DEVELOPMENT OF AN EXPERT SYSTEM BASED ON THE SYSTEMATIC APPROACH TO TROPICAL CYCLONE TRACK FORECASTING

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LONG-TERM GOALS:

The long-term goals of this project, which is being pursued in collaboration with R. L. Elsberry and M. A. Boothe, are essentially the same as those for the related project entitled "Systematic Approach to Tropical Cyclone Track Forecasting" summarized elsewhere in this report. Those stated goals are to improve not only the quantitative accuracy of official tropical cyclone (TC) track forecasts, but also the qualitative meteorological utility of those forecasts. Whereas the focus of the related project is to conduct basic research to develop the methodological framework and organized knowledge bases (i.e., of TC meteorology and TC forecast model traits) necessary to eventually accomplish the long-term goals, the focus here is to take results from that project and transform them into a prototype software tool that will, when fully implemented, enable the TC forecaster to actually accomplish the long-term goals.

OBJECTIVES:

The specific objectives of this project are to conduct exploratory research directed at:
(i) developing a prototype expert system based on the systematic approach. It is emphasized that the purpose of the expert is not to replace the human forecaster, but to be an "assistant" that methodically and consistently leads the forecaster through a sound forecast formulation process, exposes the forecaster to key information, prompts and assists the forecaster to make pivotal decisions, and accomplishes basic tasks for the forecaster wherever feasible; and
(ii) demonstrating the feasibility of such an expert system for improving the accuracy and meteorological utility of official tropical cyclone track forecasts.

APPROACH:

The approach to developing a systematic approach expert system has the following elements:
(i) Transform the three-phase procedural concept of the systematic approach (Fig. 1) into a detailed sequence of specific steps required to produce a meteorologically sound TC track forecast.
(ii) Identify the particular resources (e.g., numerical fields, imagery, data, etc.) and components of both the meteorological and traits knowledge bases that the forecaster must access either manually or with objective assistance to accomplish each step of the systematic approach process.
(iii) Evaluate the feasibility of accomplishing particular aspects of each task by objective means for evaluation and quality control by the forecaster, as opposed to simply prompting the forecaster to accomplish the task manually (without any objective assistance). For example, it is easy to access the best track files of two TCs and compute their distance and direction from each other for the purpose of alerting the forecaster to the potential for some kind of TC interaction. By contrast, is it likely to be very difficult to reliably classify by purely objective means the environmental pattern of a TC for any

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arbitrary situation, particularly when one or more TCs are nearby.
(iv) Transform the systematic approach tasks into a set of expert system modules. Key aspects of these modules include:

(1) Varying degrees of initial sophistication depending on the difficulty of each task or task component being accomplished.
(2) Flexible design so that they may be separately tested, revised, and re-tested. Flexibility is essential because the testing will reveal possibilities/needs for modification including increased or reduced objective input to the forecaster.
(3) A *HELP* function, in which a user can stop the decision process and review that aspect of the knowledge base relevant to accomplishing a particular task. Executing the expert system with a specially chosen series of archived situations then becomes an educational tool to supplement written documentation of the systematic approach. Because the information is organized and managed according to procedures of the experienced forecaster, the expert system will eventually become an integral part of the forecaster training process.

(v) From the inception of systematic approach concept, forecaster interaction and feedback have been viewed as an essential requirement for efficiently developing a product that is capable of meeting the needs of the operational forecaster. Thus, periodically, as certain key components of the prototype expert are developed, they will be provided to the forecasters at the Joint Typhoon Warning Center (JTWC) for informal evaluation and feedback to the researchers.

WORK COMPLETED:

Pursuant to project approach element (i) above, Fig. 2 illustrates how the three-phase concept of the systematic approach (Fig. 1) has been broken into a series of major tasks. Notice that Phase I has been divided into two sub-phases that differ importantly in how they treat the analysis field of the operational global model employed by the forecasters in Task 2 of each sub-phase. In Phase IA, the analysis field at the steering level of the TC (normally 500 mb) is evaluated in conjunction with other data resources for the purpose of assigning a TC environment classification that best explains the actual motion of the TC at, and immediately after, the analysis time. In Phase IB, the model analysis fields and the forecast fields are evaluated and assigned a TC environment classification, but here the analysis field is assigned a classification that is consistent with the short-term (0-12 h) forecast motion of the TC, without regard for the actual motion of the TC at analysis time. The degree of agreement between the actual (Phase IA) and model-depicted (Phase IB) environment structure classifications at analysis time then becomes a factor in assessing the likely accuracy of the entire track forecast of the model in Task 3 of Phase IB. Similarly, differences between actual TC structure and model-depicted (i.e., analyzed and forecast) TC structure also are important factors that are to be considered in Task 3.

Figure 3 shows just Phase I of the systematic approach in an expanded form that identifies the specific steps that comprise the various tasks. Each step in Fig. 3 then becomes the focus of project approach elements (ii) - (iv) above. With the exception of the HELP function, initial development of software modules and preliminary testing using archived TC cases has been largely completed for the steps in Phase IA, and presently is in progress for Phase IB. A condensed and updated version of the meteorological knowledge base that is the foundation of the systematic approach has been provided to JTWC and will be issued as a technical report (Carr et al. 1997b). The text/graphic layout of the report conforms to the format that will be used by the HELP function, and will become the main resource of the HELP function when eventually converted into soft form.
Multiple TC formation occurs with high frequency in the western North Pacific, and recently the existence of multiple modes of TC interaction (TCI) that significantly affect TC motion has been documented (Carr et al. 1997a). Thus, considerable time and effort have been expended to develop criteria based on relative motion and orientation of TC pairs that permit effective objective detection of most of the observed modes of TCI interaction, and thereby provide considerable assistance to the forecaster in accomplishing Step 1 of Task 1 in Phase IA of the systematic approach (Fig. 3). Carr and

Elsberry (1997) and Peak et al. (1997) document the results of this work, and a stand-alone TCI-detection software module has been developed and made available to forecasters at JTWC for informal evaluation and feedback.

RELATED PROJECTS:

This project is a follow-on to, and utilizes the results of, the project entitled SYSTEMATIC APPROACH TO TROPICAL CYCLONE TRACK FORECASTING by Lester E. Carr and collaborators, which is summarized elsewhere in the report.

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Phase I: Numerical Guidance Evaluation
Phase II: Objective Technique Evaluation
Phase III: Official Track Forecast Formulation

Figure 1. A listing of the three phases that comprise the systematic approach procedural framework.

Phase I: Numerical Guidance Evaluation
- **Phase IA: Classify Actual Meteorological Situation**
  - Task 1: Classify TC Structure
  - Task 2: Classify Environment Structure/Transitions
- **Phase IB: Classify Model-depicted Meteorological Situation**
  - Task 1: Classify TC Structure
  - Task 2: Classify Environment Structure
  - Task 3: Assess Numerical Guidance Accuracy

Phase II: Objective Technique Evaluation
- Task 1: Identify Track Guidance Groups
- Task 2: Select Guidance Group for Official Forecast

Phase III: Official Track Forecast Formulation
- Task 1: Construct Primary/Alternate Envelopes
- Task 2: Construct Official Track Forecast
- Task 3: Assign Confidence/Alternate Scenario

Figure 2. A more detailed listing of the three phases of that comprise the systematic approach procedural framework, and the tasks that must be accomplished within each phase.

Phase I: Numerical Guidance Evaluation
- **Phase IA: Classify Actual Meteorological Situation**
  - Task 1: Classify TC Structure
  - *Step 1: Intensity & Past Trend*
  - *Step 2: Size & Past Trend*

Task 2: Classify Environment Structure & Transitions
Step 1: TC Interaction Evaluation
Step 2: Environment Structure Evaluation

Phase IB: Classify Model-depicted Meteorological Situation

Task 1: Classify TC Structure
Step 1: Intensity & Trend
Step 2: Size & Trend
Task 2: Classify Environment Structure & Transitions
Step 1: TC Interaction Evaluation
Step 2: Environment Structure Evaluation
Task 3: Assess Numerical Guidance Accuracy

Figure 3. A more detailed listing of just Phase I of the systematic approach, which includes the tasks that must be accomplished in Phase I and individual steps that comprise each task.