Weather Decision Support using Big Data: 
A Surface Transportation Example

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NCAR’s First Big AI Success: DICast®

**Dynamic**

**Integrated**

**Forecast**

**System**

**DICast® In a Nutshell**

- Machine-Learning Post-processor of model data
  - Create predictive relationships between model output, observations and desired forecast variables
- Optimal Forecast Combiner
  - Create best combination of inputs

- Enables Decision Support
- Uses Real-Time Data – IoT
- Uses Large amounts of Model Data
  - Real time
  - Historical for training
Originally developed for The Weather Channel (now The Weather Company - part of IBM) to produce public-oriented forecasts

Development started in 1999 in Research Applications Program

Used in many other projects as the ‘weather engine’
- Transportation (MDSS, Pikalert®, DIA, MSP)
- Solar Energy (DOE, Kuwait)
- Wind Energy (Xcel Energy, Kuwait)
- Agriculture (NASA)

Commercial forecasting companies
- DTN/Schneider/Telvent/Meteorlogix/Kavouras
- Panasonic Weather Systems
- Global Weather Corp
- Skymet Weather Services of India
DICast® In a Nutshell

Dynamic Integrated foreCast System

Measurements

Integrator

Multiple Weather Variables, T, RH, PoP, ...

Wind speed example
10-15% decrease in error
**Gridded Atmospheric Forecasts: GRAFS**

**NWP Models**
- NAM
- GFS
- WRF-Solar
- GEM
- RAP/HRRR
- ECMWF

**Initial Grid**
Interpolated to 2-4 km
CONUS Grid
1-Hour Averaging
Archive data near observation sites

**Observations**
- METARs
- MADIS
- RWIS
- Radar
- Satellite
- Mesonets
- Specialized

**Statistical Correction/Blending**
- DiCast Correction
- Gradient Boosted Regression Trees
- Cubist
- Random Forests
- Analog Ensemble

**Output Products**
- Maps of surface variables
- Single point forecasts
- % of variable
- Other met. Variables

**Gridded Atmospheric Forecasts: GRAFS**

- Maps of surface variables
- Single point forecasts
- % of variable
- Other met. Variables
DICast for Road Weather and the Pikalert® System

Use the best of
• Weather observations
• Weather Forecast models
• Knowledge of roadways
• Connected vehicle data
To improve driving safety

Development funded by US Department of Transportation
By National Center for Atmospheric Research
Open Source
http://www.itsforge.net
Vehicles as Weather Instruments

Internet of Things

Antilock Brakes
Traction & Stability
Differential Wheel Speed
Yaw, Pitch, Roll

Windshield Wipers
Headlights
Air Temperature
Barometric Pressure

Speed
Location
Heading
Elevation

Accelerometer
Engine Load
Steering Angle
Throttle Position
Vehicle Data Translator – Blending vehicle data, weather observations, & model information

Assigned to user-configured road segments by GPS location and time stamp
Connected Vehicles for Smart Cities – What are we doing?

Big Data Characteristics:
✓ Volume
✓ Variety
✓ Velocity
✓ Variability
✓ Veracity
✓ Complexity

→ Value
Regional-scale model, based on WRF / MM5

\[ \frac{dx}{dt} = \ldots + GW (x_{\text{obs}} - x_{\text{model}}) \]

where \( x = T, U, V, Q, P1, P2 \ldots \)

\( W \) is weight function

Modified NWP (WRF/MM5):

- All WMO/GTS
- GOES
- Radars
- MESONETs
- Wind Prof
- ACARS
- Solar Farm Met
- Connected Vehicle

Forecast

Cold start

Obs

NWP (WRF/MM5)

FDDA

RTFDDA

Regional-scale model, based on WRF / MM5
Data Variability, Velocity

Data may not arrive on time

Engineer for Graceful Degradation

Road Weather Hazard
Data Complexity: RWH Input Data

Precipitation

- Temperature
- Dewpoint
- Wind Speed
- Wind Direction
- Wiper status
- Speed
- Headlights
- Precip type
- Precip amount
Data Complexity: RWH Input Data

- Temperature
- Dewpoint
- Wind Speed
- Wind Direction
- Headlight Status
- Vehicle Speed
- Precip type
- Precip amount
- Road Temp
- Road State
- Headlight Status
- Vehicle Speed
- Road Temp
- Road State
RWH Input Data: Data Velocity, Volume, Variability, Complexity:

- Temperature
- Dewpoint
- Wind Speed
- Wind Direction

- Temperature
- Wiper status
- Speed
- Headlights

- Precip type
- Precip amount

- EBS Status
- Traction Control
- Stability Control
- Yaw Rate

- Road Temp
- Road State
- Wind Speed
- Wind Direction

Precipitation

Visibility

Internet of Things
Data Veracity – Example QC

**Step Test**
- Detects unreasonably large changes in sensor values over a user-defined length of time. Requires a vehicle identification.
- Example: Air pressure changes from 920 hPa to 950 hPa within 15 minutes. The 950 hPa observation does not pass this test.

**Neighboring Vehicle Test**
- Vehicle observation is compared to observations from other vehicles on the same road segment. If the observation is within a user-defined number of standard deviations of the road segment mean, it passes the test.
- Example: A vehicle-observed air temperature is 1.7 standard deviations from the road segment mean air temperature. The observation passes this test.

**Similar Tests for:**
- Traffic speed and volume
- Road Weather Information System (RWIS) data
Pikalert® Present Weather Alerts

- Volume
- Variety
- Velocity
- Variability
- Veracity
- Complexity

Value

CONNECTED VEHICLES:
the Vehicle Data Translator

Doppler Radar (remote)

Weather Satellite (remote)

ESS (local)

Vehicle Data
- temperature
- pressure
- velocity
- steering
- wiper status
- headlight status

Data Processing Center (remote)

Warnings sent to approaching vehicles
Application: Travel Time for Colorado I-70

Data Mining plus Weather Forecasting Improves Travel Time Estimates
Road Weather Hazard Algorithms - Precipitation

- Decision tree - AI
- Radar (hybrid scan reflectivity and dual-polarization hydrometeor identification), air temperature, station weather, and dewpoint depression determine initial precipitation type/intensity
- Intensity modified by wipers
- Headlights and vehicle speed serve as a check on over-alerting
  - If headlights are off and/or vehicle speeds are high, precipitation intensity is likely not very heavy

Radar Image

- Volume
- Variety
- Velocity
- Variability
- Veracity
- Complexity
Road Weather Alert and Advisory Systems

Value

- RWA is used to produce phone-based advisories for a driver.
- RWH output: Low visibility
- Configuration:
  - Alert level: advisory
  - Message: Poor Visibility: Next five miles
Enhanced Maintenance Decision Support System (EMDSS)

Combines information from all sources and attributes to road segments. Assess and forecast. Can provide guidance on treatments using artificial intelligence.

Value
Summary:

- **Artificial Intelligence** is advancing applications of weather forecasting
- NCAR has been involved for a couple decades
- A **Big Data/IoT** application
- A necessary component of modern weather forecasting systems

✓ **Pikalert®** is available now and deployed in several US cities and states
  - Provides current weather conditions
  - Uses connected vehicle information to blend with weather observations and forecasts
  - Assigned weather information to road segments
  - Forecasts future road conditions
  - Recommends roadway treatments

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