A STUDY OF THE USER FRIENDLINESS OF TEMPORAL LEGENDS IN ANIMATED MAPS

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ABSTRACT

Among other topics related to the visual aspect of cartographic products, current research addresses the problem of user friendliness. The most significant research concerns those products that evolve most rapidly, a typical example being interactive dynamic maps. This group of cartographic works includes products that are relatively challenging for users with respect to their temporally fluid content and the possibility of interactive manipulation.

The article begins with a basic discussion of user-friendliness in cartographic products; in this context it addresses the historical development of the notion of cartography as a science, as well as the evolution of the ways in which it has been defined and of its subjects of interest. It demonstrates that, aside from notions of cartography as a technical discipline, it is also of interest from a linguistic point of view for its role as a mean of communication between cartographer and map user. Still greater emphasis is placed on the design aspects of cartographic production. The study offers the example of recent developments in Czech cartographic production, in which the last twenty years have seen a significant differentiation between published cartographic products and amateur cartography generally. This applies to creation as well as user base.

Next the article describes a study on the user-friendliness of temporal legends, which are very common in animated maps. The goal of this study, which was conducted during the summer of 2010, was not only to evaluate the given temporal legends, but also to investigate the extent to which users were able to work with temporal variables (with time) in a cartographic product. Among the tools for collecting data was a form of online test. This test posed questions to respondents and automatically measured the amount of time it took them to find their answers. This method was based on the assumption that, given two cartographic works containing similar content, the work which enables the user to find information more quickly is the more user-friendly of the two. The results of the test were then analyzed on the basis of an objective standard for comparing qualities in a cartography work. The authors conclude by suggesting future directions for research on the subject.

Key words: cartography, study of user friendliness, temporal legend, time, cartographic animation

1. Introduction

Through most of the twentieth century cartographic works in the Czech lands were produced primarily in two main sectors – the civilian (e.g. for land-surveying purposes) and the military. These cartographic works were often created for a narrow group of specialists, and the public did not have free access to a large portion of them. Of course, there were also high-quality cartographic works for schools and the public (e.g. school atlases, also the rare collection of maps entitled "Poznáváme svět" ["Getting to Know the World"]), but the market contained far fewer titles and was more generally less complex than it is today.

After 1989, a fundamental change occurred. With the arrival of the "Velvet Revolution," the problem of concealing map data ceased to be a priority (Maršíková and Maršík 2007) and the domain of cartography was gradually opened to the average consumer. Geodetický a kartografický podnik, n. p. (Geodesic and Cartographic Company), which arose in 1983 with the consolidation of Geodetický ústav v Praze, n. p. (Geodesic Institute of Prague) and Kartografie Praha, n. p. (Cartography Prague) – see Šíma 2004 – ceased to function as the lone publisher of cartographic literature and in 1992 its legacy was assumed by Kartografie Praha, a. s. Other manufacturers began to appear at around the same time, including SHOCart, s. r. o., which was formed in 1991.

The 1990s saw the gradual diversification of published cartographic works. With the development of the travel industry and free access to information, the wider public became more familiar with maps and their use. Meanwhile, notions about cartographic production began to change among cartographers themselves. While it goes without saying that accurate and up-to-date content remains the most important criterion when evaluating a map's quality, design aspects of cartographic production – notably the idea of "user friendliness" – have asserted themselves to an ever greater extent over time. Unlike in the previous era, the overall conception of a map's contents and legend must now conform to the needs of users, who often have no prior experience reading maps. Contributions from fields such as psychology, pedagogy and graphic semiology (Bertin 1983) are making inroads in what has until now been considered a purely technical discipline.

This trend is visible in changes in the very way cartography is defined: "CARTOGRAPHY is the science

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of making any map, embracing all phases of work from surveying to map printing." (source: UN, Department of Social Affairs, 1949, In Konečný et al. 2005).

If we may call the above a "traditional" definition, the following definition demonstrates cartography's shift into other disciplines: "CARTOGRAPHY is a unique and instinctive multi-dimensional facility for the creation and manipulation of visual (or virtual) representations of geospace (maps), to permit the exploration, analysis, understanding and communication of information about that space." (source: Wood 2003, In Konečný et al. 2005).

This shift in the meaning of cartography has led to an increase in the attention given to the problem of user friendliness. Cartographers are aware that users require maps that they can understand and easily read.

The problem of user friendliness as presented above is addressed in the following chapters, which describe the conception, execution and assessment of the study, the goal of which was to test in practice the user friendliness of three temporal legends (for the definition of "temporal legend" see Chapter 4) of animated maps.

2. User-friendliness in cartography

Use of a cartographic work entails the transmission of information between the work itself and its user (Koláčný 1967, In Pravda 2003). After the transmission occurs, an image of reality conveyed by the map should be present in the mind of the user. The quality and effectiveness of the transmission of cartographic information corresponds to the degree to which this image resembles the depicted phenomena.

One may thus identify the effectiveness of cartographic communication with the user friendliness of a given cartographic work (Novotná 2010), i.e. with the ease and speed with which that work allows the user to solve a concrete problem. The goal is to minimalize the work's demand on the mental labor of the user (Zipf 1935, In Bertin 1983). Thus, given the availability of two cartographic works containing identical content, the work which enables the user to ascertain the correct and complete solution more quickly is, from the standpoint of cartographic communication, the more effective one (Bertin 1983).

Effectiveness is usually classified within the broader category of usability and, together with practicability, ease of memorization and satisfaction, it is one of its sub-pillars (Nielsen 1999; Rubin 1994). Krug (2005: 4–5) defines usability thus:

"What we mean by usability is that a thing, whether it's a web page, a fighter jet or a revolving door, works well and that someone with average (or even below-average) ability and experience can use it for its intended purpose without becoming frustrated."

3. User friendliness and modern cartographic products

Research concerning user friendliness in cartography is not a new affair. Serious scientific research in this field was already taking place in the second half of the 20th century (e.g. Castner 1983 and Phillips 1984). The technology employed, as well as the methods of assessment and, in particular, the subjects of the research itself, have all changed over time.

Currently the focus of research has shifted from analog maps (traditional maps, most often on paper) to digital maps, i.e. maps stored on a hard drive which may be rendered on an output device, most often a monitor, or transferred to analog by printing. Digital maps are most often distributed through the internet.

In contrast to the communicative means of analog maps, which seldom change, the tools employed by maps on the internet transform very quickly, thus calling for constant improvement (Mitbø 2007).

Internet maps can provide the user with a range of functions that traditional analog maps cannot. With this, however, come greater demands on the mental exertion of the user. Maps on the web can be categorized by various critieria, and it is noteworthy that there are many concepts and typologies, of which several are mutually inconsistent or even incompatible. As far as demands on the user are concerned, the two most important aspects are the dynamic characteristics of the maps and their interaction with the user. The diagram below (Figure 1) provides an overview of the situation (Kraak and Brown 2001, modified). The diagram illustrates the scale of difficulty for the user and simultaneously the sophistication with which an active and curious user may take advantage of the possibilities inherent in the cartographic work. Individual groups of maps are connected to the most frequent types of interactivity a user may employ (Crampton 2002). The diagram has been simplified and, in addition to the literature cited, is based on the authors' personal experience.

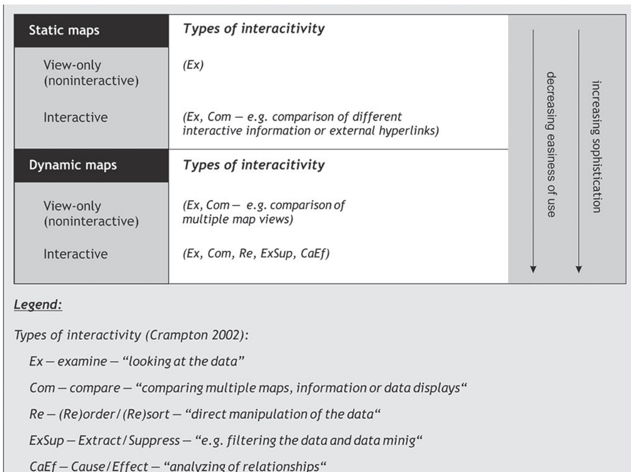

Fig. 1 Internet maps – demand on user and types of interactivity

The simplest form of internet map to use is the "static view map" which is simply an analog map transferred to web, most often in the form of a scanned image. The most challenging cartographic works on the internet are interactive maps, which communicate with the user on a certain level and react to his activity. The difficulty of using a cartographic work also increases with its dynamic characteristics. "Static" maps always represent the same spatial data, but in "dynamic" maps the map fields change in real time (Konečný et al. 2005), the displayed data loads in a dynamic fashion. We may consider the most challenging cartographic works as those that fulfill the demand for interactivity as well as dynamically generated content. Thus this area is an appropriate focus for research into user friendliness in the context of contemporary cartography.

As a sub-category of dynamic maps we might underscore cartographic animation (animated maps), which may be defined as "animation with a map field" (Vít 2010). The term "animation" itself signifies a sequence of frames which, when displayed in rapid succession, create the illusion of fluid motion or change (Harrower and Fabrikant 2008). Among the first animated maps was one that indicated the movement of German armies on Warsaw during the Second World War (Peterson 2000). This map was presented in a form that more closely resembled an animated film than a cartographic work. Cartographic animation has seen significant changes since then, most of all in creative technology and in the medium of distribution to the user. In spite of this qualitative advance, they retain their similarity to cartoons or animated films.

4. Representation of time in animated maps

4.1 The temporal legend

As mentioned in the preceding chapter, cartographic animation is often understood as a subcategory of dynamic maps. It is helpful to remember the analogous nature of animated maps and cinematographic products when considering the following. As in film, wherein single frames depict the sequence of events in time, the purpose of many animated maps is to portray action. In such a case, the map wishes "to tell some kind of story" (Turchi 2004) and it is often spoken of in this context in terms of "temporal animation" (Kraak and Ormeling 2003).

Temporal animation generally depicts action which is played out within the framework of absolutely conceived ("world") time. For example, it could be said that event A happened at time B, while event C took place over d amount of time. In order to connect events with the time in which they take place, it is necessary to supplement the map with a "temporal legend." A temporal legend gives the reader a key to understanding how to properly order within time the thematic matter represented in the map. The map reader is able to say, with the aid of a temporal legend, when the event represented in the map field occurred. It is in this regard that we must qualitatively distinguish an ordinary map legend from a temporal legend. Whereas an ordinary map legend explains the meaning of individual cartographic symbols (or connects a map's symbols to real objects and phenomena), a temporal legend assigns the map's symbols to a moment in time. Temporal legends serve a dual function: Kraak proposes that in many cases they should not just aid in the interpretation of time, but also serve as a navigational instrument, i.e., by interacting with the temporal legend, the user may move freely through the animation (Kraak, Edsall, MacEachren 1997).

4.2 Rate of time

In constructing an animated cartographic work furnished with a temporal legend, the map's creator will inevitably encounter the dilemma of uneven distribution of events within a particular length of time. It may happen that almost nothing occurs on the map field during a certain period, whereas at the other end of the time span several actions must be compressed within a short interval. Because the action is not uniformly distributed, it may be appropriate in some instances to "stretch" world time in certain segments of the animation in order for the reader to observe everything playing out on the map field, and to "shrink" it when no (or almost no) changes are taking place and it would become tedious to follow it. This might have seemed absurd before MacEachren had described time as a cartographic variable (MacEachren 1994). This also opened the possibility to modulate time, just as it is possible to modify the shape, color or size of cartographic symbols (see Bertin 1983).

As long as we accept the possibility of "elastic time", we can discuss rate of time and its modification. In terms of traditional cartography, we may consider rate of time as adhering to a particular "time scale."

Time scale is analogous to scale of distance and can be described as the ratio between real time and depicted time. That is, it concerns the speed of real time as it is captured in animation.

When dealing with a relatively low rate of time, for example, a second in animation may correspond to an hour in reality; with a higher rate, a second may correspond to a day. It is necessary to inform the map's user about the rate of time in various parts of the animation. This may be accomplished in many various ways, depending on the overall construction of the temporal legend.

Below are three varieties of temporal legend that were used in the test of user friendliness that follows (Chapter 5). These particular temporal legends were selected for their mutual dissimilarities – i.e. their methods of depicting time and changes in its speed are based on differing, in some cases even contradictory, concepts. Other possible methods for expressing rate of time (e.g. by means of other graphic variables which can be ordered – see Bertin 1983, such as degree of color saturation) are presented and discussed in a study by Vít (Vít 2010). Most, however, use a graphic permutation of one aspect or another of the temporal legends below.

1/ The temporal legend conceived as a temporal axis

a) Passage of time is typically indicated on a temporal axis by the position of a mobile pointer or "slide bar." The rate of time can be roughly inferred by observing how quickly the slide bar moves. Change in the speed of the slide bar signifies change in the rate of time. When time is stretched (changing to a lower rate of time), the slide bar decelerates; when time is compressed (changing to a higher rate of time), it accelerates. This method functions with the variable rate of motion (see Figure 2).

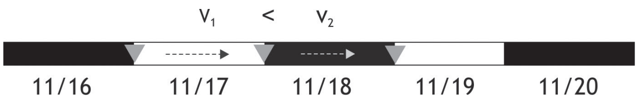

Fig. 2 Temporal legend "1/a)". Rate of time represented by changes in speed of slidebar. For 11/17 the rate of time is slower than for other days (rate of motion of the slidebar v1 is lower than rate of motion v2). Thus this day is represented in greater detail and on a larger time scale
v = rate of motion of the slidebar
11/16, 11/17, etc. = individual days represented by individual sections of temporal axis

While the concept of representing the rate of time is comprehensible and intuitive, there is the problem of the physiological limits of visual perception. In general, the smaller the change in speed of an object, the more difficult it is for the senses to perceive that change (Tremouretto and Feldman 2000, In Fukuda and Hueda 2006). The psychologist Šikl maintains that the lower relative threshold for perceiving acceleration is 20–30% of the speed of the observed motion. That is, as long as the speed of the observed motion changes by at least 20%, the human brain is capable of registering that change (Šikl 2006). The application of these findings to the problem at hand is clear: unless the change in the slide bar's speed on the temporal axis is sufficient (representing a greater contrast in tempo), the user won't be able to notice that change.

b) Another method for dealing with the problem of representing rate of time is to consider the task from the opposite position, i.e. holding the slide bar itself to a constant speed. In order to change the rate of time in this case, it is necessary to modify the size of the units on the temporal axis, using longer graphic units to indicate a slower tempo. In this case, when constructing the temporal axis one is dealing with the variable size (see Figure 3).

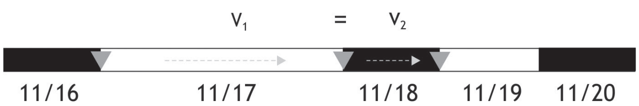

Fig. 3 Temporal legend "1/b)". Rate of time represented by varying the length of units on temporal axis. For 11/17 the rate of time is lower than for other days (the graphic unit for this day is longer, causing the slide bar to take longer to reach the end)

This method has clear advantages over the previous one, the first of which is that it is more easily to read. The user perceives changes in the unit's length on the temporal axis more easily than he does changes in the slide bar's speed. Another advantage is the fact that rate of time is expressed directly by a visible value (the user watches the temporal axis and can immediately note when the rate of time is lower and when it is higher), whereas in the previous case he had to interpolate differences in the rate of time from the various speeds of the slide bar. The fact that the slide bar moves at a constant speed also facilitates the use of the temporal legend as a means of manipulating the animation (i.e. the user may move through the animation by using the mouse to control movement of the slide bar). A disadvantage, however, is lower intuitiveness. For this reason, this method requires that the user receive instruction.

2/ Alphanumeric temporal legend (passage of time expressed textually and numerically)

An alphanumeric temporal legend entails expressing rate of time through the frequency of changes in numbers or text. Identifying changes in rate of time this way, however, is very demanding, because of the extreme difficulty of registering those changes in frequency. Thus it is desirable to express rate of time by yet other means. One possibility is to add to the alphanumeric temporal legend an appropriate graphic tool for informing the user of the rate of time. An ideal tool for this purpose is an arrow, which is commonly associated with direction and motion. Rate of time is essentially a quantitative value (it answers the question How many or how much), and therefore its representation may be achieved by sundry graphic variables that can be arranged in ascending or descending order. The most appropriate of these variables is size. In this case, a direct correlation will exist between rate of time and its graphic representation; that is, the longer the arrow, the higher the rate of time (see Figure 4).

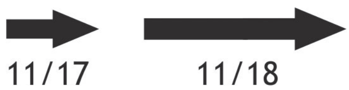

Fig. 4 Temporal legend "2/". Rate of time represented as a quantitative value. The length of the arrow shows the rate of time at a given moment. In this image, the day 11/17 is represented in greater detail (time moves more slowly) than is 11/18

An advantage of this method is the element's distinct visual dominance (the arrow can be made to draw the eye by flashing, for example). As with the previous method, the intuitiveness of this method is debatable.

Each of the three temporal legends described above has its advantages and disadvantages, and it is impossible to say unequivocally which of them is the best, especially since user subjectivity plays an undeniable role. For this reason, it was necessary to compare the proposed methods objectively and to base our conclusions on these results.

5. Studying the user friendliness of temporal legends

5.1 General methods for studying user friendliness in cartography

In studying and assessing user friendliness we may proceed by two basic methods: quantitative or qualitative testing (Krug 2009). When testing quantitatively, a task is defined and assigned to all subjects in precisely the same manner. The goal of a quantitative test is most often to prove a hypothesis (Krug 2009) or to compare two similar products. An advantage of quantitative testing is the possibility of conducting it online and thus reaching a larger pool of subjects. On the other hand, a qualitative test on a smaller number of subjects is better at determining future users' opinions of the object being tested. Common devices used in qualitative testing of user friendliness include structured conversation (Bláha 2005) and analysis of a subject's work with the product.

Testing user friendliness of cartographic works is a complex undertaking, and no method of testing is guaranteed to lead to successful results. Each test is unique and must be tailored to the tested phenomena. We may, however, trace the most common sets of tasks presented to users in studies:

– the user is given a real task, and the researcher measures the amount of time it takes him to successfully complete it,

– the user compares multiple cartographic variants of the same actuality and he evaluates them on a scale between better and worse using a semantic differential (Bláha 2005),

– the user's evaluation employs a point scale or awards "grades,"

– the user draws the mental map that he imagines after studying the cartographic work in question (Kynčlová 2009; Novotná 2010),

– a comparison of the intuitiveness of expressive media on the basis of the length of time it takes for the user to comprehend the meaning of their content,

– a study of the psychological possibilities of expressive cartographic media (the user guesses the meaning of cartographic symbols (Bláha 2010), or the user proposes cartographic symbols for specific phenomena),

– a study of the user's involuntary responses (use of eye tracking to study eye movement while studying a cartographic work – Coeltkin et al. 2009; Ooms et al. 2010); a simpler variant might entail following the movement of the cursor directed by the mouse during the user's interaction with the tested cartographic work,

– a standardized or unstandardized conversation is conducted with the user in which he evaluates the work verbally.

5.2 Methodology

A form of interactive online test was chosen to assess the user friendliness of the three temporal legends described above. While its nature was basically quantitative, in the final stage subjects were given the opportunity to write a commentary expressing their subjective opinions. For the purposes of the test, a model animated map with an American Civil war theme was created using Adobe Flash. This map was created in three variants which differed only in the temporal legend used by each. The test was conducted in the following manner: as he worked with the animated map, the user was presented with several time-related questions of varying types that required him to use the temporal legend. For each question, the subject was given a choice of four possible correct answers. A database registered whether the user had answered the question correctly and how long it had taken him to find it. Each test subject worked with only one variant of the model animated map. The hypothesis was the following: if one variant of the temporal legend is more user-friendly than the others, this will manifest itself in a higher number of correct answers and a shorter average time for those users who work with that variant.

Finally, all results for individual variants of the temporal legend were evaluated using objectivized methods (Miklošík 2005); the result was a numerical value that corresponded with overall user friendliness (see Section 5.5).

When using this method of testing the user friendliness of temporal legends it is necessary to be aware of the test's overall demand on the user. As Figure 1 in Chapter 3 demonstrates, dynamic interactive cartographic works are the most user-difficult of all cartographic production. In the case of animated maps, the user must be able to perceive (and to remember!) a great deal of information that changes over time. In the case of a static cartographic work, the average person is able to simultaneously work with seven different pieces of information (Miller 1956 In Harrower and Fabrikant 2008), but in the case of animated maps this number decreases. With a temporal legend the difficulty grows because the user must perceive not only changes in the map field itself, but also in the changing temporal legend. The very location of the temporal legend can play an important role: it is recommended that the temporal legend is placed as close as possible to the map field so that the user may follow the changes in both the map and the legend. This aspect has been studied by e.g. Mitbø, who suggests incorporating the temporal legend directly onto the map field (Mitbø et al. 2007).

In the test of user friendliness described above, users were asked questions concerning time which required the use of a temporal legend. By requiring users to interact with the legend, the researcher sought to test the following hypothesis: if a temporal legend was too demanding of the user, the user would not successfully perceive the changes in the map field. The basic hypothesis of the overall test of user friendliness was that a failure in the subsequent assessment would manifest itself in one of two ways:

– users working with the temporal legend in question would take longer, on average, to answer the questions,

– their answers would show a higher rate of errors,

or a combination of the two.

5.3 Preliminary phase of test

In the test's preliminary phase, the above-mentioned model animated map was created together with a functional interface (Adobe Flash in conjunction with the MySQL database) in order to produce an automatic testing application for the user. The most important part of the preliminary phase was the formulation of individual questions of varying types to be posed to the user during the test. The questions chosen had just one correct answer (represented in bold type in the following paragraph), and the solution of each one required use of the temporal legend. The questions were as follows:

1) On what day did the first Confederate soldiers cross into the Union territory marked in blue on the map?

a) 6/16, b) 6/18, **c) 6/15**, d) 6/21

In this case, the user was to search for an answer to the question, "When?"

2) How long did it take General Stuart to march from Salem (which he left on 6/25) to York?

a) 6 days, b) 11 days, c) 2 weeks, d) 1 day

Here users searched for an answer to the question, "How long?" in connection with the movement of an object. Searching for the answer required a de facto repetition of the answer to the question "When?"

3) Choose the correct statement about the rate of represented time on the Battle of Gettysburg map.

a) In the interval 8.00–10.00 the rate of represented time is lower than in the interval 18.00–20.00.

b) In the interval 8.00–10.00 the rate of represented time is higher than in the interval 18.00–20.00.

c) In the interval 8.00–10.00 the rate of represented time is roughly the same as in the interval 18.00–20.00.

d) It is not possible to determine the relationship between the rates of time in question.

The purpose of this question, which concerned the determination of rate of time, investigated the user's ability to recognize that variable and consciously employ it. This was the final question because it was determined to be the most difficult.

After answering the final question, the user sent the data and was directed to a webpage with a form on which he could anonymously fill in information about himself and add commentary if he chose. An important component of the form was a section in which the user employed a scale of one to five to "grade" the ease with he was able to work with rate of time and his overall assessment of the temporal legend's intuitiveness (more on this in Section 5.5).

Before testing began, a pilot study was conducted with the purpose of eliminating basic flaws in the application. Nine respondents participated in this phase (three for each variant), some of whom were students of cartography who had experience with cartographic testing. The goal was to elicit as many critical opinions as possible, on the basis of which the application would be revised.

5.4 Running the test

After the elimination of technical and conceptual flaws identified during the pilot study, the test was conducted on May 7, 2010. To recruit users, the author (Vít 2010) sent a link to the testing application to approximately two hundreds of respondents with the request that they pass it on. In this manner, the application reached a wide circle of people of varying ages and levels of education. The testing was officially concluded on June 24, 2010. A total of 216 respondents participated, resulting in 216 entries in the database. The exclusion of "sketchy" entries reduced the data pool to 172 relevant responses, approximately 60 workable responses for each of the tested temporal legends. Of these, 114 were from men and 58 were from women. The average age of respondents was 26.54 years, and the most common level of education attained was post-secondary. While this is not an entirely representative sample, the authors consider it to be acceptable given the nature of the study.

5.5 Assessment of the results

The final phase of the study involved the assessment of temporal legends in two fashions. The first was an attempt to show the relative value of different legends for various temporal questions (Table 1). The second assessed the quality of each legend overall (i.e. their consequent user friendliness – Table 2). Table 3 is an addendum that reflects how the users of the different temporal legends "graded" them (i.e. how they rated them subjectively).

Tab. 1 The effectiveness of the examined temporal legends in relation to individual questions

	1/a)	1/b)	2/
	Correct responses (%)	Correct responses (%)	Correct responses (%)
Question 1 ("when…?")	91.07	85.00	87.50
Question 2 ("how long…?")	85.71	96.67	92.59
Question 3 ("rate of time")	83.93	72.88	71.43

Tab. 2 Consequent user friendliness of the examined temporal legends

	1/a)	1/b)	2/
User friendliness (%)	75.44	68.52	50.04

Tab. 3 Subjective rating of the temporal legends by the users

	1/a)	1/b)	2)
How easy was it for you to work with the rate of time as it is represented here?	1.85	1.84	2.00
How would you rate the overall intuitiveness (comprehensibility) of the temporal legend?	1.66	1.83	1.7

Table 1 shows the effectiveness of the legends as the percentage of respondents' correct answers to time-related questions when using each legend (labeling used in the temporal legends corresponded to the labeling discussed in Section 4.2). When using the alphanumeric temporal legend, for example, 87.5% of the respondents chose the correct answer of the four they were offered for Question 1.

According to the percentage of correct answers, it would seem that for questions of the When type (Question 1) the correct answer is most easily found using the temporal legend 1/a). This was also the case for questions dealing with the rate of time. This is presumably because this method represents rate of time in the most natural and comprehensible way (there is a direct correspondence between the speed of the slide bar and the rate of time). A surprising result was the relative failure of this temporal legend in the case of Question 2 (How long?). Contrary to expectations, for this question the highest favorability went to the temporal legend 1/b). Yet this was the least successful legend for Question 1, in which case users complained of poor readability and intelligibility in general, an inevitable side effect of the various lengths of the units on the temporal axis.

For the question about rate of time, the alphanumerical temporal legend (labeled 2/) met expectations as the least favorable. Rate of time is not inferred from the design itself, but is rather framed as an independent element, and it is debatable whether it makes sense to mention it at all. One user expressed this circumstance thus: "This concept of rate of time is easy enough to grasp, but it seems unintuitive to me."

An important result of the testing of temporal legends was the establishment of their user friendliness on the whole, as expressed by a single numerical value. This was accomplished by determining weighted values for specific criteria and their subsequent aggregation (Mikošlík 2005).

First, three criteria for evaluation were established (here in order of importance):

1) ability of users to correctly answer a question with the help of the temporal legend;

2) users' subjective assessment of the temporal legend (using a grading system);

3) average length of time it takes to find a correct answer.

Next, values were assigned to the criteria according to their importance so that Criterion 1) would figure most heavily in the resulting evaluation. These values were then transferred to a uniform scale and arranged for use in the resulting aggregate function (see below). Our assignment of values for individual criteria is complex and there is no need to delineate it here (it is described in detail in e.g. Miklošík 2005), so here we will only report the resulting values:

– weight of first criterion: p1 = 0.767;
– weight of second criterion: p2 = 0.690;
– weight of third criterion: p3 = 0.614.

The final step was employing the "aggregate function," into which are entered a percentage representing the degree to which individual evaluating criteria were fulfilled and their value. For the purposes of this study, a multiplicative form of aggregate function was chosen in order to strengthen the influence of the first and most important evaluating criteria:

$U = (1) \times p_1 \times [(2) \times p_2 + (3) \times p_3]$, where
U … user friendliness of a given temporal legend (in%),
(1)–(3) … degree of fulfillment of a given criterion (in%, or 0–1),
p_1–p_3 … the weight of a given criterion.

The resulting calculated user friendliness of the studied temporal legends is shown in Table 2. As the table makes clear, from the standpoint of general user friendliness the best temporal legend is 1/a), which fulfilled over three quarters of the evaluating criteria. By contrast, the results for temporal legend 2/ (only 50%) are relatively disappointing and attest to its significant flaws.

Table 3 indicates that users regarded temporal legend 1/a) as the most user friendly. On the other hand, users slightly preferred temporal legend 1/b) for representing rate of time. Here we identify a discrepancy between subjective assessment (impressionistic rating – Table 3) and objective assessment (percentage of correct answers – Table

1), since the largest percentage of correct answers associated with perception of rate of time belongs to legend 1/a).

6. Conclusion

Based on the assessment of the overall user-friendliness of the temporal legends in the study, the best method was found to be the temporal legend with a form of temporal axis, temporal units of consistent length, and the rate of time illustrated by the speed of a movable slide bar – i.e. method 1/a. This temporal legend proved to be favorable in regard to rate of time and response to the question When? This method of representing time is intuitive and commonly used in practice. That is why we must ask whether this temporal legend is truly the best, or whether its familiarity to the users played a role.

The alphanumeric temporal legend (2/), by contrast, failed in most of the indicators evaluated. Its main problem lies in the fact that it does not provide the user a complete image of the time period the cartographic work represents. Use of an additional element (an arrow) to represent rate of time proved to be of debatable benefit.

In the overall evaluation of user friendliness, the temporal legend with units of varying lengths and a slide bar moving at constant speed (1/b) placed second. Lack of clarity was most frequently cited in negative assessments for this legend. On the other hand, it received very positive ratings for the fact that the user is able to use the mouse to manipulate the mobile slide bar. (The other temporal legends used a conventional motion bar located below the map data field.)

This study of the user friendliness of temporal legends represents a beginning in the investigation of this question in cartography. The authors are aware of a number of deficiencies and flaws in the testing described above, the most significant of which was that it was excessively complicated. The results point to certain trends in user friendliness, yet we were unable to establish unambiguous conclusions. For this reason, the authors believe that ensuing research should focus on individual aspects of temporal legends, using a greater number of subjects in each case to examine isolated qualities. A series of such tests might provide a basis for a new set of hypotheses for statistical evaluation. Further research might consider a temporal legend in which the user is able to adjust certain qualities. Of particular interest is the possibility of enabling the user to select a preferred rate of time through the manipulation of a given interactive element (Sieber et al. 2005).

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RÉSUMÉ

Výzkum uživatelské vstřícnosti časové legendy v animovaných mapách

Vedle technické stránky kartografické tvorby se v současnosti stále více diskutuje o její uživatelské vstřícnosti. Výzkum uživatelské vstřícnosti může být vhodným vodítkem pro odlišení vizualizačních technik, které má smysl dále rozvíjet a technik, které jsou z pohledu uživatele neefektivní. Článek navrhuje a diskutuje tři odlišné typy časové legendy, které řeší rozdílným způsobem samotné znázornění času (dvě odlišné formy časové osy × alfanumerické vyjádření času) a také jeho rychlost a její případné změny. První ze zkoumaných legend vyjadřuje rychlost času rychlostí pohyblivého jezdce, druhá grafickou délkou časových jednotek na časové ose. Poslední, alfanumerická časová legenda, používá ke znázornění rychlosti času speciální, uměle přidaný prvek ve tvaru šipky.

Tyto tři navržené časové legendy byly vzájemně porovnány na základě online testu uživatelské vstřícnosti. Do porovnání vstupovaly jak faktory objektivní (jak je uživatel schopen s danou časovou legendou pracovat), tak faktory subjektivní.

Z testu vyplynulo, že nejlepší způsob vyjádření času je formou časové osy, kdy je rychlost času vyjádřena proměnnou rychlostí pohyblivého ukazatele („jezdce“). Tento způsob je však v praxi nejběžněji používaný a zůstává proto otázkou, nakolik jsou výsledky testu ovlivněny faktorem zvyku uživatelů. Pro stanovení jasných závěrů by bylo třeba provést větší množství elementárních testů.