Influential Visual Design Parameters on TV Weather Maps

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ABSTRACT

Information transformation on television weather maps (TVWM) is influenced by visual elements for a broad range of viewers. This research emphasizes the cartographic aspects of TVWMs through evaluating their visual variables. Currently defined visual variables including basic, dynamic and motion variables are investigated and some suggestions are made to improve their application on TVWMs. The rates of the represented visual information within different frames and the related standard deviation are proposed as measures to improve the performance of the 'duration' dynamic variable. The concept of 'visual expressions' is introduced, and their applications at the organisational level of map design are discussed. Such expressions (including background, boundary, spatial order, zoom and overview maps) are examined as tools for 'user orientation' in particular, and their role as dominant parameters in TVWMs' cartographic communication is considered. Their incorporation in TVWMs of a number of global news channels is evaluated. Firstly, the concepts of visual design parameters are utilised as a foundation for an analytical evaluation, then an empirical evaluation is carried out based on a statistical investigation of a sample of TV viewers. The resulting ranking order and correlation coefficients for each of the elements shows a firm agreement, corroborating views on the importance and proficiency of the visual elements in communicating weather information. As a result, TVWMs of well-known global TV channels (BBC, Euronews, France24, PressTV) are ranked with respect to the effectiveness of their designs.

Keywords: Television Weather Maps; Cartography; Visual variables; User orientation

1 Introduction and proposition

The application of identified visual variables to effective cartographic design has been well-documented. The derivation of discrete characteristics which can be applied to the vast range of cartographic symbology has improved map design in several respects. Most notably, those maps whose prime purpose is the communication of known spatial data have benefitted from research showing how user perception and interpretation can be directed by judicious choice of parameters. Maps which are presented to convey a particular message, as opposed to those maps created to encourage visual exploration and user-derived knowledge acquisition, will work most effectively when the visual variables are used in such a way that the user's perception of the message is directed.

Map design, however, involves much more than the choice of point, line, area, and text symbols. Primers on cartographic design identify a level of design which is related to individual symbol choice, but also highlight the 'organisational' level of design, which pertains to the overall appearance of the map face (Dent *et. al*, 2008). Here the characteristics are not (for example) line colour, area texture or point symbol size: they involve instead more intangible properties such as clarity, hierarchy, and balance. Although more difficult to define, and certainly less well-studied in terms of the effect of their variability on map users, these properties of a map image are based

on the combinations of decisions made about employing the visual variables at individual symbol level.

To maintain the mathematical metaphor, which defines 'variables' at symbol level, we would like to introduce the term 'expressions' to refer to the characteristics of map displays at the organisational level. Mathematical expressions involve combinations of variables, and we propose the term 'visual expression' to refer to the identification and distinguishing of map elements and properties such as layout, balance, zoom level, hierarchical organisation, clarity etc. These can be recognised at the organisational level and this paper attempts to address the practical application of some of them to a specific map design and map use scenario. Some writers have used the term 'visual expression' as a synonym for the map itself (Marriott and Meyer, 1998), but any serious attempt to identify and understand the design process in cartography must recognise that there are multiple visual levels to any map document which can be de-constructed to reveal elements including the visual variables, the visual expressions and the overall visual impact of the map face. Research on visual variables has been extended since the initial work by Bertin and his school (see MacEachren, 1995, Chapter 6) which noted a number of discrete parameters related to individual symbols on traditional, static maps. Dynamic visual variables, and sonic variables, have also been presented and have themselves been examined to determine the scope and efficacy of their application.

This paper proposes the use of the term 'visual expression' to categorise those discrete design choices which apply to the organisational level of design. Some of these are described as 'map pieces' in Krygier and Wood (2011), and include items of marginal information – legend, scale bar, direction indicator – as well as enhancements such as inset/locator maps. Further visual expressions are manifest in characteristics of the map face such as foreground and background, hierarchical organisation of individual symbols, balance of individual symbols on the map face, contrast, and visual acuity as described in Dent *et al*. (2008). These items of marginal information and the application of these characteristics of the map face, are all part of the design process at a level different to that of the individual symbol, and form part of the composition of a map. The term 'visual expressions' can be used to classify these compositional elements.

2 Visual expressions on television weather maps

Identifying, distinguishing and parameterising the range of visual expressions are tasks yet to be undertaken. The study described in this paper initiates such tasks by illustrating the application of differing visual expressions, and exemplifying their application in a specific category of map, television weather maps. The intention is to show that the choices made in the design of this particular category of map can exemplify the wide variety of parameters which are available to the cartographer. An analytical exploration of these maps and their impact is attempted, and a critique of their use of some of the 'visual expressions' identified is presented. A limited empirical confirmation of this critique is sought through a user survey, and conclusions are drawn about the effectiveness of these design parameters in conveying spatial information.

With the advent of a new generation of numerical weather prediction models (Haase *et al*., 2000), meteorological technologies provide the possibility of predicting the weather of different geographical areas with high accuracy. Such accurate predictions are used to assist in planning of a wide range of human activities including navigation and travel, health resource planning, prediction of energy consumption, recreational and sporting activity, and retail management. Clearly, appropriate presentation of such weather forecasts is essential, and all types of media including newspapers, radio, television and online services are widely utilised. The internet and television, in particular, are the most common sources for receiving news and information which represents meteorological information on maps (Kraak and Brown, 2001).

Weather reports relying on such maps are disseminated widely through news media (Monmonier, 1999): the maps are a major type of representation of meteorology, and these representations influence our daily life (Monmonier, 1997) and can form part of popular culture (Carter 1998). The visualisation of weather reports is the final stage of meteorological data processing (Haase *et al*., 2000; Carter, 1988) and offers a significant impact on the communication of weather forecasts. The representation of such visualisations on television yields a non-interactive and potentially complex visual display (Lowe, 1999; Hegarty *et al*., 2010) and for effective weather information transfer, the importance of accurate visualisation on television weather maps (TVWMs) is increased. A recent survey of television news channels revealed that 51.8% of climate change reports were provided in a symbolic

and graphical way (Lester and Cottle, 2009), and the presentation of daily weather predictions is likely to be even higher.

The world's first televised weather chart was broadcast by the BBC in 1936 (Keeling, 2010), and innovation has been apparent continuously since then. For example, it is clear that although such displays are non-interactive, meteorological information communication by means of TV media increasingly allows for better orientation of users to their locations on the globe; and the visualisation of dynamic weather phenomena has markedly improved.

However, there are still some weaknesses from both a cartographic point of view and from the information communication perspective. A remaining key issue to be addressed is the fact that identification of personal location, and consequent weather information, in a time-limited TV display environment is not flexible. The lack of an exploratory environment means that there is no in-built functionality in TV representation of weather visualization (Ogao and Kraak, 2002). Further, weather maps have been described as rarely following well-established cartographic design principles (Fabrikant *et al*., 2010; Nemeth, 2005; Carter, 1998; Muehrcke, 1996) and non-meteorologists (i.e. the vast majority of viewers) usually have a poor communication with a weather map (Lowe, 1999).

Cartography, as a visualisation tool (Rystedt, 2000) and a useful contributor to geodesign (Goodchild, 2010), should enhance spatial understanding (Dodge *et al*., 2008), including optimal representation of weather conditions, rather than confuse the viewer. The study presented here attempts to evaluate the application of cartographic procedures on television weather maps (TVWMs) in order to examine their communication effectiveness. In particular, the role of design choices has been highlighted, with an aim of determining the role of more complex design elements (visual expressions) in user orientation. Background, boundary, spatial order, zoom and overview maps have been dominant parameters in TVWMs' representation and communication: these are considered as visual expressions and are addressed in this paper.

Firstly, some of the unique characteristics of TVWMs are highlighted, then some individual visual variables are discussed. Some of the basic, dynamic and motion variables are evaluated and new visual metrics (including enhancements of

dynamic variables, such as rate of represented information) are obtained for TVWMs. Five identified map design visual expressions used to assist in user orientation in particular, are introduced in Section 5. Application of these expressions is evaluated and analysed using empirical methods for TVWMs of four global news channels (BBC, Euronews, France24 and PressTV). Conclusions regarding the effectiveness of such expressions are presented by an analytical evaluation of TVWMs. To validate the efficiency of such design choices in communication, a practical user testing is designed to collect TV viewers' opinions. Suggestions for future work in this area are also presented.

3 Characteristics of TVWMs

TV visuals can play a noticeable role in the development of a wide-ranging global environmental awareness (Lester and Cottle, 2009). During any visualization for such purposes, user needs may vary and include both passive assimilation and active exploration of geospatial data (Ogao and Kraak, 2002). The latter is limited as, like most TV displays, TVWMs are representational rather than exploratory. Thus, accurate cartographic design is needed to ensure the most appropriate communication. The limited interactivity can be addressed, and is often overcome, by a standardised and user-friendly approach to TV representation of weather conditions. A number of factors can be addressed to ensure such an effective approach:

- TV display issues: time duration of forecast, video quality of TV channels, frequency of updates;
- Cartographic aspects: base-map type, map symbology, use of visual variables, wider organisational and layout issues, adoption of visual expressions;
- Other factors: e.g. explanation and interpretation of the weathercaster, intrusiveness of marginal activities such as advertising or colleagues' interruptions etc.

The information presented on TVWMs can be categorized into two general groups: temporal and non-temporal. Information related to predictions and comparison of meteorological conditions, which is the largest part of weather information, would be regarded as temporal, and is clearly suited to dynamic display. Non-temporal information that provides no data about change (Kraak and MacEachren, 1994) includes information related to weather conditions at a current or

specific time, and can be rendered in static displays. Some weather information can be represented in 3D, either by carefully designed point symbols or by solid-looking models of air mass movement and frontal systems. The latter are rarely presented on TVWMs. Table 1 illustrates some of the specific items of weather information which can be thus classified.

Table 1. TV Weather map types.

	Static		Dynamic	
	2D	3D	2D	3D
Temporal	map sequences showing conditions	-	air masses, warm & cold fronts, temperature patterns, etc.	-
Non-Temporal	'snapshots' of e.g. air moisture, wind velocity	-	min & max temperature	min & max temperature symbols

The distinction between static and dynamic displays leads to a consideration of the cartographic visual variables which affect the design of TVWMs and their ability to communicate weather information effectively. A concentration on visual variables must include those basic variables proposed by Bertin, but also extend to the enhanced range of dynamic variables, and also consider the visual expressions. The development of these complex cartographic elements, and their impact on users is presented later.

4 Visual variables on TVWMs: an initial analysis

Visual variables can be regarded as the basis for a successful information visualisation (Card *et al*., 1999), and are used in all of the visual aspects of map communication. Bertin's identification of visual variables as applied to cartography, and the effect of such variables on viewer perception of the map, has guided cartographic design for decades (Garlandini and Fabrikant, 2009). His major conclusion was that map design is driven by the data to be represented and, as a result, he presented specific guidelines for the use of each of his seven visual variables to ensure maximum efficiency of visualization and communication of information (Bertin, 1983). Bertin investigated and presented examples of the creation, application and perception of symbols, representing the spatial data to be portrayed. The impact of simultaneous variability in more than one visual variable was also considered, and the consequent complexity of data presentation and understanding in the majority of map displays was highlighted. The impact on the map face of multiple symbols and their interaction has also been considered by design researchers (Tufte, 2001). TVWMs are excellent

examples of complex visual displays with multiple symbols, combining visual variables superimposed on base maps which themselves may exhibit variability (Thomas and Cook, 2005). Contemporary TVWMs are further enhanced by those variables which have been introduced since Bertin's initial work. Thus, the study presented here focused on the main groups of visual variables including basic, dynamic, and motion variables along with user-orientation expressions for the first time. TVWMs are evaluated with respect to these variables and further expressions and consequently a number of suggestions are offered for the improvement of their cartographic visualisation.

4.1 *Basic variables*

The role of Bertin's (1967) basic visual variables in the whole process of symbol design has been explored by many cartographers. The combination and integration of the variables in determining the design of individual symbols (semiology) is extended when considering the design for the overall appearance of the map face – the 'organisational' phase of design. The users' perception at this level subsumes the variability of individual symbols to the perception of the totality of impact of the map. It is this level which is affected by variation in some of the elements introduced later in this paper – for example, background, layout, hierarchy – and therefore details of individual symbol design at the basic level are not considered further.

4.2 *Dynamic variables*

However, it *is* pertinent to note the opportunities given by, and impact of, more recently presented visual variables which have developed Bertin's ideas further. In the context of TVWMs, the role of dynamic and motion-induced variation in individual symbol design is of significant importance. Dibiase *et al*. (1992) found that time gives a new power to Bertin's basic variables and introduced three dynamic variables: duration, order, and rate of change. MacEachren (1995) added frequency, display time and synchronization to the list. Kraak and Klomp (1995) suggested that 'order' and 'duration' are the fundamental variables which can be extracted from this list, as "the other dynamic variables are functions of, or dependent on, order and duration (display date and frequency), or more or less data dependent (rate of change), or special (synchronization – multiple temporal data sets)" (p.35). The investigation of TVWMs

detailed here concentrates on order and duration as the most prominent variables (Kraak *et al*., 1997).

4.2.1 Duration

The duration variable is the length of time during which there is no change in the display (Dibiase *et al*., 1992). The display time length for TVWMs is a measure of the appearance time for each frame: this may be determined by editorial policy which dictates that the weathercaster has no control over when to change the frame and has to adapt spoken explanations to the time available. The vast majority of TVWMs form part of a sequence of maps, together forming a television weather report (TVWR). The information content of the full report will be dependent on the number of frames comprising the report. The immediate impact on the viewer, however, is affected by the amount of information conveyed in each frame, so some estimate of the information content must be considered: the quantity of visual information has been determined by the number of represented cities, the symbols of weather conditions and the temperature information available in each frame. Table 2 shows the duration and amount of visual information for each frame of TVWMs from sample broadcasts representing temperature of some worldwide cities on 5 April 2010.

The channels chosen are the BBC, Euronews, PressTV along with its sister channel IRINN, and, for some later analysis, France24. These are all 24-hour news channels, available globally, and including weather reports as a major part of their broadcast output.

Table 2. TVWMs' duration variable (*t*) and the number of items of visual information (*n*).

	Evaluated element	Frame								
		1	2	3	4	5	6	7	8	9
BBC	t (sec)	16	12	16	16	13	13	12		
	n	33	33	37	33	33	35	29		
Euronews	t (sec)	9	8	6	5	6	5	6	5	6
	n	72	54	42	51	54	36	48	48	45
PressTV	t (sec)	3	3	3	3	3	3	3	3	3
	n	5	5	5	5	5	5	5	5	5
IRINN	t (sec)	14	13	13	13	12	14			
	n	52	28	16	28	36	36			

Estimates of measures of information complexity can be related to information redundancy (Scott, 1969), number of fixation groups (Xing, 2004) and the number of visual objects (Woodruff *et al*., 1998). Xing (2004) further suggests, however, that these metrics may vary considerably, dependent on the specific characteristics of any

display. As display time limitation is the key challenge in information transfer for TVWM this study defined a 'visual information representation rate' for estimating the amount of visual information displayed on a frame within a second as:

$$r = n/t \quad (1)$$

where n is the value of visual information content (equated to the number of information items presented) and t is the duration of each frame (Table 3).

Table 3. Mean (*M*) and Standard Deviation (*SD*) of *r* on TVWMs.

	BBC	Euronews	IRINN	PressTV
M	2.40	8.14	2.47	1.67
SD	0.28	1.21	0.85	0

Clearly, a smaller value of r allows the user to have a better visual perception of the presented information. Without more focussed cognitive experiments, it is difficult to recommend an optimal value for r but values smaller than 3 appear to be most suitable. For example, if users can perceive the place of interest, comprehend its name, the weather symbol (e.g. rainy, sunny) and a temperature value within 1 second the display may be effective. However, Meksula (2003) has shown that the time of the presentation of a single static map should not be shorter than 5 seconds, and a perception of the full amount of information (typically, n >30) would require considerably longer. The limited total length of TVWRs (typically two minutes) militates against an open-ended display of map sequences. Thus, in addition to a minimum display time, a maximum value for the duration of each map must be considered. Providing excessive amounts of information for each map is not a good reason to increase the duration variable. Crowding (Stuart and Burian, 1962), masking (Legge and Foley, 1980) and degradation of the visual search performance (Rosenholtz *et al*., 2007; Wolfe, 1998) can affect displays regardless of the length of time available for their perception. The values for t in Table 2 show that TVWR creators rarely use frames for more than 12 seconds: this is a similar figure to that of Jones (2005) who identified a 12 second maximum attention span for screen images. Thus, design effort should be directed towards reducing any clutter effect by minimising the amount of text (Xing and Heeger, 2001; Xing, 2004) and other objects in each frame (Rosenholtz *et al*., 2007), and by designing each symbol according to

the guidelines of Bertin. Based on the assumptions and working above, the maximum number of visual data items to be displayed in each frame n should be about 36.

If there was a strict time limitation on TVWRs, the duration of each frame could be reduced considerably to a minimum value of 3 or 4 seconds, thus requiring an adjustment in the amount of represented information (n becomes equal to 9 or 12).

A further possible issue is the calculated representation rates (r) of successive frames within the TVWM. A lack of uniformity between adjacent frames (indicated by high values for standard deviation in Table 3) indicates a lack of balance in the design. Users can best react to constant rates in receiving information and disturbing such harmony will distract from effective transfer of information. Euronews maps, for example, show high figures for information overload and variability in display times in each frame. Consequently, the use of the duration visual variable in its weather maps is sub-optimal. Whilst the variability of r for IRINN TVWRs is high, its information content appears comparable with the most optimally balanced BBC and PressTV broadcasts. Specifically on the PressTV maps, within a constant 3 seconds the information quantity (minimum and maximum temperature of a city along with the name of city and country and weather condition symbol) well suits in each frame (where $SD = 0$). Table 4 shows an interpretation of the application of the 'duration' variable on the tested channels.

Table 4. Fitness of duration variable.

	BBC	Euronews	IRINN	PressTV
Duration	+	--	0	++

Although, PressTV has the best fitness with respect to the duration variable, the total number of presented cities is not enough for a global coverage. Section 6 has more discussion on this topic.

4.2.2 Order

Time is inherently ordered (Kraak and MacEachren, 1994), and as indicated by DiBiase *et al*. (1992) there should be temporal order among the frames of a TVWR. In the context of TVWMs, the variable 'order' could refer to the specific sequence of temporal 'snap-shots' of weather progress and development of features such as warm and cold fronts. The linkage between order and the representation of dynamic phenomena in weather maps means that motion variables will be considered in greater

depth in the next section. However, within TVWR there is a further consideration of order in assessing the way in which different parts of the global surface are introduced and discussed within a broadcast. For global weather forecasts, such a digital 'trip' through the areas of interest can be undertaken in a standard, regular order or seemingly at random. Because of the impact such an order has on how viewers connect to their location it is considered as a visual expression assisting in user orientation and will be discussed in Section 5.1.3.

4.3 *Motion variables*

Wilkinson (1999) differentiated direction, speed and acceleration as attributes of motion. In TVWMs, in addition to these variables, other variables related to the animations like view and distance (translated to change in scale) might also be considered. Maps involving simulation of flight over geographical areas are one of the main television map types. Two types of these maps are most common; firstly those with an orthographic view angle (i.e. as a traditional, yet moving, map display), and secondly with an oblique view angle concentrating on smaller area maps. The IRINN channel uses the first type and France24 channel uses the second. The characteristics of each method are investigated through the visual expression of a zoom variable (section 5.1.4). In some cases, sudden changes in displacement velocity can lead to distraction of the viewers' concentration (this is made apparent in the empirical testing described later). Therefore, it is suggested that a uniform speed in displacements and regularity of standstill in display frames can preserve users' concentration. Thus, the speed of fly-throughs in moving map displays, and change in symbol characteristics, are best done at a constant rate, with zero acceleration.

In addition to constant speed, movement direction and view angle should exhibit simplicity and regularity. Whilst acknowledging that TVWMs represent areas of variable importance, with variable numbers of points of interest (e.g. cities) and variable lengths of time duration devoted to them, distraction is minimised, in terms of navigating over the map, when speed is harmonious and direction is not changed suddenly. The France24 broadcast TVWRs do suffer from such distractions leading to lower concentration and more difficulty in user orientation – as borne out by later experimental testing.

5 Visual expressions

The role of individual visual variables has been considered thus far, and acknowledgement of such variables can improve communication of information about specific locations (e.g. city temperature) and the characteristics of some weather features (e.g. nature of fronts). However, there are other items of information needed to ensure adequate understanding of TVWMs. With the exception of navigation, orientation/positioning is perhaps the most important function of maps (Kraak and Ormeling, 2003). Yet, in the context of weather maps, often sparsely enhanced with supplementary locational text, and in which general viewers are often unable to ascertain where on the map they are located (Thornes, 1992), such orientation is often problematic. This paper suggests that a set of identifiable user-oriented visual expressions can be distinguished which can assist in the effective communication of relevant weather information. These visual expressions are compound in the sense that they make use of several of the variations already noted, but more importantly they are not applied to the semiology of individual symbols; rather, they are recognised at the organisational level of map design. Here, expressions of background, boundary, spatial order, zoom and overview are proposed as a set of user oriented design parameters. The primary role of these visual expressions in user orientation is considered in this section.

5.1 The role of visual expression in TVWM usage

5.1.1 Background

Background is equivalent to the base map for thematic maps such as TVWMs, and by definition forms the lowest level of any hierarchical organisation. It can be considered as the main element in representing the locational component of spatial data. Colour tints, shaded DEMs and modified satellite imagery (such as normalised difference vegetation index – NDVI – layers) have been used as background for TVWMs. Although this layer is background, it could facilitate the first process of engagement with a map by encoding the locational features of the display (Bertin, 1983; Carpenter and Shah, 1998). It is one of the first elements that aids users to get oriented to the overall regions of interest spontaneously: among these is the figure-ground distinction, which can be a fundamental property of the background, distinguishing, for example, land and sea. After an overall orientation based on this, users concentrate

on the specified part of a frame to find accurate location using other features e.g. boundary or city name.

Hierarchical organization of information as a fundamental cartographic design task (Dent *et al*., 2008) on TVWMs is influenced by applying different backgrounds. Backgrounds with emphasis on a specific property of the features may not be suitable. For example, on the television weather maps of France24, there is a significant emphasis on a satellite-derived, NDVI-coded, background image which cannot improve the users' orientation always; in some cases it may make the TV viewer confused and reduce the saliency of the overlaid weather information. Although backgrounds such as topography and NDVI can lead to further recognition of the users with region type, excessive complexity and image variation of the background distracts from appropriate presentation (Tyner, 2010) of weather maps. As a key rule, hierarchies should be introduced so that only task-relevant information is highlighted and emphasised (Hegarty *et al*., 2010). Of all impacting elements, background has a critical role to achieve this aim. The complexity of an NDVI background draped over a DEM and the simplicity of flat colour tint have different levels of saliency. It is clear that generalisation of the background ensures more emphasis on the weather information but is only useful if the orientation of the user is preserved.

On the TVWMs of Euronews, the continents have been represented by a dark blue tint: it does seem counter-intuitive to represent land areas with such a colour. A simple experiment was carried out, designed to evaluate the efficiency of figure and ground in this map. In order to eliminate the possibility that text and weather symbols could have an impact on recognition of land from water, all of these materials are removed from original map (see Figure 1(b)), and thus users' interaction is evaluated with outlines only. A homogeneous sample of participants (including 50 males and 50 females, aged 18 to 35, and with varying levels of education) was exposed to a sample map similar to that in Figure 1 (b) for 5 seconds only: they were asked to immediately identify the water and land areas by pointing at the screen. Experimental results showed that a large number of participants (45%) perceived land as water. Factors such as familiarity with landmass shape may assist those who have a correct perception, and superimposed textual information and weather symbols make it clearer to find the continents: however, this choice of background colour has negative

impact in itself possibly leading to distraction of the users' experience and interpretation.

(a) Original (b) tested for figure-ground distinction

Figure 1. Misleading background on the Euronews weather map.

5.1.2 Boundary

As cartographic objects, political boundaries are considered as legislated lines (Mark and Csillag, 1989). Often these are the only line types used on TVWMs: a few countries may be emphasised and identified solely by their borders. In some cases weather reports are bounded by national frontiers with no information presented outside at all – thus boundaries are often the sole cartographic feature in areas without any weather information (e.g. Figure 2(b)). These unwanted boundaries should be excluded to ensure visual direction to the regions of interest (Xing, 2004). Although political divisions for continents and countries can orient users accurately, generalisation (including omission of some boundaries) should be applied. For focussed TVWMs, the number of boundary polygons far removed from weather information should decrease, and it is suggested that this will, in fact, have little effect on users' orientation. In the BBC TVWM (Figure 2 (a)), all national boundaries are included (albeit in a subdued grey colour), but their concentration in Europe, where on this map no weather information is placed, causes some distraction. Figure 2 (b) presents a further example of such distraction away from the map focus. On the France24 maps, no boundaries are provided (Figure 2 (c)), but the IRINN map even shows internal boundaries within the one country of interest (but none outside).

(a) BBC (b) PressTV

(c) France 24 (d) IRINN

Figure 2. Boundary variables on TVWMs.

5.1.3 Spatial Order

The 'order' visual variable, which is presented by Dibiase *et al*. (1992), has the ability to assist in representing temporal data. Clearly, all dynamic displays involving map sequences and animation rely on correct representation of the spatial data using appropriate ordering. In addition to this concept, the idea of 'spatial order' within a TVWR is considered here as an expression of design. User orientation and

recognition is assisted by regularity of observance of defined regions of interest on the maps within a TVWR and a logical order when covering extensive geographical areas (including the whole globe). A spatially divergent path intended to allow sight of a sequence of maps covering an extensive area could potentially leave gaps and address areas adjacent on the globe in a random way. A sequential travel path smoothly traversing the surface of the earth would avoid confusion of users' orientation. The creation of such a spatial order is influenced by various factors such as motion direction, coverage of TV channel viewers, and the importance of different areas from the viewpoint of the TV channel or its viewers. National TV channels mostly concentrate on their own territory and often the complete country is portrayed in each TVWM of the weather report: thus no traversing of the country may be necessary. For such channels, any coverage outside the country is likely to be highly selective and focus on a very few specific locations which have no inherent connection. The spatial order in weather maps of global news channels, however, may well require global or near-global coverage, and be relevant to viewers wherever they are in the world. The result is that TVWRs employ a consistent path of discrete maps, or occasionally pan across a globe representation. Familiarisation with such a consistent coverage of the globe within a TVWR aids interpretation and has led the news channels to use a regular spatial order (Figure 3) in their coverage.

(a) BBC (b) Euronews (c) PressTV

Figure 3. Spatial order variable on TVWMs.

In the BBC channel directed to world-wide viewers, for example, presentation of the continents is in successive discrete frames without emphasizing a specific place: due to its size, the relevant parts of the Asian continent are presented in two images (frames 2 and 3). Therefore, the spatial order expression has been applied logically and sequentially. Figure 3(b) indicates that Euronews' Asia coverage, however, has been presented in non-successive frames 4, 7 and 8, decreasing familiarity and orientation in comparison to the BBC's. There are displacements also in the France24 maps which may also mislead the users' orientation by leaving gaps and returning once more to the adjacent areas.

5.1.4 Zoom

In dynamic weather maps, the display usually starts with a view of the total region of interest and then magnifies a specific zone: this zoom process is expected to facilitate user orientation by working 'from the whole to the part'. As the scale of representation changes, so different categories and instances of weather symbol display can vary. Continuous variation of zoom level, notably in the course of fly-throughs, can cause specific visualisation problems. The weather map of France24, for example, employs a regular oblique fly-over type and movement in the viewer's peripheral vision can be distracting. However, in this TVWR map, the initial general view of continents is shown, and then this view suddenly disappears to be replaced by a separate zoomed area: it is not clear which part of region has been magnified and user orientation can suffer. In the weather maps of the IRINN channel, the representation of movement, distance and scale is logically presented as zooming occurs smoothly and users' orientation is not lost.

5.1.5 Overview map

The role of an overview or locator map has been considered by standard cartographic textbooks (e.g. Robinson *et al*., 1995; Slocum *et al*., 2005). When dynamically linked, as can easily be done in the animated TVWM environment, the main map and inset overview map can have cursors, bounding boxes, or shading, to indicate the area of coverage of the larger map. Once again, such information is communicated with the orientation of viewers as the main purpose. In the case of PressTV (Figure 4), the overview map is created in real-time as a result of dynamic linking in order to facilitate users' orientation. Such inset maps can have various purposes – to present areas in greater topographic detail than the level of generalisation in the main map permits (i.e. the inset map covers a smaller area than the primary map); to present a specific theme as the sole subject, or in greater detail (thus the inset map can be the same scale or larger than the primary map); to show the location of the primary map in a wider regional or global context (i.e. the inset map is at a smaller scale than the main map); and to assist in the orientation of users, by identifying neatline boundaries of the main map on a smaller scale map. It is the latter of these functions which is normally used as a visual expression on TVWMs.

Figure 4. Application of over view map (PressTV).

5.2 *Summary of expressions*

The prime purpose of 'identification of position', in order to most effectively subsequently understand the weather information presented cartographically, has been considered with respect to each of the expressions presented here. A qualitative evaluation of user orientation expressions with respect to the theoretically supported statements of the research is presented in Table 5.

Table 5. Fitness of user orientation expressions: proper (+), fair (0), improper (-), not applicable (NA).

	BBC	Euronews	France24	PressTV
Background	+ +	- -	-	-
Boundary	+ +	+	-	- -
Spatial Order	+ +	+	-	0
Zoom	+	+	-	0
Overview Map	NA	NA	NA	+

6 **TVWM contents**

The specific items of weather information included in weather reports can include maximum and minimum temperature, wind velocity, humidity level, air masses movement, cold and warm air fronts, temperature patterns and weather risk level, etc. Whilst such comprehensive weather reports can be easily communicated over sequential information media, including the web, on TVWMs the information content is constrained by time and visual space, the lack of an exploratory and hyperlinked environment, and limitations of textual presentation. Hence, it is important that the most important and appropriate meteorological information be selected for broadcast by TV channels, and this may require some flexibility of approach, which is often not present. For instance, on Euronews TVWMs, the maximum temperature is always presented, although the minimum temperature may well be more important in cold seasons (presenting both maximum and minimum temperatures, whilst possible, does increase the amount of detail). Similarly, PressTV channel presents only the weather information of official capital cities, despite the fact that other main cities (including important commercial centres) should be considered in order to satisfy the viewers of a global coverage.

A further issue of information presentation is that TVWMs are usually accompanied by a spoken interpretation of the weathercaster – who may be visible or not. Such a role can enhance communication, and may be used to overcome any perceived cartographic shortcomings of TVWMs. The appearance and body motion of the weathercaster is another facilitating factor in weather representation on TV (Carter, 1998). Carter (1998) mentioned the "fans of presenter" in his typology of TVWM viewers and, further, Henson (1990) noted attractive weathercasters as a positive factor to turn the viewers' attention to weather maps. When TVWMs and the physical presence of the weathercaster are presented at the same time, there are multiple attractants in the visual field (Desimone and Duncan, 1995). It is suggested that TVWR can be optimised by:

- Coordinating spoken and textual information with a map displaying relevant content
- Offering clear, brief and useful explanations
- Avoiding multiple weathercasters or other distractions, in order to maintain viewers' concentration
- Having simple clothes and undemonstrative appearance by reporters in order not to distract viewers

The recent use of animated characters as substitute weathercasters (Bech *et al.*, 2010) needs even more care when associated with an overall design strategy for cartographic design of weather maps.

7 Expressions validation and comparison of TVWMs

The application and value of the visual expressions elucidated in this paper must be examined in the context of map use, and some experimental testing has been undertaken to validate the statements presented above which have resulted from our analysis. This section presents the analytical evaluation followed by the empirical investigation.

7.1 *Analytical evaluation*

This evaluation is a comparison of tested TVWMs, which shows their distinction relative to the variables and expressions examined. In this method, observance of the cartographic factors and efficiency of the visual expressions have been numerically

evaluated for each of the TVWMs. A qualitative evaluation of each expression's application, as presented in Tables 4 and 5, along with other factors mentioned in the text, is considered through pairwise comparisons (using the Analytic Hierarchy Process in Expert Choice software version 11.1) of TVWMs (see Table 6). Average score is calculated based on the six visual elements which are available on each TVWM, and scores are normalised. A number of specific points considered in the analytical evaluation were elucidated:

- Background: In the BBC TVWMs, the rainfall layer is superimposed as a blue colour on base map. Although a subtle transparency parameter is applied, this layer does cause masking in some cases and makes it difficult to identify exact locations. In the Euronews maps, elevation is represented by colour values. Point symbols of cities and circular stamps indicating temperature are both similar shapes and colour. Although temperature symbols are larger than city symbols it does reduce the chance to find particular locations. As was indicated in Section 5.1.1 the background colour for the Euronews map is not considered appropriate. Despite this potential problem in user orientation, the addition of city names does provide useful locational information. In the France24 TVWMs, presentation of different land uses facilitates locational perception, but some generalisation is required to increase the saliency of the actual weather information. The city names and temperature information provided on a 3D transparent tablet are almost illegible due to the high colour diversity of the background. In PressTV, a different representation method is favoured. Each weather map frame presents weather information of just one location highlighted by changing the area colour. This colour changing, along with an animated loading symbol inside a target frame, actually carries more visual weight than the weather information and transfer of information to viewers may be disturbed. Locational and weather information for adjacent polygons is not provided, either by background colour or by textual information.
- Boundary: In BBC maps, although some linear generalisation is applied, the national boundaries are so thin and occasionally masked by the blue rainfall layer that they are usually very much faded. With Euronews, the boundaries are prominent for different countries and states. France24 TVWMs have no national frontiers portrayed, relying for user orientation on the coastline shapes and colours

of different areas to make them distinguishable. In Press TV each frame presents just one country emphasised by distinguishing it from a background colour. Thus, one national boundary identifies the nation to assist in user orientation, but other boundaries are portrayed giving no weather information and little assistance in location identification.

- Spatial order: as indicated in section 5.1.3, a logical spatial order is observed properly on the BBC maps with Euronews, France24 and PressTV respectively adopting increasingly less obvious orders.
- Zoom: with the exception of the France24 TVWMs, smooth zooming is used to focus on specific areas at larger scale. Absolute scale and view distance (scale is not indicated directly in any of the TVWMs) can be considered as a further linked factor in ranking the maps.
- Overview map: PressTV is the only channel using an overview map in its TVWR, due to its specific representation method. It is intended to have positive impact on the viewers' orientation, but this expression does not appear in the other tested TVWMs.
- Duration: the length of time made available for each frame is used, along with its standard deviation, to give some idea of how long viewers are given to absorb locational and subject-specific information.
- Motion variables: The cartographic points discussed in section 4.3 are used to determine the effectiveness of dynamic expression, particularly for the France24 and PressTV maps.
- Content: It is considered that each of the tested TVWMs present adequate levels of weather information, although the PressTV maps present very few city locations.

Table 6. The results of analytical evaluation of TVWMs using pairwise comparisons

	User orientation expressions				Dynamic variable			
	Background	Boundary	Spatial order	Zoom	Duration	Content	Avg. Score	Rank
BBC	0.48	0.31	0.49	0.46	0.30	0.28	0.39	i

Euronews	0.09	0.47	0.30	0.33	0.13	0.28	0.27	ii
France24	0.27	0.08	0.08	0.07	0.08	0.28	0.14	iv
PressTV	0.16	0.14	0.13	0.14	0.49	0.16	0.20	iii

The analytical evaluation reveals that almost all the visual elements considered are applied better on the BBC's weather maps than the others. Euronews presents lower scores due to weak background and duration variables, whilst results for PressTV and France24 reveal some shortcomings.

This interpretation of the design composition can be validated, and correlation coefficients indicating relative importance can be scored, by undertaking some empirical evaluation. An overall ranking order based on both evaluations would reveal the effectiveness of TVWMs' communication.

7.2 *Empirical evaluation*

Because understanding human-map interaction is critical for effective cartography (MacEachren, 1995) and the "democratisation of cartography" (Morrison, 1997) is a reality, an empirical method was developed to support the analytical statements presented above and especially to validate the proposed user orientation expressions. User testing is designed to collect the television viewers' opinions and reactions, and record their satisfaction and preferences (Koua *et al*., 2006) related to TVWMs. General television viewers are considered to have little knowledge about cartographic aspects; therefore, to carry out the evaluation, and determine the role and importance of the elements highlighted, some general questions were posed. Such user-oriented research into human map interaction replicates numerous other studies (e.g. Dillemuth, 2005; Nagi, 2004).

Initially, a sample of active participants was approached to undertake an empirical evaluation of the TVWMs considered. The intention was to assess the relative effectiveness of each map and to determine the role played in the measurement of that effectiveness by the visual expressions identified. Initially, the role of TVWMs in daily life was assessed by means of a general questionnaire (Appendix A) filled out by a sample of 300 participants who responded to a web invitation in English. 62% of participants reported that weather information is very important and useful in their daily life. Further outcomes from this survey are that 73% are using television as the main medium to receive weather information, 81% are

interested in having a visualised and map based communication, and 65% agree (totally or partially) that visual improvement of TVWMs is essential.

7.2.1 Participants

70 students (35 males, 35 females), from varied academic backgrounds, participated in more direct user testing. Participants who had extensive experience or background knowledge concerned with TVWMs were excluded.

7.2.2 Experimental Procedures

User testing was undertaken in an academic computer laboratory. Each participant was asked to sit at a computer screen, with a welcome page that explaining the purpose and methodology of the experiment. A media file, including four TVWRs of a specific date (5 April, 2010) was shown and a questionnaire was presented (Appendix B). Respondents evaluated the TVWMs, giving a 1 to 5 score for each element highlighted. As TVWMs are transitory and as dynamic maps do not remain in working memory for more than a few seconds (Ayers, 2005; Harrower, 2007), the playback was repeated and the questions answered for each TVWR sequentially. Assistance was available whenever the participants were faced with a problem in understanding.

7.2.3 Statistics and results

The processed results of participants' opinions are presented in Table 7. Means of empirical scores are calculated and then normalized for each expression. Moreover, a specific row is considered to check the variables validation. In this regard, TV channel's ranks in both analytical and empirical methods are compared and in the case of getting same order are checked as valid variable. Also, a correlation coefficient is calculated for each variable. Final evaluation is conducted based on both ranking order and correlation coefficients.

Comparison of the ranked order of each element was undertaken: the analytical and empirical testing matched for each element except 'background' and 'zoom'. For example, the ordering of effectiveness of the visual expression 'boundary' (Euronews, followed by BBC, Press TV, then France24) is the same for both tests. Further, the individual scores of the pairwise comparisons in both the analytical and the empirical testing were correlated. For the 'boundary' expression, for example, the analytical scores (respectively 0.31, 0.47, 0.08, 0.14) were matched with the user-testing scores

(0.26, 0.27, 0.22, 0.25) giving a correlation coefficient of 0.88. In this way, a validation of the importance of each visual element has been achieved.

Table 7. The results of experimental evaluation of TVWMs (ρ: correlation coeficient).

		User orientation expressions				Dynamic variable			
		Background	Boundary	Spatial order	Zoom	Duration	Content	Avg. Score	Rank
BBC		0.28	0.26	0.3	0.27	0.29	0.29	0.28	i
Euronews		0.24	0.27	0.27	0.24	0.22	0.29	0.25	ii, iii
France24		0.23	0.22	0.2	0.19	0.19	0.22	0.21	iv
PressTV		0.25	0.25	0.23	0.3	0.3	0.2	0.25	ii, iii
Validation	Rank order	×	✓	✓	×	✓	✓		
	ρ	0.73	0.88	0.97	0.35	0.93	0.71		

Both ranking order and correlation coefficient (ρ) are acceptable for the visual elements except for 'background' and 'zoom', for which some disagreement and uncertainty exists. Among the results, the 'background' expression of Euronews is rated higher in the empirical evaluation than in the analytical evaluation. This may be because the superimposed textual information in the actual TVWM reduces the negative impact of background colour. Also, the zooming and motion variable of PressTV is evaluated better than France24 by participants, confirming the theoretically discussed concepts in section 4.3. The overview map appears as a visual expression only on the PressTV, but 78% of participants indicated that this specific element has a high impact in assisting their orientation, and it is felt that its inclusion has a positive impact on the overall ranking of the PressTV TVWMs. The correlations and consistency of rank order for the empirical and analytical evaluations validates the inclusion of the expressions and variables highlighted when considering map design for this medium.

8 Conclusions and Suggestions

Cartographic visualization of TVWMs has a major impact on the communication quality of TVWRs. TVWMs are primarily 'maps for viewing' rather than 'maps for exploring'. Thus, effective use of visual variables and visual expressions is a central issue. This paper has built upon the long-established work of those cartographers who

have researched the visual variables and formalised some of the more wide-ranging parameters of cartographic representation. The development of a 'visual information representation rate' (r) as a factor to adjust the amount of information being represented in a frame has expanded the application of current visual variables such as the duration. In applying r, values smaller than 3 were considered suitable. Euronews maps were considered poor from this viewpoint ($M = 8.14$). Moreover, standard deviation of r, as an element to preserve the viewer's harmony in receiving information, should tend to zero, with little or no variation in information content of successive frames. Uniform speed and zero-tended acceleration of displacements on TVWMs were suggested as desirable characteristics of motion variables.

In addition, the term 'visual expressions' has been introduced and explored. Five new visual expressions of user orientation (background, boundary, spatial order, zoom and overview/locator map) were introduced, evaluated and validated on the weather maps. According to our overview of these expressions, and the need to optimise viewer experience and use of TVWMs (notably the need to preserve the users' positioning and orientation), some specific conclusions can be drawn. Appropriate generalisation and consideration of the figure-ground relation of the background are required. Political boundaries should be generalised so that discrete polygon objects which may lack overlaid weather information are reduced. The 'spatial order' expression can orient users by observing and presenting logical neighbourhoods and maintaining a sequential order when navigating from one view to another. The 'zoom' variable in dynamic weather maps (albeit not under viewer control) does facilitate user orientation by presenting the overall display, magnifying the important locations, and occasionally introducing an inset location map.

These selected expressions have been evaluated through investigating the correlation of the authors' derived analytical evaluations and the user-sourced empirical responses. Overall, there is agreement on matching the relative importance of the visual expressions, and subsequent scoring of the TVWMs of four news channels. The BBC, Euronews, PressTV and France24 cartographic visualisations are ranked with respect to successful cartographic communication based on the expressions tested.

While the results in this paper appear promising in formalising map design elements which require attention, it must be noted that a wider range of expressions

and cartographic factors are involved in representation of TVWMs. Further variables and expressions (particularly those dealing with user orientation) are likely subjects for further investigation. For example, 'visual balance' could be profitably studied (an example of lack of such balance is the channel logo of Euronews in the upper right side of the display which appears visually heavier (Arnheim, 1969) than the weather information itself). In addition, the effect of spatialised sound is noteworthy. The common use of presenters (either visible on-screen and giving their interpretation with the BBC TVWRs or reading a descriptive commentary on the France24 TVWRs) is an obvious further means of communicating weather data. It has been shown that such enhanced maps reduce cognitive overload (Brunken and Leutner, 2001) and can increase learning efficiency (Mayer, 2001). However, it has also been shown that care must be taken: a split attention effect might disturb effective representation. In some cases, for example with Euronews and France24, the presenter's vocal communication of information is replaced or supplemented by background music. On the former, the music played is standard throughout, with no relationship to the areas portrayed. On France24, TVWRs are regularly accompanied by specific music representing regions of interest, giving a geographical orientation through culturally varying sound. It is suggested that the interaction between sound variables and visual expressions is an area for further investigation in optimising television weather maps.

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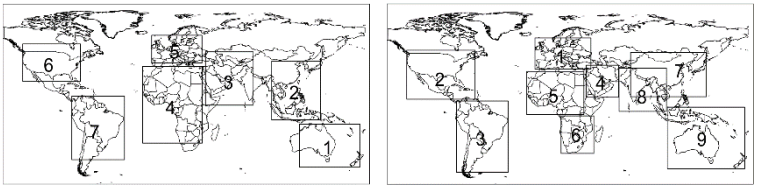
Figure captions:

Figure 1. Misleading background on the Euronews weather map.

(a) Original (b) tested for figure-ground distinction

Figure 2. Boundary variables on TVWMs

(a) BBC (b) PressTV (c) France24 (d) IRINN



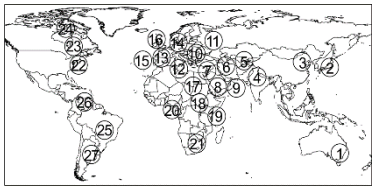


Figure 3. Spatial order variable on TVWMs

(a) BBC (b) Euronews (c) PressTV

Figure 4. Application of overview map (PressTV).