CO-263

A FIRST STEP TOWARDS A PROPOSAL FOR A SEMIOLOGY OF ANIMATED GRAPHICS : AN EXPERIMENTAL TOOL.

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Animated maps offer the possibility of constantly updating the display of spatio-temporal changes. Their use in map production is becoming more widespread and has been the subject of many theoretical studies since the 1990s, the earliest of which led to the emergence of variables of animation (DiBiase et al., 1992, Peterson, 1994, MacEachren, 1995). Recent proposals on the representation of spatio-temporal data now feature various animation possibilities (Cauvin et al., 2008).

Many papers (e.g. Josselin & Fabrikant, 2003) give details on how to create one or more animated maps along with the choices involved when it comes to representing a particular phenomenon. However, it appears that no semiotic practices have been established to guide one through this process. In these animated maps, the pragmatic approach has often preceded the theoretical one. We believe that systematic testing of the various graphics possibilities is the first necessary step towards establishing such a practice.

However, testing and assessing the efficiency of graphic representation modes for representing spatio-temporal information in real cases is no mean feat; our ambitions for the tool that we are presenting are much more modest. Different graphics choices are applied to one, even two, spatial features. The 200 or so prototypes that were created are therefore less complex than the animated maps themselves, which comprise a large number of spatial features. Such simplification of information is not unimportant, and, to some extent, defines the scope of the experiment.

The first section of this paper will consist in defining and examining the properties of the mapping of moving changes, that is the data (spatio-temporal information), time (medium of representation) and visual variables in an animation. The second section will focus on the tool itself, which is accessible on the Cartomouv' website ; all the prerequisites and the entire process are described step by step. We will end our paper by demonstrating, by means of an example, how the investigation of a series of prototypes allows us to test the relevance and efficiency of the various representation modes offered by the tool.

SECTION 1: MAPPING MOVING CHANGES: THE ELEMENTS THAT MAKE UP A MOVING MAP IMAGE

Animated maps that represent spatio-temporal changes are complex objects in several respects. This complexity can be appreciated with respect to familiar map items such as static maps: it lies as much in the information being represented (multidimensional) as in the display medium (introduction of time), or even the representation itself, which allows the distinction between not only the characteristics of various spatial features, but also the successive states of each feature.

The experimental tool that we are presenting in this paper is the fruit of our efforts to break down this complexity: each prototype has been built to test the efficiency of mapping modes for expressing the evolution of the characteristics of a specific spatial feature.

1. The multidimensional nature of spatio-temporal information

The formalisation of spatio-temporal information that we propose here was built on a simple example, namely the variation of a single attribute (A) over time (cf. Figure 1).

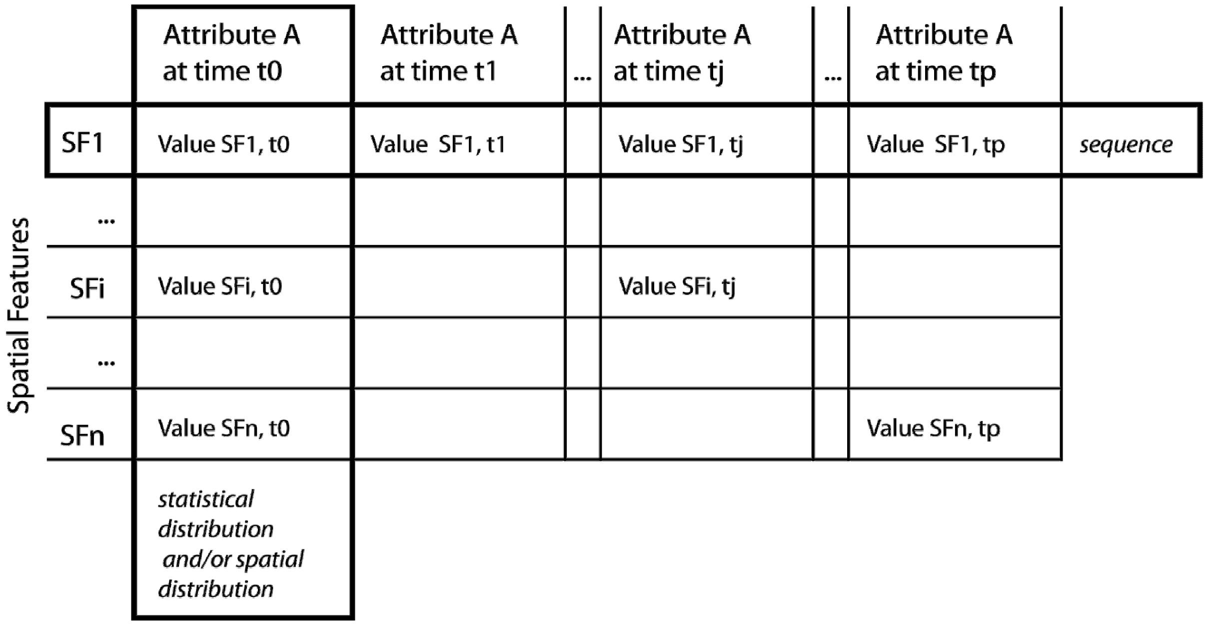


Figure 1 : formalisation of spatio-temporal information

a) Spatial distribution and evolution sequences

This attribute (A) is typically semantic in nature and may provide information such as the demographic weight of spatial features. Therefore, at each recording date (column-by-column reading of the table), the information corresponds to a *statistical distribution.* When used in a map, such information gives an appreciation of the *spatial distribution* of the various values, thereby revealing the spatial structures of the phenomenon being observed at the time of the recording.

The attribute may also be geographic, in which case the information would concern the location or shape of the spatial features themselves. At each date, the static map takes the form of a spatial distribution of points, which may be regular, or, conversely, irregular, at the time of the recording.

In both cases (semantic or geographic), the static map may be read at two different levels: the detailed level indicates the values that characterise each spatial feature, and the global level reveals the spatial structures such as they are displayed in the map.

Animation allows us to represent information at different recording dates within a single map item. The animation process involves both reading levels: at the global level, the map tries to reproduce the evolution of spatial structures; at the detailed level, the map reproduces the evolution of the values that characterise a given spatial feature. We suggest naming this series of states that a spatial feature goes through a *sequence*.

Based on the formalisation of information proposed in Figure 1, we may observe that the evolution of spatial structures corresponds to the series arrangement of statistical or spatial distributions, in other words the table columns. The representation of sequences corresponds to a row-by-row reading of the table.

The complexity of animated maps lies in the simultaneous representation of table columns and rows – in other words, the evolution of the statistical and spatial distributions of sequences. Changes affect both global and detailed reading levels simultaneously. We propose to distinguish between the two in order to focus on the analysis of sequences.

b) Temporal sequences and spatio-temporal sequences

The nature of a sequence depends on the type of attribute being considered. When semantic attributes are involved, sequences are temporal: only the thematic element of spatial features is affected by a change, whereas their location remains stable. In animated and static maps alike, the spatial dimension of information depends on the relative positioning of the spatial features in the plane. If each spatial feature is considered in isolation, sequences can be thought of as losing their spatial dimension.

When it comes to geographic attributes, sequences are not only temporal in nature but also include a spatial dimension: it is the location of spatial features that is affected by a change. When considered individually, sequences retain their spatial dimension.

The experimental tool presented here applies to the representation of both temporal and spatio-temporal sequences.

2. Time: a medium for representing change

The plane is a mapping medium; the incorporation of spatial features into the plane enables the map to express the spatial dimension of the phenomenon being observed. This medium is far from neutral: on the contrary, by reproducing the actual relative positions of spatial features using scaling techniques, the two dimensions of a plane become an essential element of the cognitive contribution of a map. The proper interpretation of neighbourhoods, proximity and distances is made possible thanks to the correspondence between spatial features incorporated within the plane and the geographical positioning of these features.

In animation, time is introduced as a second mapping medium. Far from being neutral, this second medium contributes just as much to the intelligibility of the information being represented as the plane itself. The succession of values according to chronological *order* and *duration* is what characterises sequences. Thus, we are able to appreciate the pace at which changes occur by relating the extent of a change to the duration for which it is represented. This combination of animation time and extent of a change is traditionally referred to in the literature as the *rate of change* (Di Biase et al., 1992).

In order for the animation time to reproduce the rates of change that characterise each sequence, the animation time must be proportional to the observation time of the phenomenon; this is achieved through a scaling technique similar to that linking the map plane to the geographical space.

3. Assessing the efficiency of visual variables in an animation

When creating either static or animated maps, the choice of visual variable depends largely on the analysis of the information to be communicated.

In cases where a change affects the location of spatial features, this information is expressed by the position of these features in the plane (which brings to mind the plane dimensions established by Bertin, 1967). Visual variables as such are not used to express changes. However, we do find visual variables being used to represent the variation of a semantic attribute over time.

Animated mapping (as opposed to static representation) does not allow us to predict the diminished capacity of visual variables to convey the order, relative quantities or differences/similarities between values. Therefore, the same representation rules may be applied to both static and animated maps – here, we refer to the rules established by J. Bertin some forty years ago. Our experimental tool was built based on these very rules.

However, there is nothing to indicate that the efficiency of visual variables is the same when the latter are used to create either static or animated maps. Most notably, assessing the length of a visual variable – in other words, its capacity to differentiate between attribute values – proves to be a complex task when it is used in animated representations. The visual variable must express the changes in states that make up the sequence and, on another level, those changes that affect the overall spatial structure.

By focusing on the graphic representation of sequences, we are concentrating on a particular aspect of the efficiency of visual variables applied to animated maps, namely their capacity to express changes that affect a given spatial feature. We will now momentarily set aside the representation of overall spatial structures and the changes that may affect it.

SECTION 2: A DISPLAY TOOL FOR ANIMATED SEQUENCES

We have created an online tool that offers more than 200 sequence prototypes for displaying sequences.

A prototype is an animated graphic representation corresponding to a certain type of information that is portrayed through a certain representation mode. Our objective is to assess, via these prototypes, the ability of animation to express (semantic and/or spatial) attribute variations over time, as well as convey the purely temporal dimension of a change (pace, rate of change). These prototypes have been built with the aim of comparing the efficiency of different representation modes and are available in several options ('jerky' or smooth effect; with or without visual record of previous states).

Users access these prototypes via a user interface that invites them to define the characteristics of the data to be represented and the representation modes.

1. Prerequisite 1: definition of the characteristics of the information to be represented

The upper part of the user interface (cf. Figure2) allows users to define the information to be represented.

Figure 2 : User Interface

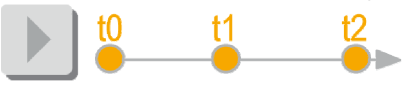
First, users are asked to identify the layout of the spatial features. Indeed, J. Bertin (1967) demonstrated how the length and efficiency of a visual variable varied according to the layout of the representation; here, we wish to test these differences in efficiency within an animated representation.

Next, users must specify the temporal dimension of the information to be represented.

The animations that we propose represent the state of a spatial feature recorded at different dates. Our aim is to assess how the temporal aspects of an evolution are perceived, especially in terms of pace. To do so, we distinguish the cases where recordings are done in a regular manner from those where recordings are carried out at irregular time intervals (Figure 3).

Time (data)

- regular: If successive states are recorded at identical time intervals throughout the entire period that is covered, the time is said to be regular (e.g. weekly, monthly or quarterly monitoring).



- **irregular:** If recordings are carried out when changes occur, with a variable time interval over the period being covered, then the time pertaining to the data is said to be irregular (at each event, e.g. at each flood).

Figure 3 : the temporal dimension of the information

When the observation time is regular, the duration between dates t0 and t1 is identical to that between dates t1 and t2. Conversely, when the observation time is irregular, the duration between dates t0 and t1 is three times that between dates t1 and t2. Thus, the rate of change (ratio of the extent to the duration of the change) reflects these different temporalities of observation.

In the tool that we are presenting, neither the chronological order of the states in a sequence nor the proportion between the observation and representation times may be modified. Indeed, these are two elements that we identified as being essential for representing the temporal dimension of information.

Finally, users define the type of attribute and change to be represented. Based on the usual concepts, most notably those presented by Cheylan (2007), we may identify three types of changes over time, namely geometric (variation in shape and/or position), semantic and identity (creation, disappearance, split or merge of spatial features) changes. Figure 4 presents these types of changes.

Object of a change

Changes may affect any one of the three generic components of spatial features, i.e. geometry, semantics and identity.

- Geometric: *geometric changes affect the shape of a feature (i.e. change in the X, Y coordinates of the points that define the feature). Geometric changes are expressed by a deformation and/or displacement of* *a feature in space. NB: We consider that the creation or disappearance of a feature does not affect its geometry, only its identity.*

> deformation: *change in the geometric shape of a spatial feature. E.g. an oil slick on water.*

> displacement: change in the spatial location of a spatial feature, which can take the form of a translation or a rotation. E.g. movement of an army.

- Semantic: semantic changes affect the semantic attributes that describe the spatial feature. In static mapping, the relationships between attribute values, differences, order and proportion are traditionally expressed through visual variables (size, value, colour, orientation and shape).

> Difference relation: the values of a nominal qualitative variable are all related in terms of differences. E.g. land use, business sector, political colour of a state. The visual variables that are typically used to express such differences are shape, orientation and colour/shade.

> Order relation: the values of an ordinal qualitative or relative quantitative variable (numerical data measured on an 'interval' scale) are all related to one another in terms of order. E.g. business sizes (small, medium, large), the number of working people as a proportion of the total population, the temperatures at a meteorological station. The visual variable that is traditionally used to express such differences is the value (black and white or varying colour intensity).

> Proportion relation: the values of an absolute quantitative variable (numerical data measured on a 'ratio' scale) are all related to one another in terms of proportionality, according to the relative quantities involved. E.g. the number of inhabitants in a city. The visual variable that is traditionally used to express proportion is size.

- Identity: identity changes affect the identity of the feature. The identity allows us to distinguish one feature from another. A change in identity may concern the very existence of a feature (appearance/disappearance) or its genealogy (feature resulting from a split or merge).

> appearance: a spatial feature that did not previously exist creates itself or is created.

> disappearance: a spatial feature that previously existed ceases to exist.

> split: a spatial feature arises from a spatial (sub)division of another, previously larger feature. The split process therefore gives rise to a feature of a smaller area.

>> ID change: During split, new identifiers are assigned to spatial features. E.g.: A parcel of land is divided up; it loses its original number and the new lots that are created are numbered from the last number used in the cadastral registry.

>> Stable ID: During split, the feature that has the largest area keeps its identifier and smaller features are assigned new identifiers. E.g. in estate management: Pierre's estate is divided into two; Pierre keeps one of the two and the other is sold.

> merger: a spatial feature arises from spatial aggregation (i.e. a geometrical combination or assembly) between two or more features that were previously distinct entities. The merge process therefore gives rise to a feature of a larger area.

>> ID change: During merger, new identifiers are assigned to spatial features.

>> Stable ID: During merger, the spatial feature that has the greatest area keeps its identifier. E.g.: during the reunification of the Federal Republic of Germany and the German Democratic Republic, the designation 'Federal Republic of Germany' was kept (even if it is more commonly known today as Germany).

Figure 4 : Type of changes

2. Prerequisite 2: definition of the characteristics of representation modes

The lower part of the user interface allows users to define the parameters of the representation modes, i.e. continuous/discontinuous, visual record of the previous state.

a) Continuous or discontinuous representation?

The distinction between discontinuous and continuous representations is similar to that between frame-based and cast-based animations (Peterson, 1994). In the first case (frame-based), the animation is created image by image, much like a slide show: each image that is displayed corresponds to a known recorded state. In the second case (cast-based), the animation is based on key frames and the use of morphing techniques (tweening or colour cycling), which generate intermediate steps through simple linear interpolation to achieve a smooth visual effect (Cauvin et al., 2008).

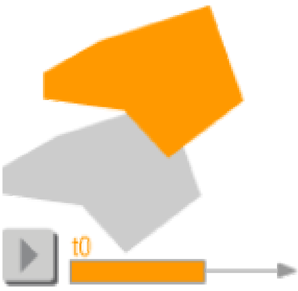
These two options do not only exist for aesthetic reasons; indeed, they serve to reinforce the purpose of the map, which is to highlight either steps or evolutions.

b) Keeping a record of the previous step?

We offer users several graphics solutions for tracing the state of a spatial feature back to its previous state. This proposal is based on the assessment by Cheylan (2007) of the point of a 'visual persistence' for interpreting the current situation: it appears that is is necessary to *'find symbolisation methods that, by means of explicit persistence, aid the mental reconstruction of processes that express the known records of previous (or future) states without over-clouding the perception of the current state. This brings to mind a reinforced symbolisation method that highlights the state being displayed at each instant of the simulation process, accompanied by a finer symbolisation of the previous states (shades of grey, fine lines, softer shades, etc.)*'.

Users are offered the choice between three different representation modes: succession, imprint and trace (Figure 5).

• Succession: no graphic effects are used. Only the succession of states is represented.



• Imprint: at time t+1, the situation at time t+1 and that at time t (in grey) are represented in order to keep a visual record of the previous situation.

• **Trace:** at time t+1, all the intermediate steps between the situation at time t and that at time t+1 are represented.

Figure 5: 'Graphic effect':

Given that such graphics possibilities are still unfamiliar to many cartographers, it is all the more important to be able to experiment with such techniques.

SECTION 3: EXAMPLE OF TESTING ON A SET OF PROTOTYPES

Here, we present an example of how our tool may be used to test the visual effect and efficiency of animated graphic representation modes, when employed to express the same type of information. The prototype parameters pertaining to the layout of the spatial feature (zonal in this case) and the type of change (a semantic change difference) are therefore the same. Colour visual variables, which were identified by Bertin (1967) as being the most selective, are used here to convey nominal qualitative information. We focus on the difference in the perception of sequences according to the type of representation (continuous or discontinuous). The visual effects are assessed according to the type of graphic effect: succession (A), followed by imprint (B). The perception of changes in pace is then examined: irregular time (C).

1. Sequence Group A: a spatial feature in a zonal layout, a semantic change, a regular recording time, succession. Comparison between discontinuous and continuous representations.

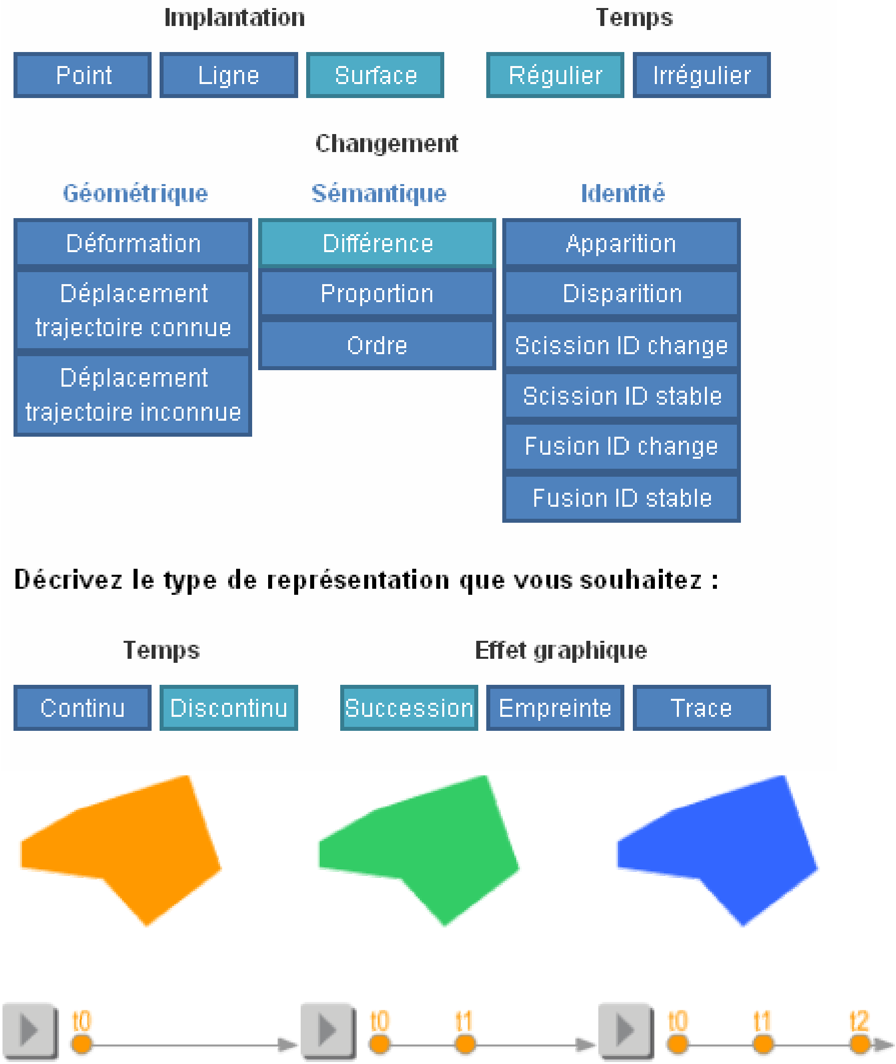


Figure 6: frame of sequence 1 (A): semantic change (difference) in zonal layout, regular time, discontinuous representation, succession

When the representation is discontinuous (Figure 6), i.e. created without using interpolation, the animation is simple, clear and readily comprehensible. This seems to be an effective solution if the objective is for the reader to be able to identify and memorise each state.

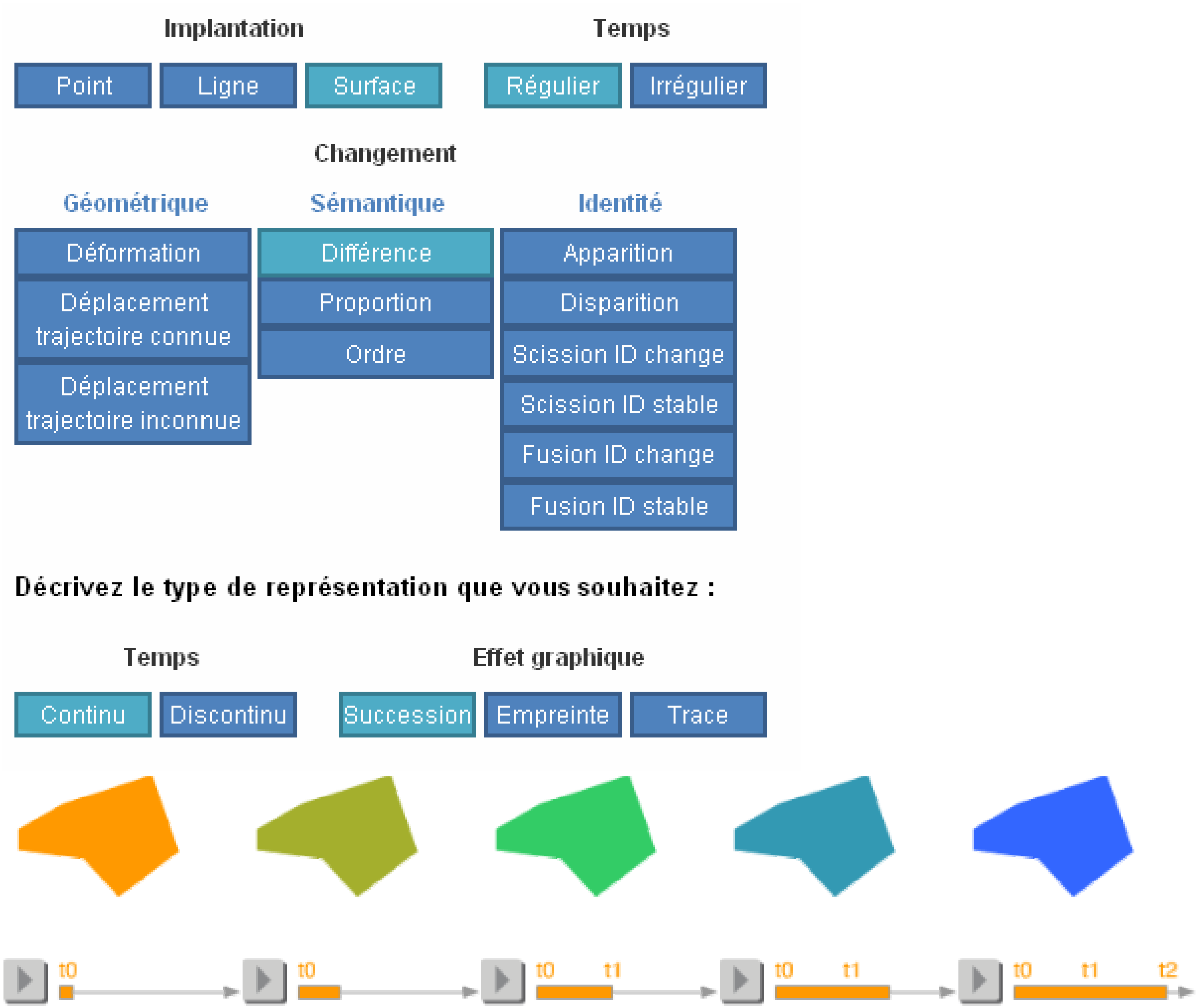


Figure 7: key frame (and intermediate images obtained through interpolation) of sequence 2 (A): semantic change (difference) in zonal layout, regular time, continuous representation, succession

When the representation is continuous, i.e. the states that lie between known states are simulated using linear graphical interpolation, the animation is naturally smoother, but also more complicated. In sequence 2 (Figure 7), the three steps are represented by 'pure' colours, and in spite of the interpolation, the three known states are still easily identifiable. Indeed, the intermediate colours created using interpolation correspond to 'dirty' shades, which are identified as 'transition' states.

We may therefore assume that the use of complex colours to represent various known states would make the latter less perceptible.

2. Sequence Group B: a spatial feature in a zonal layout, a semantic change, a regular recording time, imprint effect. Comparison between discontinuous and continuous representations.

In the case of a semantic change concerning the difference is expressed by a colour visual variable, the trace effect cannot be achieved. Indeed, there is no change in position of the spatial feature, and the representation of all intermediate states would lead to an invisible graphical superimposition.

However, to create a 'visual persistence', we may use the imprint effect by playing about with the colour variation of the contour. In this case, changes in state are expressed through changes in the colour of the interior, and the previous state (t-1) is represented from t by the colour of the contour, which remains the same until the next change in state (t+1).

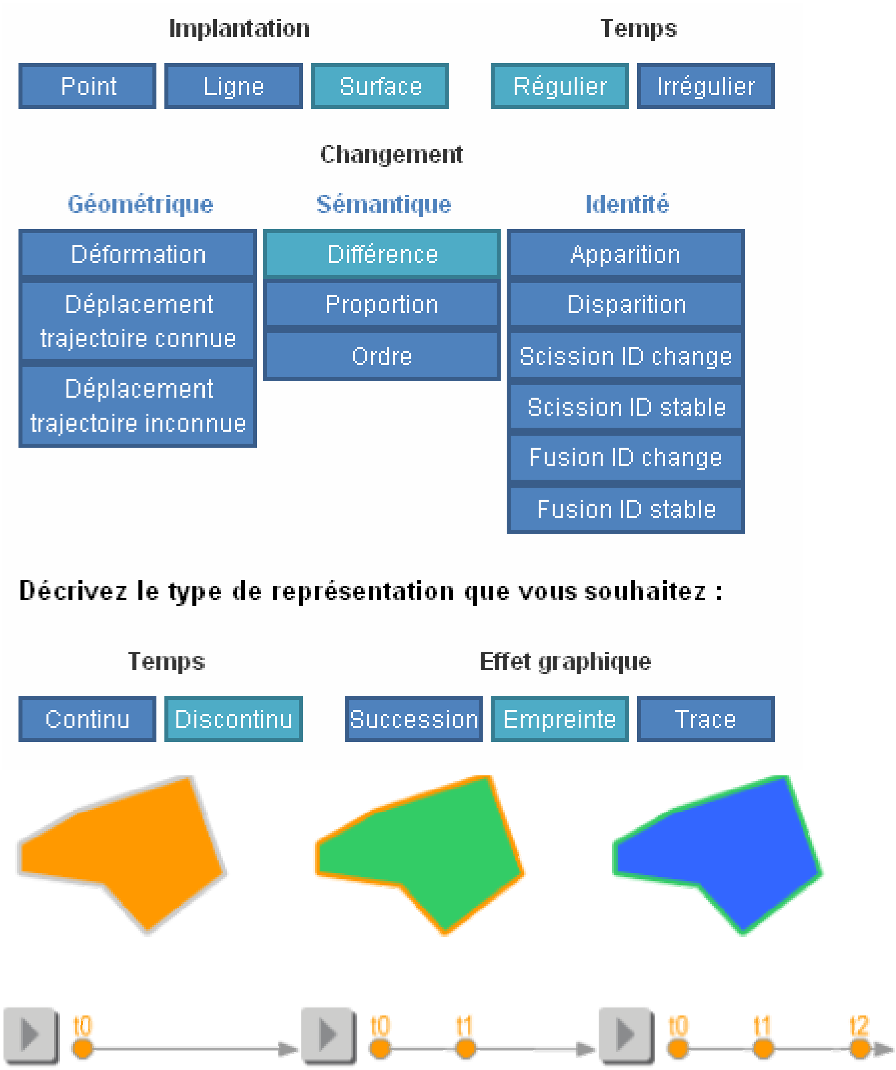


Figure 8: frame of sequence 1 (B): semantic change (difference) in zonal layout, regular time, discontinuous representation, imprint effect.

When the representation is discontinuous (Figure 8), the contour-interior combination is clear, and identification of state t/state t-1 is possible. There is thus greater scope for comparing states and understanding evolutions.

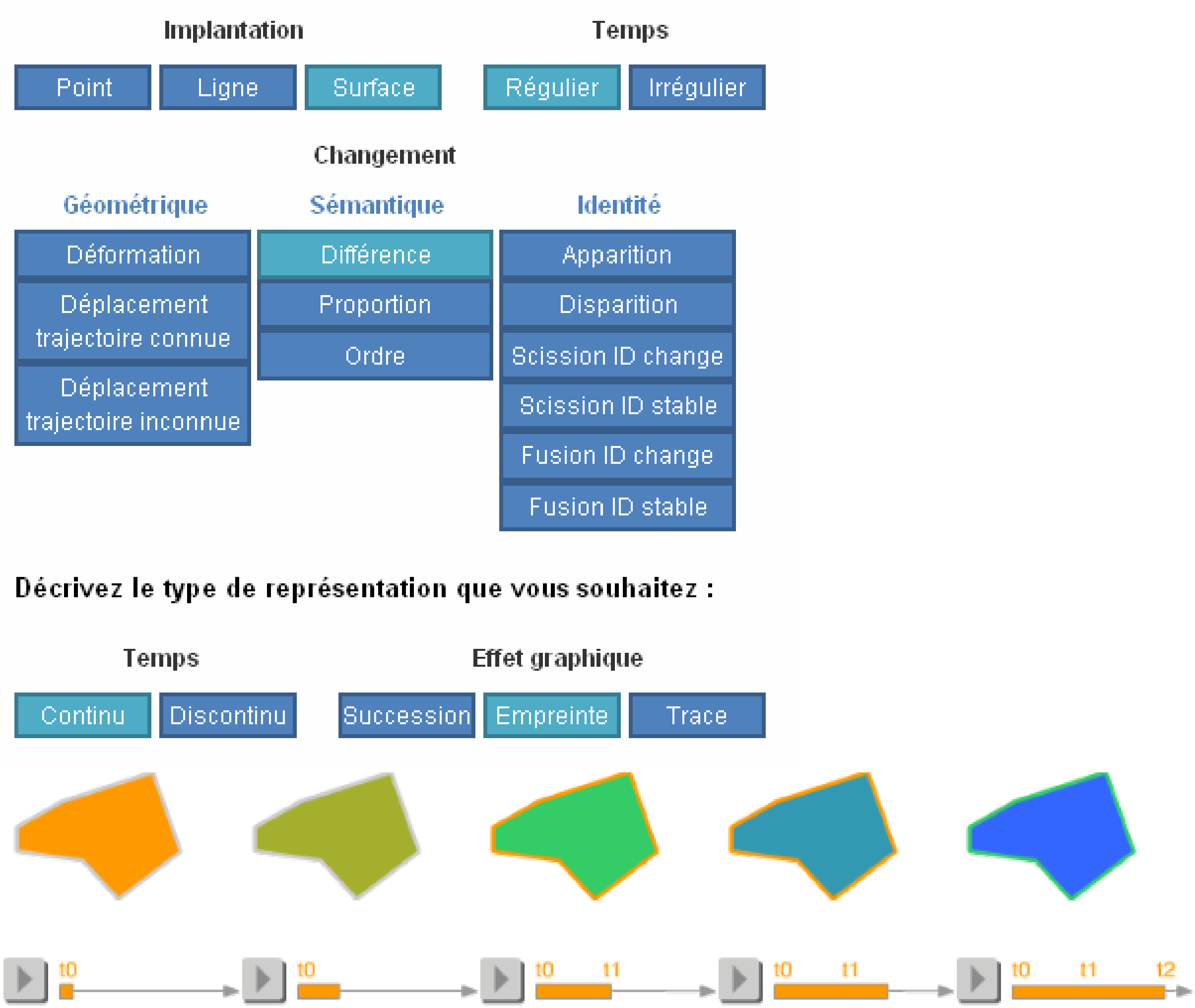


Figure 9: key frame (and intermediate images obtained through interpolation) of sequence 2 (B): semantic change (difference) in zonal layout, regular time, continuous representation, imprint effect.

When the representation is continuous (Figure 9), interpolation is only applied to the colour of the interior, and not to that of the contour.

Without using graphic effects (succession, sequence group A), we noted the effectiveness of the 'purity' of colours in terms of the identification of known states. This effectiveness is reduced when a second colour (that of the contour) is introduced as it makes the overall visual impression more complex. The identification of known states becomes more difficult when an imprint effect is introduced.

Therefore, based on these comparisons between sequences A and B, we may conclude that the use of colour visual variables to represent qualitative semantic variations in animation must be done by keeping to pure colours as interpolation gives rise to 'dirty', intermediate colours. On the other hand, the use of 'dirty' shades is hardly compatible with the graphical means for 'visual persistence' as the eye does not seem to be capable of capturing differences in the interior/contour colours when such 'dirty' shades are obtained through interpolation.

3. Sequence Group C: a spatial feature in a zonal layout, a semantic change, an irregular recording time, succession. Comparison between discontinuous and continuous representations.

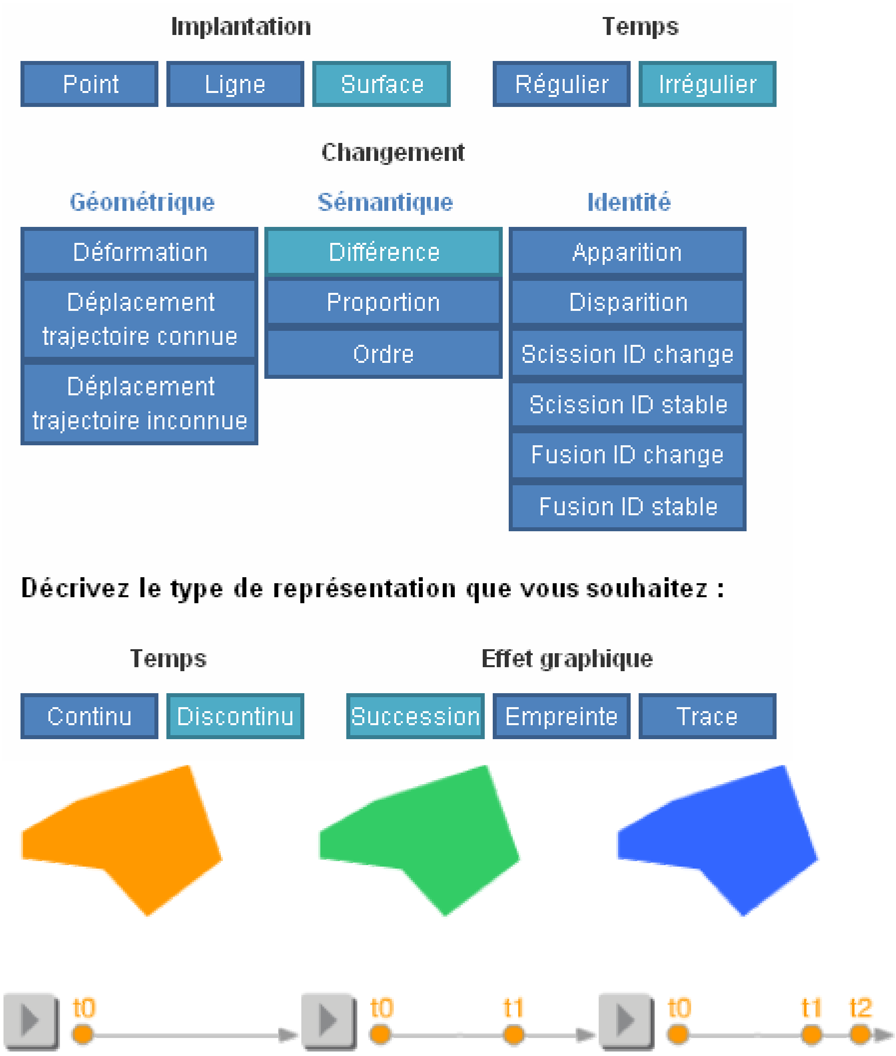


Figure 10: frame of sequence 1 (C): semantic change (difference) in zonal layout, irregular time, discontinuous representation, succession.

When the representation is discontinuous (Figure 10), variations in the rates of colour changes are easily perceived (long times where colours are stable, followed by rapid change).

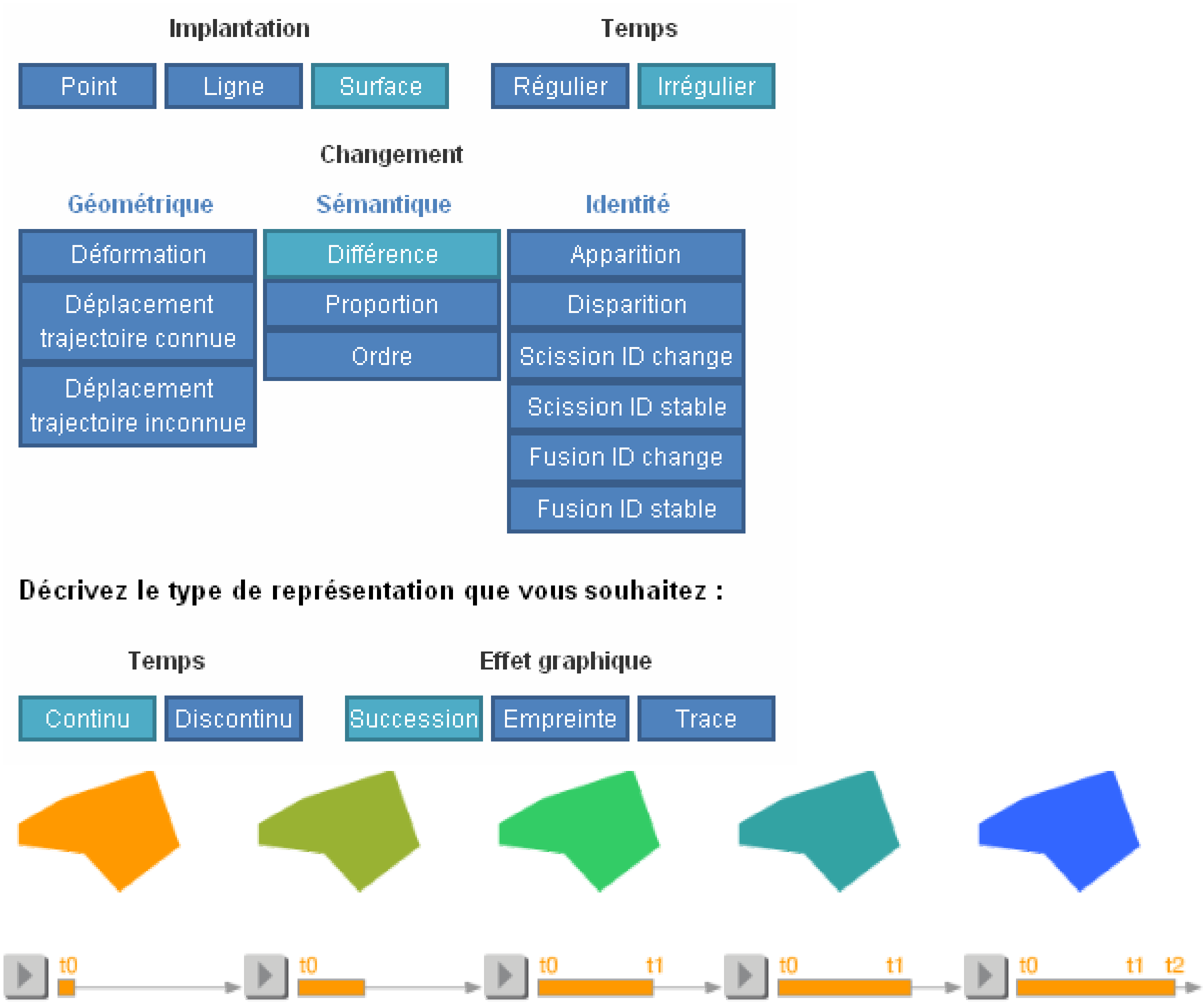


Figure 11: key frame (and intermediate images obtained through interpolation) of sequence 2 (C): semantic change (difference) in zonal layout, irregular time, continuous representation, succession.

When the representation is continuous (Figure 11), variations in rates are hard to perceive because of the continuous change in colour created by interpolation.

All in all, the analysis of sequences A, B and C seems to indicate that when a semantic change is represented using colour, the graphical interpolation of colours (continuous display), although enabling a smoother visual effect, tends to 'cloud' the perception of known states and rates of change.

CONCLUSION AND PERSPECTIVES

The tool consists of a total of 200 prototypes corresponding to a combination of various criteria that characterise a sequence - defined as the succession of states pertaining to a spatial feature. Each prototype has been designed as a basic building block that must be multiplied or combined with others in order to form the final map.

This empirical approach constitutes a way forward in the assessment of the visual efficiency of the various possibilities in map animation. To go even further, it would be beneficial to complete the tool in at least two ways. A new parameter that would allow us to play about with the animation's duration could be added to the defining criteria of the representation time. The rate of change could therefore be adapted to the amplitude of the evolution - just as the extent of an increase in value or the proportions between representations may be adapted for a better portrayal of the relationships between the data. Parameters that would allow us to test the effects of interactivity on the comprehension and memorisation of sequences should also be incorporated into the tool.

The next step in this experiment would be to observe the visual efficiency of animated mapping within a complex image that expresses the evolution of sequences as well as that of spatial distributions. The efficiency of graphic representation modes for expressing change could therefore be assessed at two levels: one pertaining to sequences and the other to spatial structures. This approach should enable us to set out a certain number of semiological rules for representing spatio-temporal phenomena. Indeed, new markers relating the temporal dimension of a change to the various possibilities in animated mapping should be added to the traditional rules that link map representations with information types.

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