Model-driven hypermedia access to weather information

Stephan Kerpedjiev
NOAA/Environmental Research Laboratories/
Forecast Systems Laboratory, R/E/FS1
325 Broadway
Boulder, Colorado 80303

e-mail: kerpedjiev@fsl.noaa.gov

Abstract: A framework is presented for hypermedia access to weather information originating from gridded data sets. The information is presented on different media (map, text, graph, table, image), depending on what aspect is emphasized. The user navigates by selecting an element that is already displayed, and a new product is generated that provides additional details about the selected element. The contents of a product is represented by a description, which is an organized chunk of assertions. Each assertion provides a single weather characteristic to a given region and time period. Three knowledge bases (weather, territory, and time models) define the objects participating in the assertions and drive the generation.

Keywords: hypermedia, domain modeling, media modeling, assertional systems, applications

1. Introduction

We are in the era of numerical weather analysis and forecasting. Advanced data sets are generated with high temporal and spatial resolution. However, these data sets cannot be completely utilized by end users for various reasons; among them is the lack of efficient and flexible techniques for tailoring the data sets to diverse users. Since users are specialists in areas other than meteorology and computer science, e.g., emergency management, they cannot be expected to learn sophisticated computer languages to express their needs of weather information. Therefore, access to the information should be natural and should not distract users from their main duties.

Hypermedia is a good candidate for a basic design principle of a system that provides weather information to non meteorologists. According to this approach, the user gets the information in steps, beginning with summary products and going to more detailed ones. The user accomplishes a transition from one product to another by selecting the element of interest on the summary product, and the system responds by generating a new product that presents the relevant details on the medium best suited to the particular type of information.

In this paper, I describe a framework and a system for handling and managing weather information based on assertions. An assertion provides a single weather characteristic to a given region and time period. Assertions are extracted from data sets and then are combined into descriptions, larger coherent units of information that represent the contents of a whole product. The coherence of a description ensures easy perception of the information by humans. It is achieved by ordering the assertions on the basis of a certain (e.g., temporal or spatial) relation. A description is mapped onto a single-medium product that is eventually provided to the user.

The paper is organized as follows. Several works are described that inspired some key ideas about the project. Hypermedia access is discussed, and an example is given to illustrate the navigation. Then a general approach to generating various products is described. The next sections describe the basic concepts involved in generating such products. The paper concludes with explaining how the system works for the example in section 3.1.

2. Related Work

This work is based on a previous study of the generation of multimedia general-purpose weather reports from weather observations [Kerpedjiev, 1992] and is part of the dissemination project being developed at NOAA Forecast Systems Laboratory. This project [Small, 1992] aims at understanding the utility of weather data sets to various user groups (e.g., emergency managers, highway departments, public services). Its ultimate goal is to develop a technology and a system for transferring weather information to such groups in a format that takes into account user needs.

In Hoffman [1991], the design of meteorological workstations is considered from the perspective of human factors psychology. Although the author studies the consequences of certain design solutions as they pertain to professional forecasters and research meteorologists, many

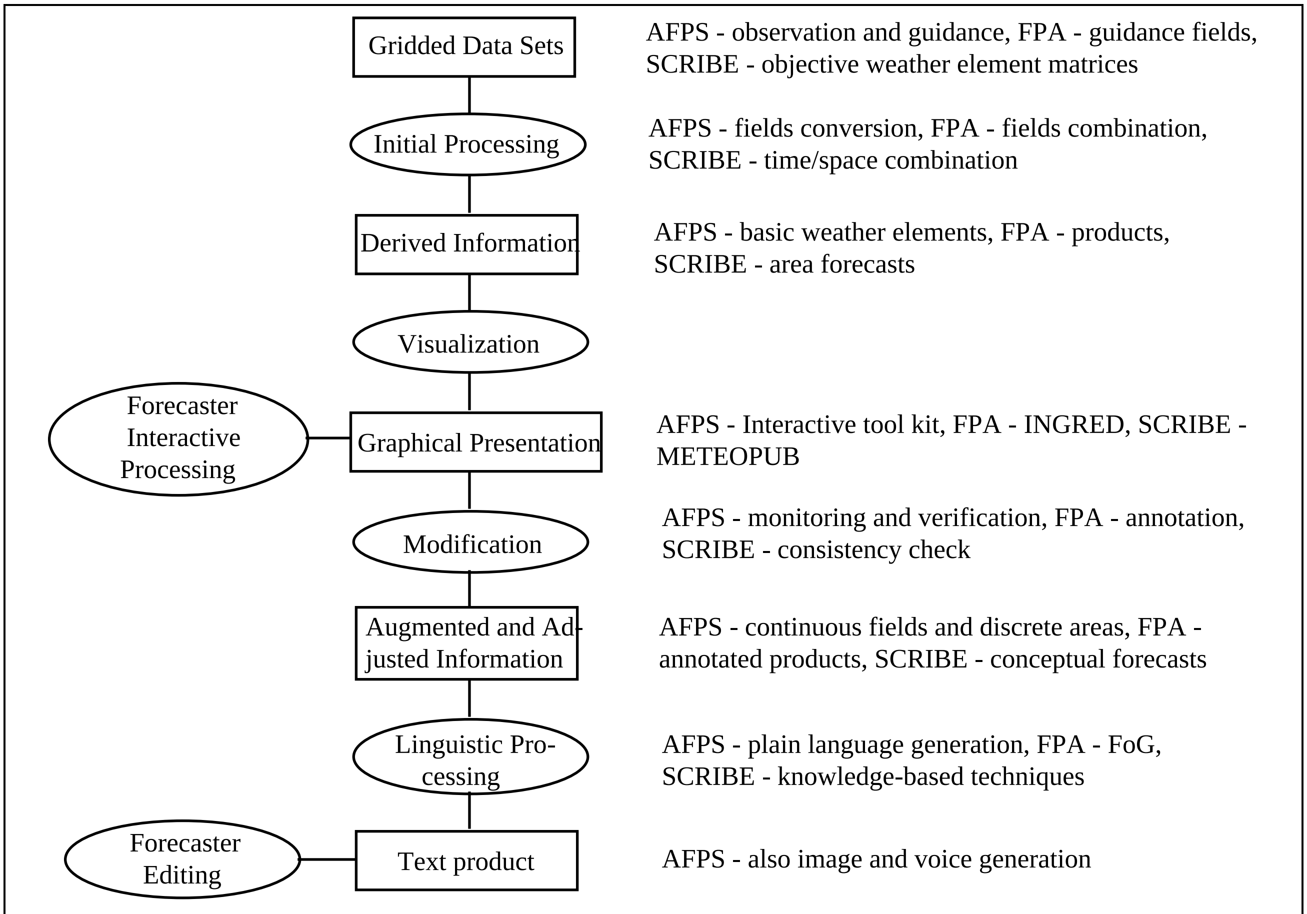


Fig. 1. The flow of information in the systems AFPS, FPA, and SCRIBE (the boxes represent information, the ovals represent processors). The specific terms used in each system are given to the right.

of his recommendations are valid for non meteorologists as well. He suggests that several media should be used to express weather information efficiently.

Bertin [1993] is the most comprehensive text about graphics regarded as a semiological system. On the basis of a thorough semiological analysis of graphical objects, Bertin offers a representation of graphics structure and rules for generating such objects. Arens and Hovy [1990] is a first step toward the creation of a similar semiological theory of multimedia information objects (information expressed on different media: text, graphics, sound). Goldberg et al. [1988] made a significant first attempt to apply computational linguistics techniques to weather report generation. Their system accepts manually produced predictions of weather parameters and composes a natural language text using a lexicon and grammar. Mackinlay [1986] offers a computational approach to generating graphical presentations of quantitative information. Our work can be regarded as another attempt to computationally treat the problem of generating multimedia objects, starting from quantitative information (weather data sets), passing through assertional representation, and leading to expressive multimedia products.

AFPS [LeFebvre et al., 92], FPA [Paterson et al., 92], and SCRIBE [Boulais et al., 92] are three systems that share the same objective: "to provide forecasters with tools to maintain a digital forecast database from which alphanumeric products will be generated and disseminated" [LeFebvre et al., 92]. All the three systems are designed on similar architectures as abstracted in Fig. 1. The initial gridded data sets are presented graphically in two steps so that the forecaster could manipulate them. Then the adjusted data are presented as text products, possibly edited by the forecaster, and disseminated to the end users. The difference between our project and the three systems is significant mostly because of the audience they address. Meteorologists need weather information to better understand the atmospheric processes, and therefore, a system supporting their work has analytical function. We envisage a system for non meteorologists who need to know what the weather is or will be in order to make decisions; hence, our system has communicative functions.

3. Hypermedia access

Medium	Diversity	Spatial resolution	Temporal resolution	Precision	Perceptibility
Map	High	Medium	Low	Low	High
Text	High	Medium	Medium	Low	Low
Image	Low	High	Low	Medium	High
Animation	Low	High	High	Medium	High
Graph	Medium	Low	High	Medium	High
Table	Medium	Medium	High	High	Low

Table 1. An overview of the media employed in the presentation of weather information (*high*, *medium*, and *low* mean the degree to what the medium has the corresponding capability)

The following features characterize the system as a hypermedia system:

- The information is presented on different media.
- The information is presented at different levels of detail, beginning with summary information and then going into more detail.
- A more detailed product is obtained by selecting an element on the summary presentation about which additional information is needed.

The media employed in the presentation of weather reports are characterized in Table 1 with respect to five properties. Diversity is the ability of a medium to present several attributes in a single product. Spatial and temporal resolution reflect the ability of a medium to adequately present the change of a parameter in the spatial and temporal domain. Precision specifies to what extent a medium differentiates between the values of the parameter being displayed. Perceptibility is the capability of the medium to present the information in such a way that it could be assimilated easily and quickly by the user.

At the summary level, we use a map or text because they can incorporate many parameters into a single product, although this product will probably have insufficient resolution and precision. At the most detailed level, we use one of the other media, depending on the aspect that the user is interested in. If the user needs a presentation with a high spatial resolution, then an image will be used. If the user needs a product that displays the development of a parameter for a single region with high temporal resolution, then a graph or table will be used. For both high spatial and high temporal resolution, an animated series of images will do best.

The hypermedia approach, as described above, is natural and user friendly. A summary presentation gives a concise overview of the situation; from it, the user determines some elements of interest; simply pointing to one of these elements informs the system about a need; depending on the selected element, the system decides what product to create and how to provide it to the user.

To support hypermedia access to weather products with different levels of detail, the system must be able to generate summary information from gridded data sets, present this information on different media, and formulate queries by itself based on only as little input from the user as clicking on an element of a displayed product.

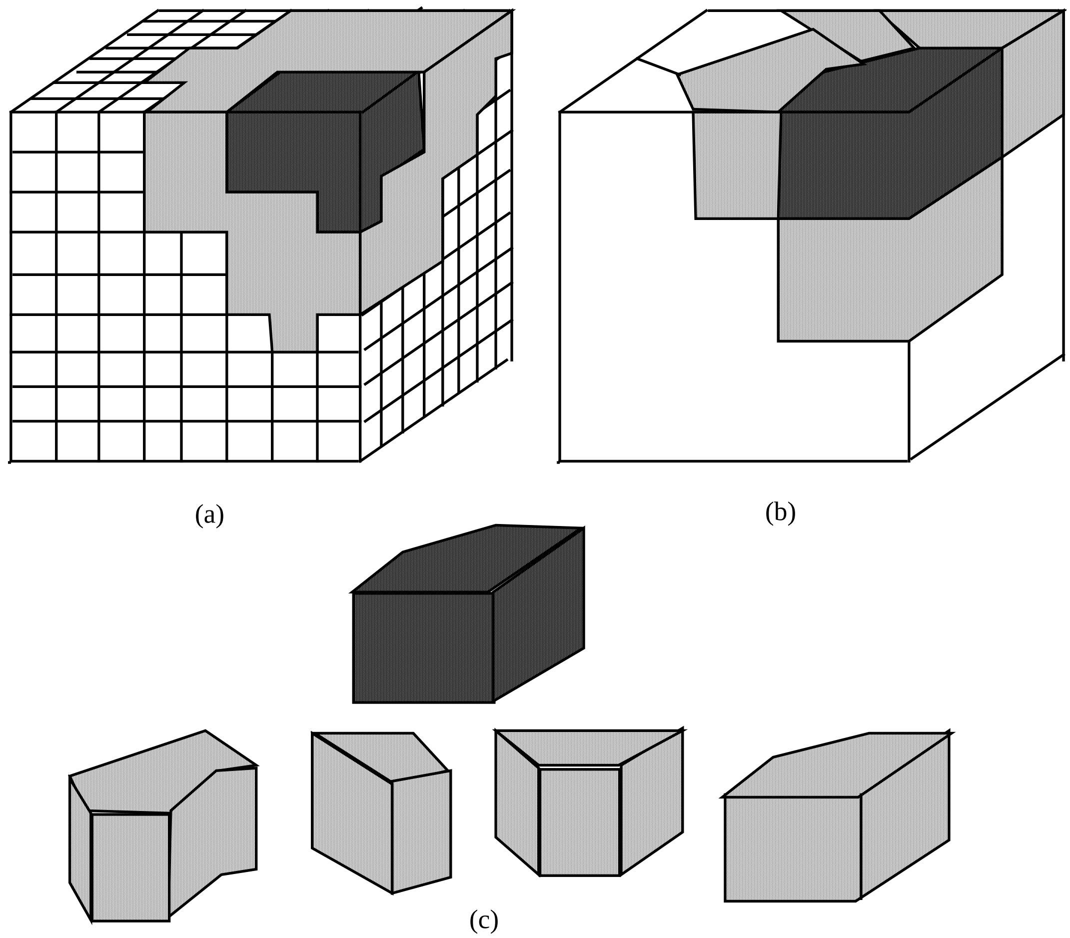
3.1. An example

The following example illustrates how the navigation proceeds. At the beginning, the system provides a summary information of the particular weather situation in the form of a map in which different weather elements are represented by icons that symbolize particular qualitative weather states or processes (e.g., cloud cover, temperature ranges, storms, low, or high winds). The icons are placed over the areas they represent. An icon not only informs the user about the particular weather element but also is an invitation to have a more precise look at this element. By clicking on the icon, the user calls for more detailed information. Because the system still has incomplete information about the particular user needs, it shows a summary text product describing the parameter. This product displays, along with the qualitative state, the mean, maximum, and minimum values of the numerical parameter, and the major trends (increasing, decreasing, stable), all related to the regions that pertain to the area marked by the icon. The text is organized by region, and each portion has a button associated with it. Clicking a button makes the system display a graph showing the development of the parameter in the corresponding region. From the graph product, the user can request a table presenting the particular values of the parameter for each moment in the interval. In addition to the buttons associated to the portions of the particular regions, the text product has another button that allows the user to get an image representing the values of the parameter at the grid points. Then the user can either animate the image or select a point; the latter tells the system to create another text product describing the parameter in the regions that the point belongs to.

This example shows how the user moves from one product to another, getting additional details, and not unnecessary information.

4. From data to assertions to descriptions

We use a cube metaphor to describe the process of generation of weather products. This metaphor helps the reader create a pictorial representation of the problem and allows us to build the system of concepts in a rigorous way.



(a) (b) (c)

Fig. 2. Weather data representations: (a) the initial data set, (b) the set of assertions extracted from the data set, (c) the set of assertions ordered by value

The initial data set of a weather parameter is conceived as a cube (Fig. 2a). Each horizontal plane of the cube represents the gridded data at a fixed moment. Hence the cube consists of as many planes as the number of grids for that parameter. The individual data items reside in the cells of the cube and represent the values of the parameter for single grid points at single moments.

An assertion summarizes the data in a cylinder in the cube to provide a single weather characteristic for a region and time period (Fig. 2b). The base of the cylinder corresponds to the region that the assertion relates to, and its height corresponds to the time interval of the assertion. Note that cylinders can have an arbitrary shape, not only circular.

The description determines in what way the cylinder of a query is divided into subcylinders corresponding to the assertions constituting the description (Fig. 2c). For example, the assertions referring to the same parameter and region, but providing values for successive time periods covering a larger time period, constitute a temporally sliced description for that parameter, region, and period.

To define the concepts assertion and description rigorously, we need precise definitions of the concepts of region, time period, cylinder, and weather parameter. They are introduced in the next section.

5. Specialized knowledge bases

Three specialized knowledge bases are involved in the process of generation: territory, time, and weather models. For each model, we define the objects that constitute the corresponding domain as well as certain relations and operations between them, which allow the system to extract assertions and organize them into coherent chunks of information.

5.1. Territory model

The territory model provides a mechanism for reasoning in the spatial domain. The objects constituting the territory

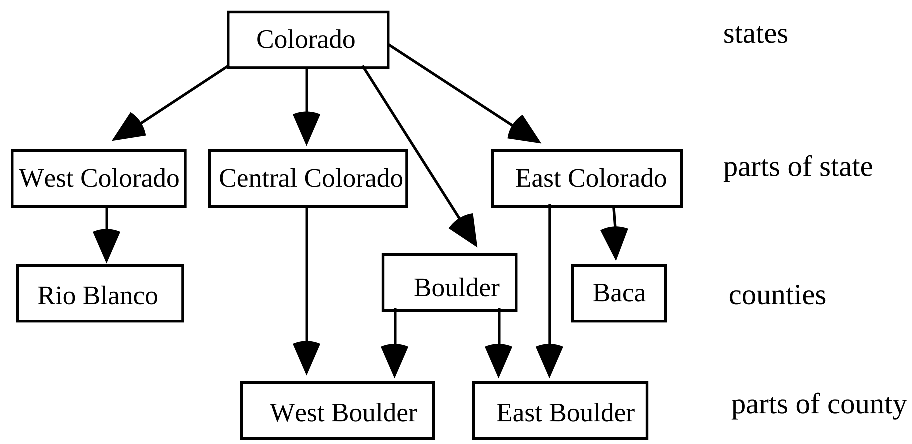


Fig. 3. A part of a lattice representing the territory model for Colorado

model are called *regions*. Any region is a set of grid points. The *area* of a region is the number of grid points that constitute the region. The definition of the region as a set of points implies that all set operations and relations can be applied to regions. They include the operations of *union*, *intersection*, and *difference*, and the relation of *inclusion*. In addition, we introduce the relation of *coverage*. A set of regions are said to cover another region if the regions are mutually disjoint and their union is equal to the covered region.

The relation of *subset/superset* allows us to organize the regions into a lattice (an example is shown in Fig. 3). In the lattice, only the immediate subregions of a given region are connected to it. Thus, even though East Boulder is part of Colorado, there is no direct link between them; instead, East Boulder is connected to Boulder, which is the smallest region that contains East Boulder entirely, and Boulder is connected to Colorado, because there is no other region that contains Boulder and is part of Colorado. Such a representation is efficient enough because it contains the minimum number of links from which the relation of inclusion can be computed for each pair of regions.

5.2. Time model

The time model supports reasoning in the temporal domain. The original data sets refer to fixed time points (*moments*) arranged equidistantly on the time axis. The time between two consecutive moments is called *temporal resolution* of the system. The *time period* is a set of consecutive moments. The *length* of a time period is the number of moments it consists of. In addition to the relations of *subset/superset* and *coverage*, inherited from the set nature of the periods, the relation of *precedence* is used as well, reflecting the ordered nature of the periods.

A simple time model is shown in Fig. 4. The resolution is 1 h, the time domain is 12 h, and there are five layers of time periods: moments corresponding to the valid times of the data sets, six 2-h periods, three 4-h periods, two 6-h intervals, and one 12-h period.

5.3. Cylinders

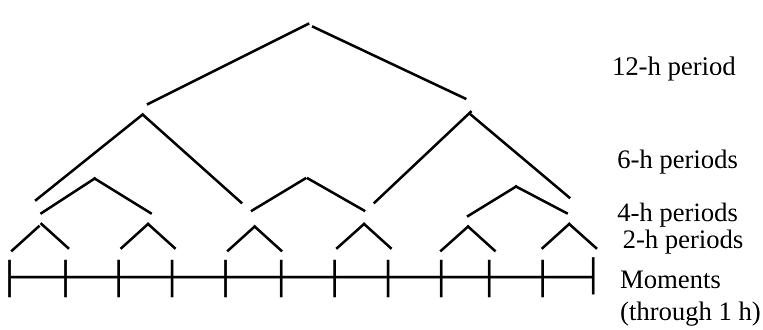


Fig. 4. An example of a time model consisting of five layers.

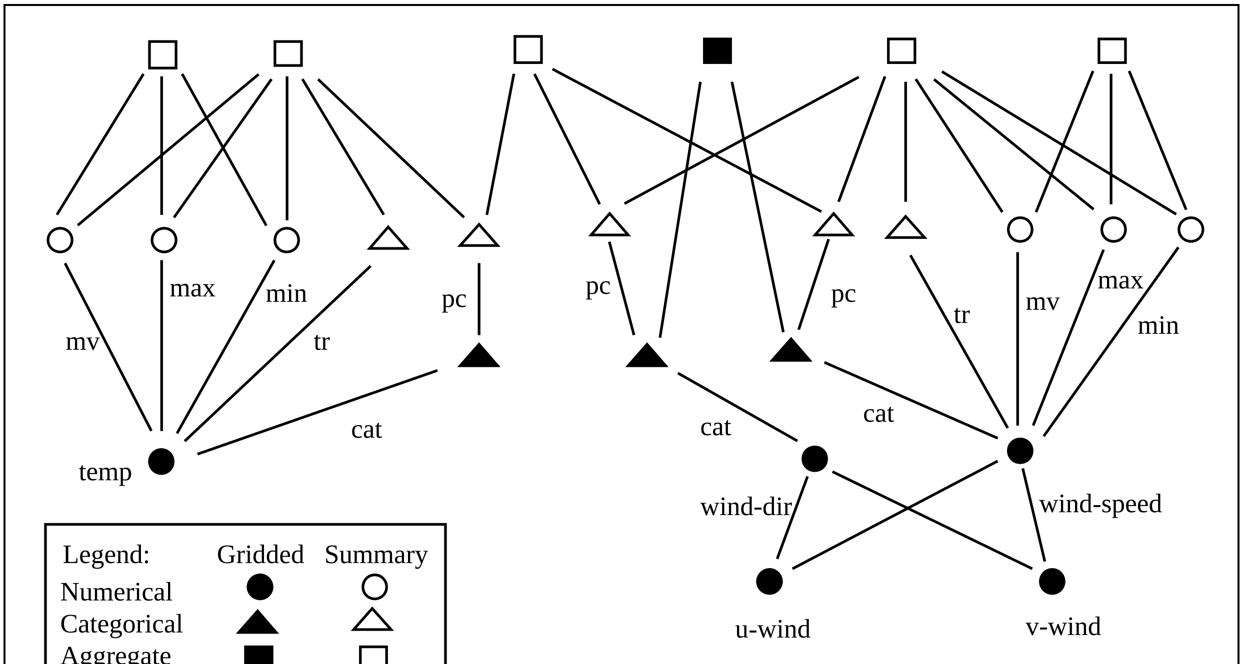


Fig. 5. An example of a weather model

For the sake of compactness, it is convenient to combine the region and time period of an assertion into a cylinder. The region represents the base of the cylinder, and the time period represents its height. Cylinders have both spatial and temporal dimensions, and as such, are convenient for representing assertions assigning weather values to regions valid for a certain period. The *volume* of a cylinder is the number of grid cells that constitute the cylinder. The relations of *subset/superset* and *coverage* are defined for cylinders in the same way as for regions and time periods.

We use the figurative expressions "temporally sliced cylinder" and "regionally sliced cylinder" to refer to two different ways of dividing a cylinder into subcylinders. Temporal slicing divides the cylinder into subcylinders that refer to the same region and to successive subperiods (i.e., the subcylinders are one above the other), whereas regional slicing divides the cylinder into subcylinders corresponding to the same period and to different subregions (i.e., the subcylinders are one beside the other).

5.4. Weather model

The weather model defines the weather parameters involved in generating weather reports. The original data set contains data about certain *basic* parameters (e.g., temperature, relative humidity, radar reflectivity) determined by observation, instrument, or numerical models. From the basic parameters we compute derived parameters that reflect more precisely user needs. The derived parameters can be gridded vs. summary, numerical vs. categorical, and aggregates vs. single-valued. We employ four methods to derive other parameters: *categorization, summarization, merge,* and *aggregation*.

Categorization (cat) is the conversion of a numerical parameter into a categorical one. The domain of a categorical parameter is a finite set of categories. Typically, a numerical parameter is categorized by dividing its domain, which is a closed interval of real numbers, into subintervals, and assigning a category to each subinterval. For example, the Beaufort scale converts wind speed into wind force using 13 subintervals.

Summarization means converting a parameter defined on the grid into a parameter defined on the set of cylinders. Since the summarization may, and usually does, distort the original information, we control the degree of distortion by computing a *precision rate* along with the value of the parameter. Typical summarization methods are accumulation (acc), mean value (mv), extreme (max or min) value, predominant category (pc), and trend (tr).

- *Accumulation*. Applies to numerical parameters. The value is equal to the sum of the parameter values in the cells of a cylinder. The precision rate is 1.
- *Mean value*. Applies to numerical parameters. The value is equal to the mean value of the parameter data found within the cylinder. The precision rate is inversely proportional to the average deviation of the mean value.
- *Max value*. Applies to numerical parameters. The value is equal to the maximum value found in the data set for that parameter within the cylinder. The precision rate is 1.
- *Min value*. It is defined like the max value but actually asserts the minimum value.
- *Predominant category (mode value).* Applies to categorical parameters. The value is the category with

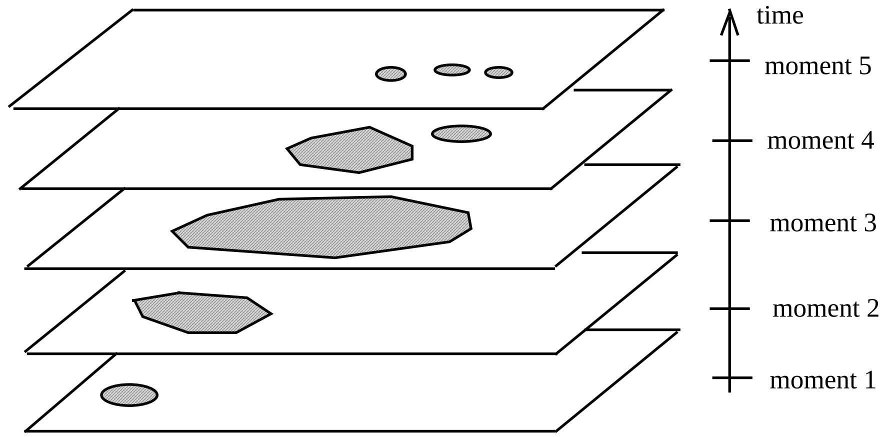


Fig. 6. A floating area consisting of five slices showing a storm that grows and then gradually dissipates.

the maximum number of occurrences within the cylinder. The precision rate is equal to the ratio of the number of occurrences of that category and the volume of the cylinder.

- *Trend*. Applies to numerical parameters. The value is one of three categories: *stable*, *increasing,* or *decreasing,* indicating the trend of the mean value for the region over a period.

By merging two or more parameters, we get a new numerical or categorical parameter. For example, wind speed is derived from the basic parameters u-wind (the north-south component) and v-wind (the east-west component).

The aggregation of several parameters is a new parameter that has composite values rather than single numbers or categories. For example, wind aggregates the parameters wind speed and wind direction. The role of aggregation is highlighted below where I discuss the generation of descriptions.

An example of a weather model built on three basic parameters (temperature, u-wind, and v-wind) is shown in Fig. 5 (the nodes represent the parameters, and the lines represent the methods used to compute the derived parameters). The model is built bottom up. Each derived parameter is identified by the composition of methods used to compute it from the corresponding basic parameters, e.g., $tr \square temp$, $pc \square cat \square temp$, $pc \square cat \square wind\text{-}speed \square (u\text{-}wind, v\text{-}wind)$.

6. Floating areas

Weather defines regions of its own, which do not reside permanently in the territory model but rather are associated with the existence of certain phenomena. An example of a weather-determined region is the area under a storm. Such an area is defined by a certain condition imposed on one or more parameters (e.g., we can use the parameters wind speed, precipitation amount, radar reflectivity, and lightning activity to define a floating area of type storm). As the parameters change with the time, the area changes as well; hence the name *floating area.*

A floating area consists of several *temporary areas*. The temporary areas are contiguous and are defined for single moments. A point belongs to a temporary area if it satisfies the condition of the floating area. Most often the condition is that the value of a certain parameter for that point at that moment exceeds a given threshold (for numerical parameters) or is equal to a given category (for categorical parameters). For example, the temporary areas of a storm can be defined by the condition that the radar reflectivity exceeds a certain value. Being a still area at a moment, the temporary area can be treated in the same way as the other regions.

Not just any collection of temporary areas makes a floating area. They need to be linked in some way. We posit that two temporary areas are linked if they are determined by the same condition, refer to two consecutive moments, and overlap each other. Two temporary areas are also linked if there is a third temporary area that is linked to both of them.

A floating area over a time period is the set of linked temporary areas pertaining to that period. Floating areas extend the concept of the cylinder by allowing volumes of arbitrary shape in the reports. In Fig. 6, an example of a floating area is shown. From moment 1 to moment 3 it grows as it moves east, then splits into two smaller areas, and from moment 4 to moment 5 splits again into three even smaller areas.

A floating area can be described in reference to permanent regions and using additional categorical parameters: *duration* of the floating area, which is equal to the time period of its existence; *size* of the floating area at each moment; *motion-direction* over a time period; *topological-metamorphosis*, a categorical parameter having three values, *split*, *merge*, and *no-change*; and *geometrical-metamorphosis*, another categorical parameter having three values, *grow*, *shrink*, and *no-change*.

7. Assertions

The assertions relate weather or other characteristics to cylinders, including floating areas. The elements of an assertion are its *parameter, cylinder, value,* and *precision rate*. The cylinder (a region and time period, or a floating area) determines the spatial and temporal scope of the assertion; its parameter determines which aspect of the reality is specified; value is what is asserted; and precision is the measure of how well the assertion represents the original data. Since a single value is asserted, the parameter cannot be an aggregate.

We can regard the assertion as a function that maps a pair of a parameter and cylinder into a value and a precision rate. Thus the computation of assertions is a way of processing simple queries in which we give the parameter and the cylinder, and obtain the value.

8. Descriptions

A description organizes a set of assertions in a consistent way, which means that several assertions can be organized into a description if a relation exists that unifies them into a whole unit. Such a relation would make the perception of the individual assertions easier.

A description is specified by elements that are similar to the assertions elements. Like assertions, it has a *cylinder* and a *parameter,* which can be an aggregate, and is characterized with a *precision rate*. The precision rate is used by the system that displays the descriptions to warn users about possible distortion of the information. Unlike assertions, the description has no value associated to it. Instead it is characterized by a structure that is filled in with assertions or other descriptions; hence the descriptions have hierarchical structure. The structure of a description is specified by its *type*.

Like assertions, the descriptions are created in responses to queries. In a query, we specify the parameter (which physical phenomenon we are interested in), the cylinder (the spatial and temporal scope of our interest), and the type (how do we want the assertions be organized). The response is a chunk of assertions, possibly structured at several levels, and an overall precision rate of the description.

The following types of descriptions are used:

- *Assertion*. Consists of a single assertion specified by the parameter and cylinder of the query. The precision rate of the description is the same as the precision of the assertion.
- *Regional distribution*. Consists of subdescriptions for each region in a given coverage of the query region. The parameter and the time period are the same as those of the query. The overall precision rate is averaged from the precision rates of the subdescriptions using the volumes of the subcylinders as weights.
- *Grid distribution.* Represents a particular case of regional distribution. The coverage consists of the grid points that make up the query region.
- *Temporal distribution*. Consists of subdescriptions for each subperiod in a given coverage of the query period. The parameter and the region are the same as those of the query. The overall precision rate is averaged from the precision rates of the subdescriptions using the volumes of the subcylinders as weights.
- *Time series.* Represents a particular case of temporal distribution. The coverage consists of the moments that make up the query period.
- *Histogram*. Consists of assertions for the volumes of the floating areas corresponding to each value of the description parameter, which must be a categorical one. The precision rate is 1.0.
- *Parametrical*. Consists of subdescriptions for each subparameter of the description parameter which should be an aggregate. The cylinders of the subdescriptions are the same as the cylinder of the query. The precision rate is an average of the precision rates of the subdescriptions.

9. Generation of reports

The goal of the system is to create reports on different media. There are rules that determine how the descriptions of a certain type are presented using the means of expression of the different media.

- *Natural language text.* Every text product is built according to a certain template. The template is a sequence of canned phrases with slots that can be filled in with data items. To express a description as a text, there should be a template corresponding to that type of description. The mapping from the description structure to the template defines which elements of the description constituents fill in which slots of the template.
- *Table.* The table is a structure that organizes data in columns and rows. It is typically used for presentation of descriptions with fixed structure such as *time series, histogram,* and *fixed regional distribution.* The mapping from a description to a table is specified by saying which elements of the description are included where in the table.
- *Graph.* The graph displays correspondence between two variables. It is very efficient for presenting time series and histograms. The only difference between the specification of graphs and the specification of tables is that in graphs we assign description elements to coordinate axes rather than to columns.
- *Map.* The map is used for presenting a description whose cylinder is regionally sliced to obtain the cylinders of the constituent assertions and whose parameter is categorical. The values of the particular

assertions are represented by icons placed over the regions that the corresponding assertions refer to.

- *Image*. Images are used for presenting categorized fields. The categorical values of the parameter are color coded, and each cylinder is a single grid point. An animated image presents a description of type *time series*, the constituents of which are subdescriptions of the same parameter referring to the whole grid and to single moments.

10. How the system works

I use the example in section 3.1 and the models in Fig. 3, 4, and 5 to illustrate how the system works. The map display represents a description generated in response to query *q*:

$$\begin{aligned} q = (&typ = par \circ (reg\text{-}distr \circ assert,\\ &\qquad\qquad reg\text{-}distr \circ par \circ assert),\\ &par = aggr \circ (pc \circ cat \circ temp,\\ &\qquad\qquad \mathrm{aggr} \circ (pc \circ cat \circ wind\text{-}speed \circ\\ &\qquad\qquad\qquad (u\text{-}wind, v\text{-}wind),\\ &\qquad\qquad\quad (pc \circ cat \circ wind\text{-}dir \circ\\ &\qquad\qquad\qquad (u\text{-}wind, v\text{-}wind))),\\ &cyl = (Colorado, 12\text{-}hour)) \end{aligned}$$

This query is decomposed into two subqueries, *q1* and *q2*, the first of which is given below:

$$\begin{aligned} q1 = (&typ = reg\text{-}distr \circ assert,\\ &par = pc \circ cat \circ temp,\\ &cyl = (Colorado, 12\text{-}hour)) \end{aligned}$$

Subquery *q2* is obtained by combining the second subtype of *q* with the second subparameter of the aggregate. Query *q1* is further decomposed into three subqueries, *q11*, *q12*, and *q13*, corresponding to the three regions representing a coverage of Colorado, viz. Mountains, Foothills and East Colorado. Query *q11* is shown below:

$$\begin{aligned} q11 = (&typ = assert,\\ &par = pc \circ cat \circ temp,\\ &cyl = (Mount, 12\text{-}hour)) \end{aligned}$$

Queries *q11*, *q12*, and *q13* each lead to the computation of a single assertion, the value of which is a category summarizing the temperatures over the corresponding region. The categories correspond to ranges of ten degrees, e.g., 10•–20•, 20•–30•. Each category is represented by a color box or a box on which the temperature range is written. Wind is represented by a barb, an arrow oriented opposite to the wind direction and marked by bars whose number corresponds to the wind force.

Each icon is associated with a parameter and region. Clicking on an icon causes the system to generate a text product from a description corresponding to the parameter and the region. For example, if the icon of temperatures over East Colorado is clicked, a description will be generated in response to the following query:

$$\begin{aligned} q = (&typ = reg\text{-}distr \circ par \circ\\ &\qquad (assert, assert, assert, assert, assert),\\ &par = aggr \circ\\ &\qquad (pv \circ cat \circ temp, mv \circ temp, \max\circ temp,\\ &\qquad \min\circ temp, tr \circ temp),\\ &cyl = (E\ Col, 12\text{-}hour)) \end{aligned}$$

This query is decomposed into subqueries until assertions are obtained. Then the subdescription combining all the assertions that refer to the same region is rendered as a separate paragraph, and a button is associated with it. If we click this button, a graph will be generated from a description produced in response to the following query

$$\begin{aligned} q = (&typ = par \circ (time\text{-}series \circ assert,\\ &\qquad\qquad time\text{-}series \circ assert,\\ &\qquad\qquad time\text{-}series \circ assert),\\ &par = aggr \circ (mv \circ temp, \max\circ temp, \min\circ temp),\\ &cyl = (r, 12\text{-}hour)) \end{aligned}$$

where *r* is the region whose paragraph was selected. The description consists of three time series, one for each parameter participating in the aggregation. Note that the particular values in a time series are obtained by summarizing the temperatures over the grid points of *r* at the moment corresponding to the position of the value in the time series. A table is generated on request from the same description.

In addition to the buttons assigned to the individual text paragraphs, there is a button associated with the whole text. This button causes the system to generate an image created from a description specified by the query:

$$
\boxed{\begin{aligned} q = (&typ = grid\text{-}distr \circ assert,\\ &par = cat \circ temp,\\ &cyl = (\text{grid}, moment\text{-}12))\end{aligned}}
$$

The description contains an assertion for each grid point. The categories of $cat \circ temp$ are color coded and the product is a bit map image, each pixel having the color of the corresponding grid point. An animation of the image is created from a description specified by the following query:

$$
\boxed{\begin{aligned} q = (&typ = time\text{-}series \circ grid\text{-}distr \circ assert,\\ &par = cat \circ temp,\\ &cyl = (\text{grid}, 12\text{-}hour))\end{aligned}}
$$

The description consists of 12 subdescriptions corresponding to the moments of the 12 hour interval. Each subdescription alone is represented by an image, and the whole description is represented by a sequence of images.

11. Implementation status

The system we have built uses data sets from the Local Analysis and Prediction System. The spatial resolution of the 61×61 grid is 10 km, and the temporal resolution is 1 h. This grid covers Mid and East Colorado as well as small portions of Wyoming, Nebraska, Kansas, Oklahoma, and New Mexico. The temporal domain is 12 hours.

The first implementation was in FORTRAN on VAX and it dealt with a limited subset of descriptions. A second version, the MeteoAssert system, was implemented in Microsoft Visual C++ on IBM PC and it supports the full range of description types presented in this paper. The system handles most of the queries within one second, but queries for floating areas are usually processed for 4-8 seconds depending on the complexity of the floating area.

The descriptions produced by MeteoAssert are presented to the user as a text, map, image, graph, or table by LookSee, a visualization system written in Microsoft Visual Basic. It runs on another computer and exchanges queries and descriptions with MeteoAssert through the network. Both MeteoAssert and LookSee are experimental systems developed within the Dissemination project at NOAA Forecast Systems Laboratory. This configuration is being tested as a watch/warning system in Boulder county.

12. Conclusion

This paper presents a framework for hypermedia access to weather information generated from gridded data sets. The information is presented in single-medium products: map, text, graph, table, and image. The user navigates from a summary product to products emphasizing specific aspects of the weather. The framework allows easy customizing of the system to particular applications and uniform generation of various products.

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* Author's permanent affiliation: Institute of Mathematics, Bulg. Acad. of Sci., Bl. 8, Acad. G. Bonchev street, 1113 Sofia, Bulgaria.