence (P_{dc})
Computing Power Requirements (P_{cp})
Environmental Sensitivity (dP/dE)
Population Sensitivity ($dP/dPop$)

Model-based Performance Sensitivity Studies contribute to System Design

- How do environment and population affect performance?
 - Technology Testing
 - Scenario Testing
 - Operations Testing
- How can we do better?

Building Model via Empirical Performance and Sensitivity Study

- Randomly separate Empirical Results into three Data Sets
- Model Training Data
 - Build models of various complexity
- Model Selection Data
 - Optimize model Complexity (Over-fit/Under-fit? Bias-variance tradeoff)
 - Select Candidate Models
- Model Evaluation Data
 - Determine confidence in model
- Express performance/sensitivity as a function of the relevant environment and population variables
- Compare with models from alternate biometric solutions

Empirical Results and Theoretical Model

- Build theoretical model through detailed system analysis
 - Intrinsic Information Content
 - Presentation
 - Capture
 - Extraction/measurement
 - Match determination
 - Fusion
- Analyze empirical results against theoretical model
 - Leads to understanding of the relevance of empirical results
 - Identifies 'weak links' which may promise improved performance
 - Empirical results improve understanding of descriptive model and provide input to mathematical model

Conceptual building-blocks of the Performance Limit Model

- Intrinsic Physiological **Information Content**
- Measurement Process **Discrimination**
- Sample Data Feature-Space **Distribution**

Understanding Performance Limits through biometric feature analysis

- Information content and characteristics of biometric features
- Distribution and Correlation of features
- Discrimination confidence of the feature measurement process
- Feature extraction computing requirements

Modeling Information Content

- Intrinsic Physiological Information Content
 - Invariant vs. Temporal
- Physiology to presentation to capture to extraction to matching to fusion
 - Information Flow -- Loss and Contaminants
- Analogy: Communication System

Information Flow through the Biometric Model

Information
Flow



- Intrinsic Information Content
- Presentation
- Capture
- Extraction
- Match Determination
- Fusion

Modeling Measurement Discrimination

- Probability Distribution of confidence in a feature measurement
 - Step-wise ?
 - Gaussian ?
- Feature Measurements with high Discrimination
 - > Higher Information Content

Modeling Feature Distribution

- Probability distribution of a feature
 - Clustering ?
 - Extreme values ?
 - Stepwise ?
 - Gaussian ?
- Features with high Distribution
 - > Higher Information Content

Mathematical Model

- Biometric Feature Space
 - Total Information contained in one feature
 - Total Information contained in multiple features
- Standard Probability and Statistical Tools available for simplified modeling given empirical data within feature space from relevant population.
- Covariance matrix to identify optimal features

Modeling the Theoretical Performance of Biometrics

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Information
Flows
Through
the
Biometric
Model



- Identifying research areas for improvement
- Optimizing large-scale systems
- Understanding relevance of empirical studies
- Developing Scientifically Rigorous Analysis
- Identifying gain factors affecting performance
- Identifying primary features for extraction
- Identifying potential New Biometrics



Continued Research: Descriptive and Mathematical Models

- Progressing from Art towards Science
 - Identifying key research areas for improvement
 - Optimizing large-scale systems
 - Understanding relevance of empirical studies
 - Developing Scientifically Rigorous Analysis
 - Identifying main Factors affecting performance
 - Identifying primary Features for extraction
 - Identifying potential of New Biometrics



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