# IDEAS FOR THE USE OF CHERNOFF FACES IN SCHOOL CARTOGRAPHY

Reyes Núñez

José Jesús
jesus@ludens.elte.hu

Eötvös Loránd University
Department of Cartography and Geoinformatics
Pázmány Péter sétány 1/A, 1117 Budapest, Hungary

## Abstract

Hermann Chernoff (now Professor Emeritus of Applied Mathematics, Department of Statistics at Harvard University) created this method in 1973 for the graphic representation of statistical data, to represent specific multivariate data using only one symbol (a human face) changing its features. Only four years later, from 1977 the Chernoff faces began to be introduced also to cartography abroad, using the human faces to represent data on a map following the traditional methods of thematic representation. The first and more famous (today considered a classic) example is the map entitled “Life in Los Angeles, 1970”, made by Eugene Turner from the Geography Dept. at the California State University in 1977. In the past two decades new maps were made taking advantage of the technological development represented by the daily use of personal computers to complete different map tasks, mainly during the making of different types of thematic maps. These solutions are characterized not only by the use of the original method, but also by its new variations. At present, the processing of data using Chernoff faces is included in a common way in statistical software (e.g. Statistica, S-PLUS or Systat), but not in software related to cartography or/and GIS, which can be one of the reasons why the method has not been used more widely on maps. The present paper includes some examples from international research on this theme and the general use of this method on maps (Dorling 1991, Fabrikant 2004 and Nelson 1997-2007). Some of the practical experiences acquired by the author are also presented: the majority of them were obtained during the theoretical and practical teaching of this method for MSc students of Cartography at Eötvös Loránd University. These experiences are illustrated by some thematic maps made by the students using the original Chernoff faces and its adaptation to represent data on maps. Some new proposals about the possible future use of the Chernoff faces in school cartography (mainly on thematic maps in school atlases) are also presented, first of all how to adapt the original Chernoff method for its use on maps made for pupils in Elementary and Secondary Schools, modifying the original method in the interest of improving the map reading. At present, these questions are studied within an international project counting with the participation of Argentine and Hungarian specialists. The main task of this

bilateral project is the organization of a survey about the cartographic use of Chernoff faces in both countries, to be applied for pupils in Elementary and Secondary Schools.

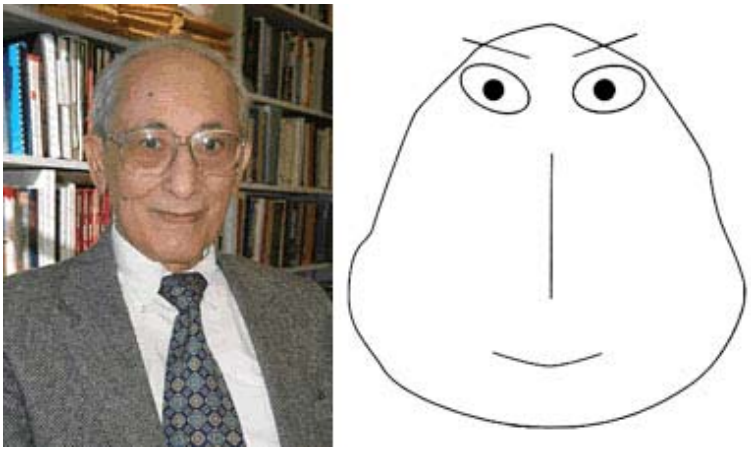

Figure 1. Herman Chernoff in 2008 and the original face from 1973

## 1. Introduction: a very brief history of the Chernoff faces

In 1973, Hermann Chernoff (Figure 1) created his method for the graphic representation of statistical data, which was explained in the article entitled „The use of faces to represent points in *k*-dimensional space graphically", published in the Journal of the American Statistical Association.

He decided to use a human face as a symbol (called multivariate symbol), on which its features (eyes, ear, nose, mouth etc) can be used to represent different variables, changing the specific characteristics (parameters) of each feature depending on the values of these variables. Chernoff affirmed that up to 18 different themes or variables can be differentiated using a wide cast of features of a human face.

During the last 30 years different research about the method has been made by specialists, trying to improve its capability for graphic representation. Two of the most famous works were made by Bernhard Flury and Hans Riedwyl in 1981 (dividing the face in two halves to increase the number of variables that can be represented from 18 to 36), and B. T. Kabulov in 1992 (generalizing data before representation and increasing the number of features to use for mapping the data), but the obtained results did not facilitate the reading and understanding of data represented by a face.

## 2. Cartographic research related to the Chernoff faces during the last 30 years

Only four years after the publication of the article written by Chernoff, this method of representation began to be introduced also to cartography abroad, using the human faces to represent data on a map according to the traditional methods of thematic representation. The first and more famous (today considered a classic) example is the map entitled "Life in Los Angeles, 1970", designed by Eugene Turner (Figure 2) and drafted by Richard Doss from the Geography Department at the California State University in 1977. Eugene Turner wrote about this map: "*It is probably one of the most*

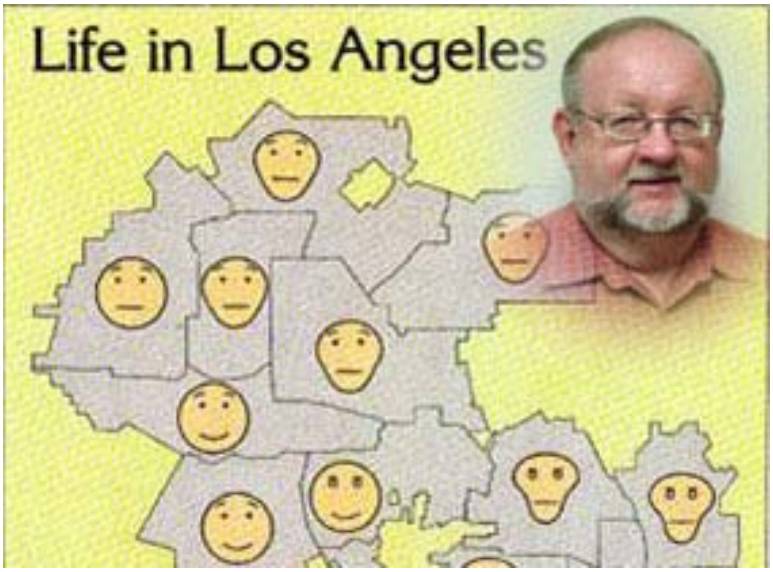

Figure 2. Eugene Turner and a fragment of his map

*interesting maps I've created because the expressions evoke an emotional association with the data. Some people don't like that.*" (Turner, 2004)

Two years later, Howard Wainer (at present adjunct professor of Statistics at the Wharton School of the University of Pennsylvania) used the Chernoff faces to make a map representing social differences in the United States, obtaining a graphic result that was quite different from Turner's one.

From the 90's mainly two names are related to research on the map use of Chernoff faces:

- Danny Dorling, who beginning the decade finished his PhD research on the theme of visualization of spatial structure, combining his cartograms with Chernoff faces to represent the results of data analysis about elections in Great Britain (Dorling 1991).
- Elizabeth S. Nelson, who from the second half of the 90's began to research on specific aspects of this theme, as feature salience and natural correspondence on faces and the exam of search process when information is represented on a map using Chernoff faces (Nelson 1997-2007).

Other specialists have sporadically "visited" this research field. One of them was Sarah Irina Fabrikant, who at present is Head of Geographic Information Visualization and Analysis Unit of the Department of Geography at the University of Zurich. In 2004 she drew a USA map of the presidential elections in that year (Fabrikant 2004), combining choroplets (percentage of urban population in each state) with a photographic and morphing version of Chernoff faces to represent two more variables (number of votes

by face size and morphing effect to represent the percent of popular votes for President Bush).

By now, the processing of data using Chernoff faces is included in internationally recognized statistical software (e.g. Statistica, S-PLUS or Systat), but not in software related to cartography or/and GIS. This situation can be considered as one of the reasons why the method has not been used more widely on maps. Some statistical software gives us the option to export data represented by Chernoff faces to very simple sketch maps (maps that generally are formed only by state or province frontiers), but analyzing the results from a cartographical point of view it can be affirmed that the quality of representation is very low and these solutions do not contribute to popularizing the method among specialists on cartography.

## 3. Why can a cartographer be interested in Chernoff faces?

First of all, we should not forget that it is not a method created for mapping activities. Herman Chernoff is not a cartographer or a specialist on graphic works. By this reason, the use of this method on maps requires a cartographer's experience to adapt it for the cartographic conditions to make a readable map with good graphical quality. An international workshop run by Prof. Henry Castner (Greensboro, USA) during an international conference organized in Wroclaw (Poland) raised my interest in Chernoff faces 11 years ago (in 1998). In the next years I could only sporadically follow the study of the method until 2005, when this topic was introduced as one of the themes to teach in the final semester of the subject entitled "Thematic Cartography" developed for MSc students of Cartography at Eötvös Loránd University in Budapest, Hungary. The teaching was addressed to the adaptation of the original method on maps, trying to improve it with the use of techniques developed by the traditional thematic cartography or combining its use with other traditional methods of representation, first of all with choroplets.

During these years numerous positive and negative practical experiences were acquired and discussed by the author with his students, concluding that the correct use of Chernoff faces is determined by the answers that can be given to questions characterized by psychological (called "emotional" by Turner) and editing factors:

Psychological questions, factors:

- Can the Chernoff faces be used to represent negative themes?
- Questions related to the psychological reading of Chernoff faces (face and features perception): How can the psychological message of a face be read? How can each feature influence this reading? What is the role of each face feature during the reading: which features are perceived better than others, which feature(s) determines the psychological message of the face?

The psychological questions about Chernoff faces have been examined in a general context by specialists from different research fields. But these questions had little research on cartographic use: the most important research on this topic has been made by Elisabeth Nelson (1997, 2007), and Daniel Dorling (1991) also had tried new solutions on this field.

Starting from my own experiences on the teaching of this theme, I can affirm that negative themes (e.g. epidemics, suicides, unemployment, etc) can be represented by Chernoff faces, however I did not recommend this kind of usage of the method during the theoretical and practical lessons with my MSc students. Still some of them selected negatives themes and made maps with interesting results, which are characterized by the correct use of graphic solutions to reflect the negative nature of these themes. An example can be seen in Figure 4: a map combining simplified faces with features having a low-key expression and the use of the black color and different tones of grey to remark the negative atmosphere of the message (unemployment in a Hungarian county).

A more difficult question is the reading of the psychological message of a face. This question should be divided into two parts (based on Nelson, 2007): the reading of the general message (analyzing the face as a whole) and the reading of each feature, including the influence of the features to transmit the general message.

Previous general research on this topic is very rich, beginning from Chernoff (1973), including specialists as Flury and Riedwyl (1981) or Kabulov (1992) to the more recent cartographic works from Nelson (2007) or the critique written by Kosara (2007). Nelson relates this theme to two concepts: feature salience (*concept of perceptually ordering facial features from those that produce the most noticeable changes to those that produce the least noticeable changes*) and natural correspondence (*designing face symbols so that the overall attitudinal labels of the symbols correspond to the overall physical meaning of the mapped data*).

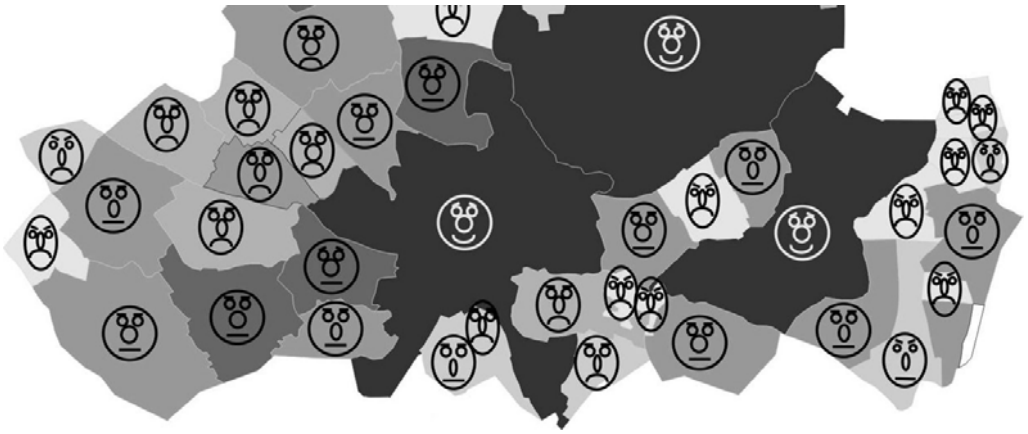

Figure 4. Use of Chernoff faces to represent a negative theme (fragment of a map made by Janos Nyerges in 2005)

*Natural correspondence* or the reading of a face as a whole that expresses an identifiable human feeling (happiness, sadness, etc.) according to the represented data, is perhaps the most difficult aim to reach designing Chernoff faces. This general psychological message is influenced by the expression suggested by each of the features forming the face, and the expression of each feature (that can be called as individual) is determined by a specific value within a data set of the represented variable. Each feature on a face has its individual expression, which can be the opposite of the individual expression of other neighbor feature, and can provoke a discernible contradiction between these features (e.g. “angry” eyebrow and smiling mouth within the same face). The only one solution that I found to ease these differences is simplifying the faces’ drawing, limiting the number of variables to draw and making a very careful selection of graphic changes for each feature that also depends on the theme to represent.

This last affirmation takes us back to the importance of the concept of *feature salience*. If we are able only to ease the contradictory expressions that we order to the features, it is very important to determine which features play a relevant role transmitting the psychological message of a face as a whole. During the last four years I had multiple opportunities to exchange ideas and opinions with my MSc students on this question. Based on our experiences, the parameter considered essential to reflect the nature of a message is the curvature of mouth: the expression of a face is determined by the fact that it is smiling or crying, and other features’ influence is subjected to this one. There are also other “cartographic” parameters that play a determinant role, which are treated within the editing questions.

Editing questions, factors:

- How many variables can be represented without causing difficulties to read and compare information (data)?
- Which graphic (editing) solutions (size, shape, fill) can be transferred (adapted) from the traditional methods of thematic representation to improve the use of Chernoff faces?
- Can Chernoff faces be combined with other traditional method(s) of thematic representation (choroplets)? Or can they be used with success as a traditional method of thematic representation (symbol, proportional symbol, cartogram, etc)?

The number of variables to be represented within a theme is one of the aspects that have a particular influence in the reading of the faces, and also determines the graphic solutions that we can use during the design of a face. In his original work Chernoff (1973) wrote that up to 18 variables can be represented using a face. Considering the human abilities to recognize graphic differences and to make graphic comparisons, the reading and analysis of 18 variables on a face is a very difficult task that demands too much time and attention. Posterior research emphasized that the number of variables to

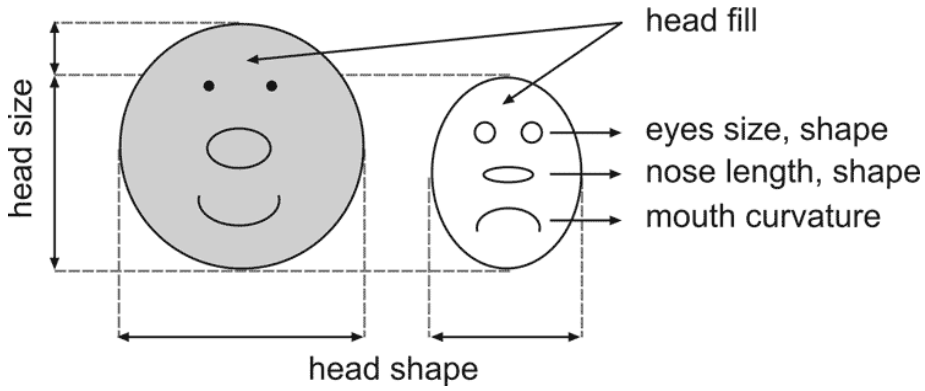


Figure 5. The six elemental graphic parameters to change in a Chernoff face for thematic mapping

represent should be kept on a number less than 18; e.g. Bradley Mohr (2008, who created the Faces 2.1 screensaver module for Mac OS X) kept this number on 11 and John Wiseman (1998, University of Chicago) limited it to 10.

Based on my own and my students' experiences using Chernoff faces on maps, the number of variables to be represented on a simplified face should not be more than six. The parameters to change according to the values of variables are: head size, head shape, head fill, mouth curvature, eyes shape or size, and nose length or shape (Figure 5). Two of these six parameters (head size and head fill) are purely cartographic and were adopted from the traditional use of proportional map symbols on thematic maps. The change of head size or/and shape is perhaps the second more important parameter after mouth curvature, being a parameter that is easily recognized, giving map users a general idea about the spatial distribution of a specific variable. By this reason I recommend for my students to use this parameter to represent one of the main variables within the general theme of the map.

During our practices, the students created thematic maps combining Chernoff faces (used as proportional symbols) with choroplets and applying very different solutions, e.g. the use of faces without any fill or with a transparent effect to see better the variable represented by choroplets. The most interesting international experiences on the use of Chernoff faces as a traditional method of thematic representation were the works made by Dorling (1991), Fabrikant (2004) and Nelson (1997-2007), as was treated in Chapter 2, but this theme demands more research to determine how Chernoff faces can be used as (or can complete) a traditional method of representation on the maps.

**4. Possibilities of using the Chernoff principle in school cartography**

Despite being a method that provokes professional discussions about its applicability and possibilities, specialists coincide on that it is an "unusual" pictorial method for data

representation. This general characteristic motivated me to think about its possible use within school cartography, asking myself if it can or not arouse the children's attention (interest) more than a traditional method of thematic representation. A very simplified version of the Chernoff faces (e.g. representing no more than three or four variables) could be used to make easy thematic maps for school atlases. But a more interesting solution is to adapt the principle followed by Chernoff to the traditional cartographic symbols. Chernoff divided a human face into its features, and each of these features was used to represent a different variable. A cartographer can do the same with a cartographic (pictorial or geometric) symbol: e.g. a pictogram can be divided into its more relevant and graphically better recognizable elements (components, features), and each of these elements can represent a specific variable (data set). It is recommendable to follow the general ideas described in the previous chapter and especially to limit the number of variables to a maximum of six, to help the faster and easier reading and comparison of the different symbols.

By this solution we can improve the traditional use of symbols in (school) cartography: for centuries symbols were used to represent only one theme, changing the size (proportional symbols) and/or the shape of the symbol to express how a theme can change depending on a value. Sometimes other graphic parameters of a symbol (fill color or outlines) were also changed. But using the Chernoff principle new parameters can be changed within a symbol (Figure 6), growing automatically the number of themes that can be represented on one thematic map only.

A more appropriate scope for the use of Chernoff faces or the adoption of the Chernoff principle could be the atlases edited for the first grades in Elementary Schools.

In Hungary, a First Atlas is made for pupils between grades 3 and 5 (ages of 8 to 10) and by now there are no thematic maps in this atlas. For children, the use of this method

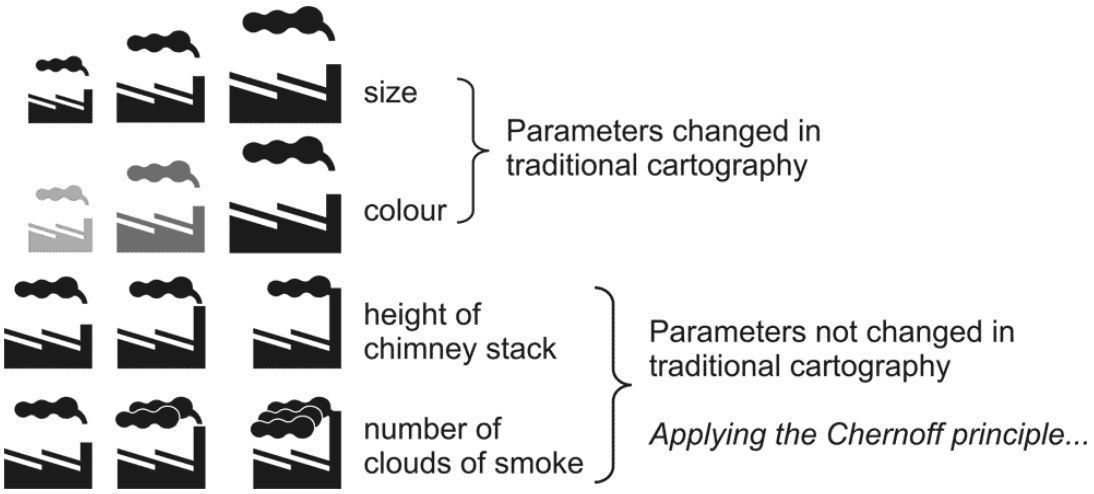


Figure 6. Example for the use of the Chernoff principle on a cartographic symbol

can be a more staring/striking solution than the traditional methods of thematic representation (bar, pie or other charts). A cartographer/researcher's responsibility is to survey how to use Chernoff faces or to adopt the Chernoff principle without the detriment of map reading and understanding in school cartography.

## 5. An international project about Chernoff faces in school cartography

At present, these questions are studied within an international project counting with the participation of Argentine and Hungarian specialists. The main task of this bilateral project is the organization of a survey about the cartographic use of Chernoff faces in both countries, to be applied for pupils in Elementary and Secondary Schools.

Between 2004 and 2005 Argentine and Hungarian specialists cooperated in a research project entitled "Map reading by children in school age: Cartographic education and practice in Hungary and Argentina", organized within the frame of a bilateral agreement for scientific and technical research (Reyes, 2007). One of the conclusions obtained within this project was a proposal emphasizing the need of further research in the field of thematic maps for school cartography.

Accomplishing this proposal, a two-year research project was begun by the same team in Hungary and Argentina from 2008, under the title "The possible uses of the Chernoff faces for data visualisation in school cartography". During the first year (2008) we followed theoretical research about this method, which is described in the present paper. Simultaneously we began to organize a survey on this topic for 7-8th grade pupils in Hungarian Elementary Schools and 1$^{st}$ grade students in Argentine Secondary Schools, designing a graphic questionnaire formed by four questions and asking themes represented with different variations of Chernoff faces. This survey was applied between March and June of 2009, counting with the participation of about 1000 pupils in each country. At present, both research teams are finishing the data input and beginning the analysis of the results.

All the details about this project are also stored on the Web, on a homepage written in Spanish and Hungarian languages that includes the questionnaires in pdf version, Excel tables with the answers given by the participants and the papers and posters presented in different conferences. The address of the website is:

http://lazarus.elte.hu/hun/dolgozo/jesus/ma0809/proyect1.htm

Colleagues participating in this research would like to invite all the interested specialists to visit our website and contact us to exchange opinions and ideas that indubitably can constitute an important contribution to the successful conclusion of our project and a possible starting point for new international joint projects in the near future.

References:


Dorling, D., 1991: *The Visualization of Spatial Structure, PhD Thesis*, Department of Geography, University of Newcastle upon Tyne [Online] Available at: http://www.sasi.group.shef.ac.uk/thesis/chapter8.html [Accessed 21 May 2009]

Fabrikant, S. I., 2004: 2004 Blue and Red America (Crayola nation : paint by votes!) [Online] Available at: http://www.geog.ucsb.edu/~sara/html/mapping/election/election04/election.html [Accessed 21 May 2009]

Kosara, R., 2007: A critique of Chernoff faces [Online] Available at: http://eagereyes.org/VisCrit/ChernoffFaces.html [Accessed 6 June 2009]

Mohr, B. D., 2008: Faces 2.1[Online] Available at: http://bradandkathy.com/software/faces.html [Accessed 7 June 2009]

Nelson, E. S., 2000. The Impact of Bivariate Symbol Design on Task Perfomance in a Map Setting. *Cartographica*, 37(4), pp. 61-78

Nelson, E. S., 2007. The Face Symbol: Research Issues and Cartographic Potential. *Cartographica*, 42(1), pp. 53-64

Nelson, E. S. et al.,1997. Visual Search Processes and the Multivariate Point Symbol. *Cartographica*, 34(4), pp. 19-33

Reyes, J. et al, 2005. Reading thematic maps in Argentine and Hungarian schools: experiences in both countries, *Digital Proceedings of „Mapping Approaches into a Changing World" 22nd International Cartographic Conference (ICC 2005)*

Turner, E., 2004. *Gene's Map Gallery* [Online] Available at: http://www.csun.edu/~hfgeg005/eturner/gallery/gallery.htm [Accessed 21 May 2009]

Wainer H., 1979: Graphic experiment in display of nine variables uses faces to show multiple properties of States. *Newsletter of the Bureau of Social Sciences Research*, 13, pp. 2-3

Wiseman, J., 1998: Chernoff Faces (in Java) [Online] Available at: http://people.cs.uchicago.edu/~wiseman/chernoff/ [Accessed 7 June 2009]



*The present research is developed in the framework of activities of the MTA-ELTE Research Group on Cartography and GIS, financed by the project ARG-3/2007 of the National Office for Research and Technology of Hungary and the project 68302 of the Hungarian Scientific Research Fund (OTKA).*