STORM-LK:
A Human-Centered Knowledge Model For Weather Forecasting

Robert R. Hoffman, Ph. D.
John W. Coffey, Ed.D.
Kenneth M. Ford, Ph.D.
Mary Jo Carnot, M.A.
Institute for Human and Machine Cognition
40 Alcaniz St.
Pensacola FL 32501

Presentation at the Second Workshop on Interactive Meteorology and Oceanography
Held at the Naval Pacific Meteorology and Oceanography Center (NPMOC),
North Island Naval Air Station, California, on August 29 — August 31. Supported by the Future Naval Capability Program, Office of Naval Research.

ABSTRACT

STORM-LK stands for System To Organize Representations in Meteorology-Local Knowledge." STORM-LK was created as a part of a project aimed at illustrating the paradigm of Human-Centered Computing. The selected domain of application was weather forecasting, and in particular forecasting in the Gulf Coast region. Expert, journeyman, and apprentice forecasters at the Naval Training Meteorology and Oceanography Facility (NAVTRAMETOCFAC) at Naval Air Station-Pensacola participated in a number of knowledge elicitation procedures, including: Workplace Analysis and Workpatterns Analysis (see Vicente, 1999), the Critical Decision Method (Hoffman, Crandall, & Shadbolt, 1998), the Cognitive Models Procedure (Hoffman, Coffey, & Carnot, 2000), and Protocol Analysis. After identifying local weather forecasting expertise as a good leverage point for the prototyping effort, the forecasting skill of experts was captured in models of reasoning and models of knowledge. These were then implemented in the form of Concept-Maps using the CMap Tools' software. The resulting prototype demonstrates: (1). The feasibility of using the CMap approach to knowledge elicitation to generate large-scale knowledge models containing dozens of Concept-Maps, thousands of propositions, and hundreds to thousands of multimedia resources; (2). The use of CMaps to integrate and navigate through the resources the various data types used in weather forecasting, such as real-time satellite images, radar, text, graphics, video, etc. It is envisioned that a system such as STORM-LK can be used to support distance learning and the acquisition of expertise and the processes of knowledge rescue and preservation at the organizational level.

INTRODUCTION

STORM-LK was created to illustrate the paradigm of Human-Centered Computing in the context of a single domain of application, going all the way from bootstrapping to a finished "cognitive prosthesis" a computational system that leverages and extends human intellectual, perceptual, and collaborative capacities. A greater variety of techniques of Cognitive Work Analysis and Cognitive Field Research (CWA/CFR)was brought to bear than has ever been applied in a single project

on a single domain, with the purpose of identifying leverage points where a relatively modest technology infusion might have a proportionally larger effect (see Hoffman & Woods, 2000). We then followed up on a selected leverage point and created STORM-LK to exemplify the cognitive prosthesis notion.

METHODS

Participants (n = 22) were senior civilian forecasters, junior Aerographers (i.e., Apprentices who were qualified as Observers) and senior Aerographers (i.e., Advanced Journeymen and Journeymen who were qualified as Forecasters) at METOCFAC-Pensacola Naval Air Station.

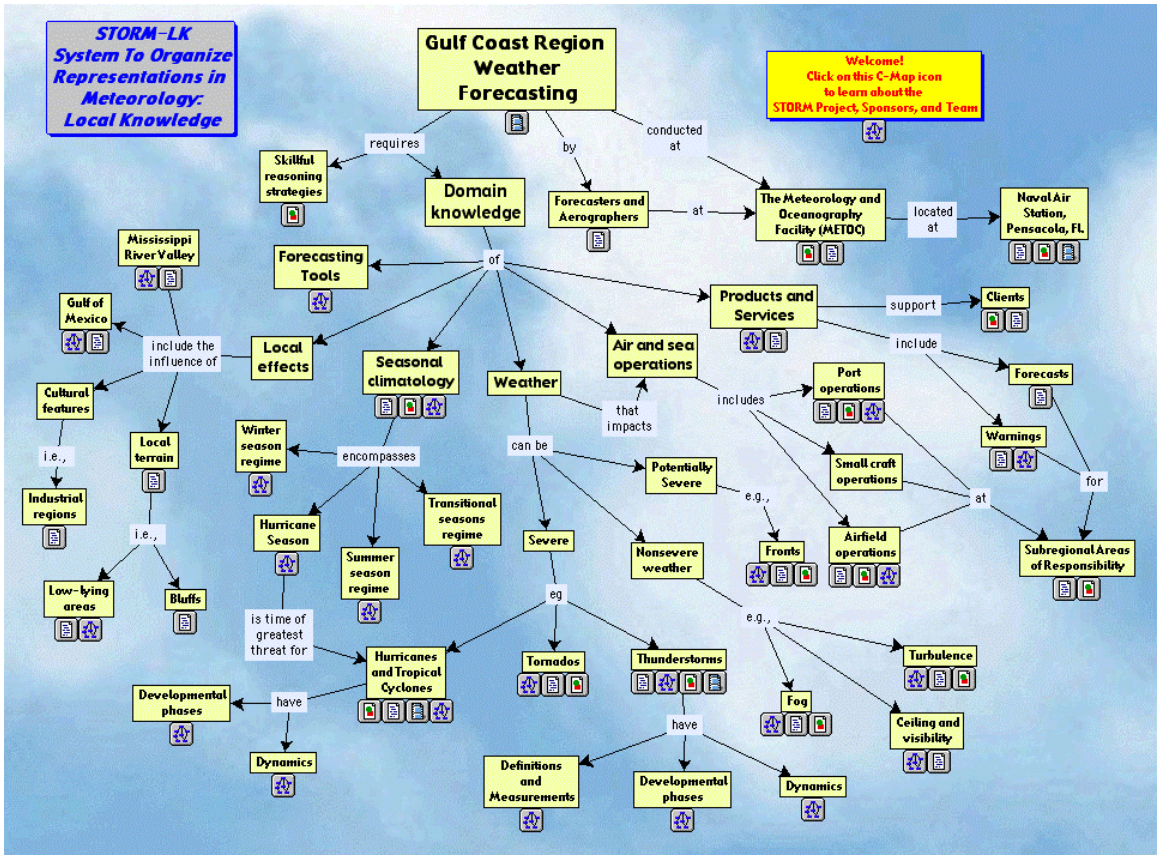
The following methods of CTA/CFR were utilized:

- Bootstrapping (documentation analysis, analysis of SOP documents, the Recent Case Walkthrough method),
- Proficiency Scaling (Participant Interviews; comparison of experience versus performance) (see Hoffman, Shadbolt, Burton, & Klein, 1995),
- Client (i.e., pilots and pilot trainers) Interviews,
- Workspace Analysis (Photographic survey, detailed workspace mapping) and Workpatterns Analysis (live and videotaped Technical Training Briefings, Watchfloor observations) (see Vicente, 1999),
- The Knowledge Audit (Militello & Hutton, in press),
- Decision Requirements Analysis,
- The Critical Decision Method (CDM) (see Hoffman, Crandall, & Shadbolt, 1998),
- The Cognitive Models Procedure (see Hoffman, Coffey, & Carnot, 2000),
- Protocol Analysis, and
- Concept-Mapping using the CMap' software tools (see Novak, 1998).

After identifying local weather forecasting expertise as a good leverage point for the prototyping effort, the forecasting skill of experts was captured in models of reasoning and models of knowledge. These were then implemented in the form of Concept-Maps using the CMap Tools' software.

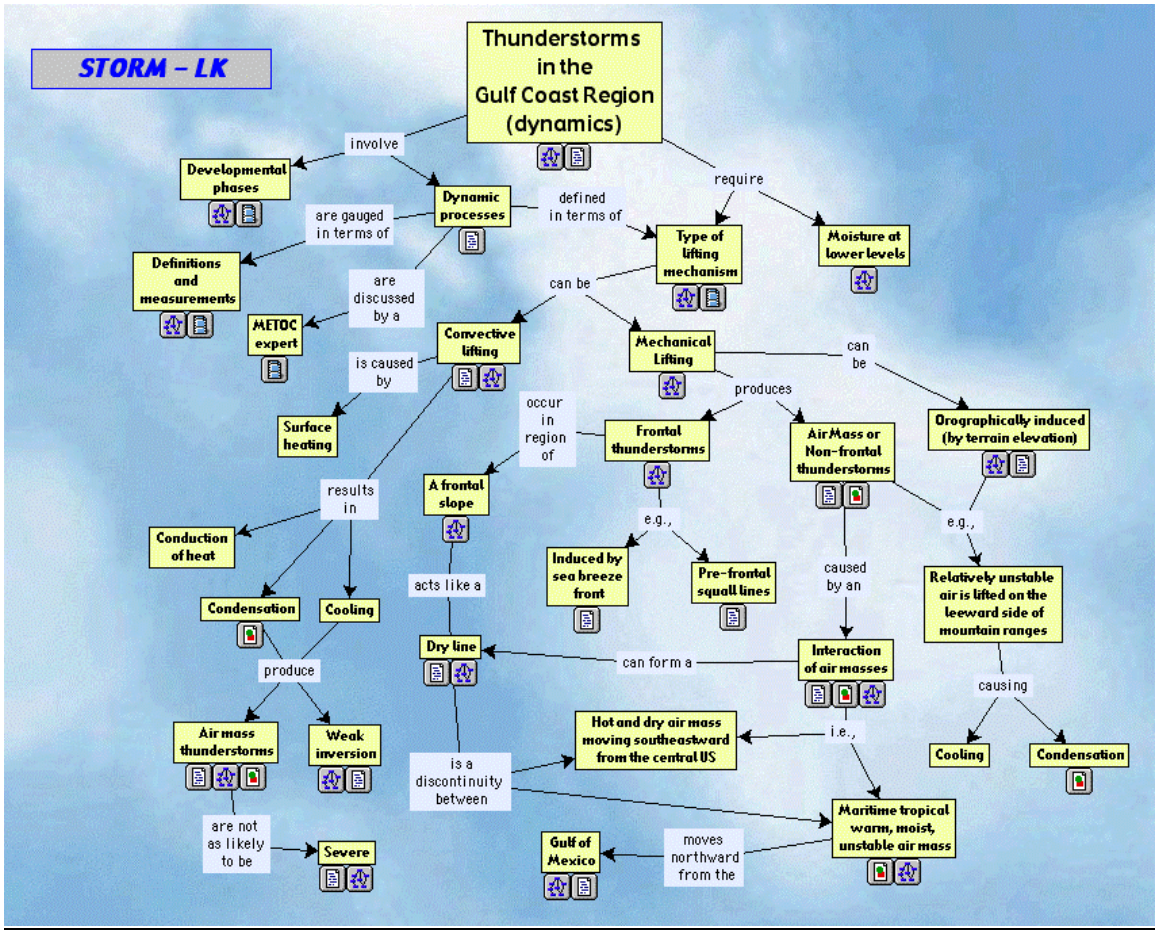
RESULTS

Screen shots of representative Concept-Maps appear in the following two figures. The first Figure is the "Top Map" a map of maps that provides an overview of the topics covered in all of the other Concept-Maps.



Below some of the concept-nodes in this Figure are a small icons that look like a Concept-Maps. Clicking on such an icon takes one to the Concept-Map .

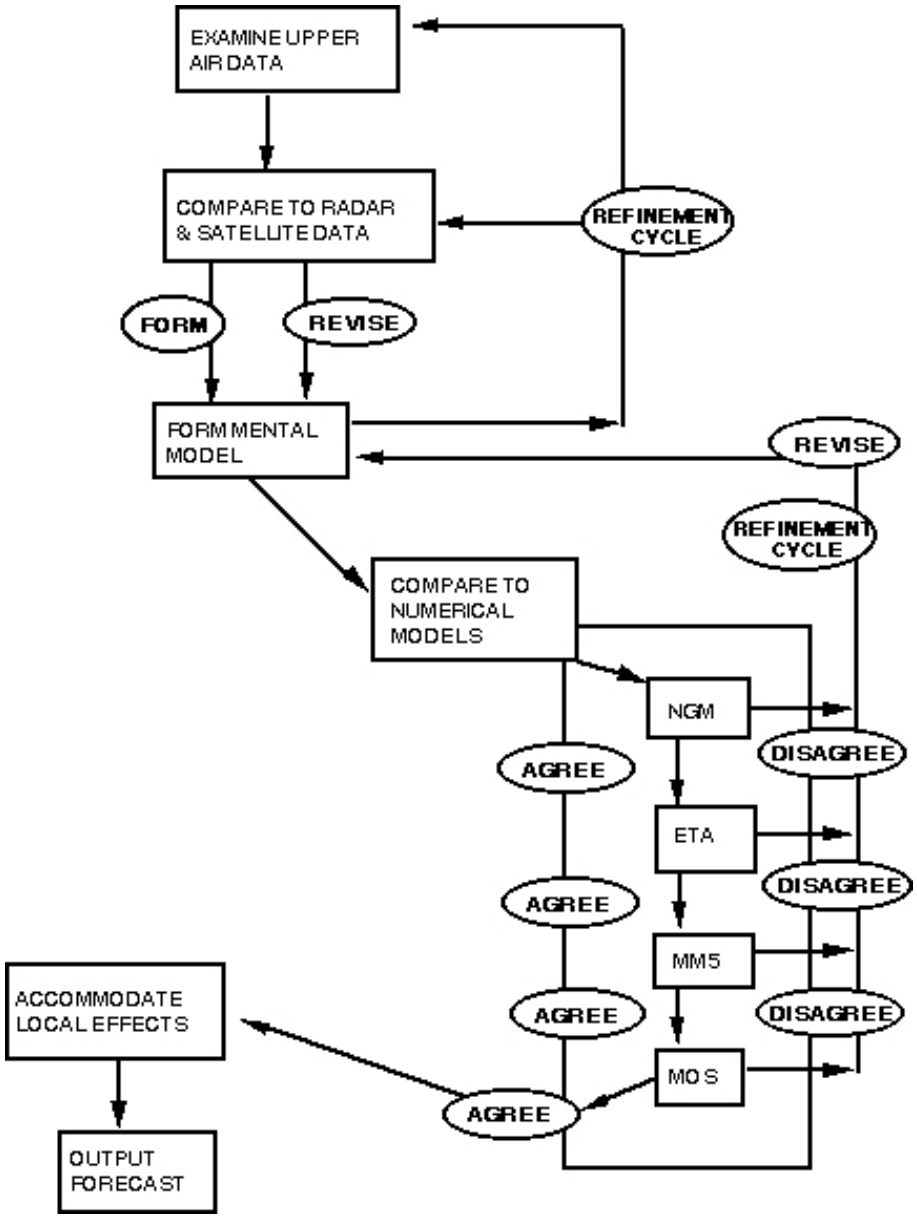
indicated by the node. Thus, in the example above, clicking on the node "thunderstorms" takes one to the Map that appears in the following Figure.



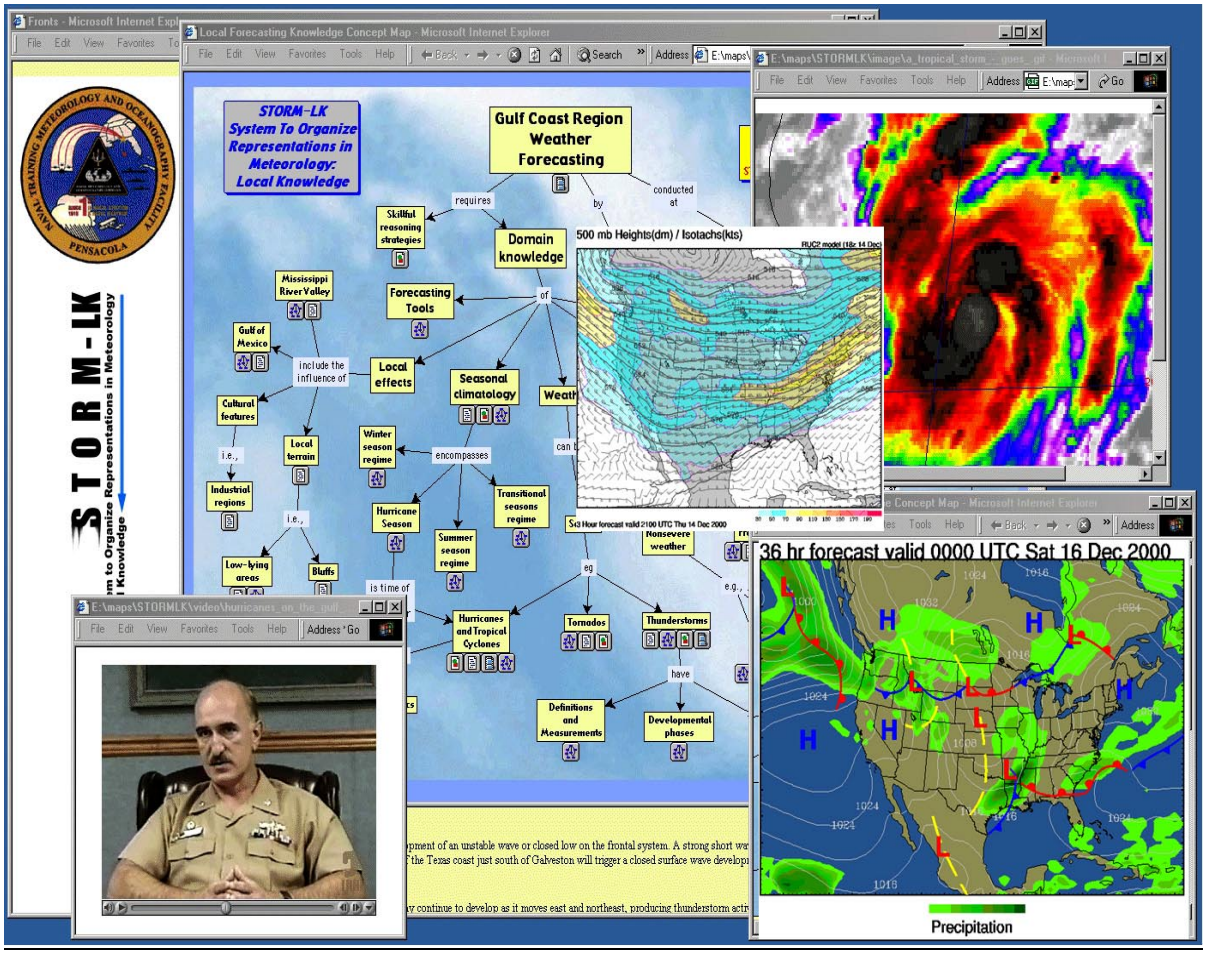
Attached to the top node in every Concept-Map is a Map icon that can be used to navigate back to the Top Map and to all other Concept-Maps that are associated to the given Concept-Map. Thus, for example, thunderstorms are treated in a Concept-Map that is just about storm dynamics and another Concept-Map that is about thunderstorm developmental phases. Through this mechanism of linking Top Maps to sub-Maps, one can effectively get from anywhere in the knowledge model to anywhere else, in two clicks at most. This contrasts starkly with common experience at using web pages, i.e., the "back" button is the one that is used most often, especially when one looses track of one's surfing path.

By design, STORM-LK contains all of the information that is included in the "Local Forecasting Handbook," which is a traditional text document utilized at all US Navy METOC facilities. (A similar type of document is utilized at forecasting offices of the National Weather Service.) Using the CMap interface enables one to escape the confines of traditional linear text, it permits the integration of dynamic media and multi-media, and it serves as a "living e-document" that can be continually refined and expanded by the incorporation of new knowledge models and models of situation-specific reasoning. Thus, icons take one to text resources and graphic resources. Graphic attachments include models of expert reasoning for given weather

situations, as illustrated in the following Figure.



Another type of resource attachment takes the viewer to digitized videos that allow the apprentice to "stand on the shoulders" of the expert by viewing mini-tutorials in which senior experts themselves explain such things as thunderstorms associated with cold fronts, or the ways that the NEXRAD radar is used in Gulf region forecasting (i.e., "local user functions"). A screen shot depicting the variety of resources in STORM-LK appears in the following Figure.



What cannot be expressed in these static Figures is that STORM-LK allows one to access all of the real-time, animated data types and data fields that are used in weather forecasting radar loops, satellite image loops, outputs of computer forecasts, prognosis charts, etc. and one can do so within the context of a set of Concept-Maps that provide the explanatory glue that makes the forecasting process hang together.

The use of STORM-LK will be illustrated by walking the audience through a hypothetical scenario in which a Journeyman forecaster who is unfamiliar with weather in the Gulf coast (e.g., fog) is assigned on short notice to a carrier group that is about to engage in a winter-time exercise. The Journeyman has to get up to speed quickly, and achieve journeyman-level competence at forecasting winter weather in the Gulf Coast region.

Discussion

The STORM-LK prototype demonstrates:

- The feasibility of using the CMap approach to knowledge elicitation to generate large-scale knowledge models containing dozens of Concept-Maps, thousands of propositions, and hundreds to thousands of multimedia resources,
- The use of CMaps to integrate and navigate through the various data types used in weather forecasting.

It is envisioned that a system such as STORM-LK can be used in many ways:

- To support distance learning,
- To accelerate the acquisition of expertise,
- To support distance collaboration in the refinement of knowledge models,
- To support the process of knowledge preservation at the organizational level,
- To substitute a new type of "living e-document" for the traditional Local Forecasting Handbooks that are used by both the military and the National Weather Service. A STORM system can be continually refined and expanded by the incorporation of new knowledge models and additional models of situation-specific reasoning.

References

Hoffman, R. R., Coffey, J. W., & Carnot, M. J. (2000, November). Is there a "fast track" into the black box?: The Cognitive Models Procedure. Poster presented at the 41st annual meeting of the Psychonomics Society, New Orleans, LA.

Hoffman, R. R., Coffey, J. W., and Ford, K. M. (2000). "A Case Study in the Research Paradigm of Human-Centered Computing: Local Expertise in Weather Forecasting." Report to the National Technology Alliance, Arlington VA.

Hoffman, R. R., Crandall, B., & Shadbolt, N. (1998). A case study in cognitive task analysis methodology: The Critical Decision Method for the elicitation of expert knowledge. Human Factors, 40, 254-276.

Hoffman, R. R., Shadbolt, N., Burton, A. M., and Klein, G. A. (1995). Eliciting knowledge from experts: A methodological analysis. Organizational Behavior and Human Decision Processes, 62, 129-158.

Hoffman, R. R., & Woods, D. D. (2000). Studying cognitive systems in context. Human Factors, 42, 1-7.

Hoffman, R. R., Shadbolt, N., Burton, A. M., & Klein, G. A. (1995). Eliciting knowledge from experts: A methodological analysis. Organizational Behavior and Human Decision Processes, 62, 129-158.

Militello, L. G., & Hutton, R. J. B. (in press). Applied Cognitive Task Analysis (ACTA): A practitioner's toolkit for understanding cognitive task demands. Ergonomics
Special Issue: Task Analysis.

Novak, J. D. (1998). Learning, creating, and using knowledge. Mahwah, NJ: Erlbaum.

Vicente, K. (1999). Cognitive work analysis: Toward safe, productive, and healthy computer-based work. Mahwah, NJ: Erlbaum.