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METHOD OF RASTER LINE DYNAMIC SMOOTHING

The method of line smoothing based of the physical laws of motion of a body having its mass is proposed in the paper. The method enables dynamic updating of the smoothed line during the process of the line drawing by a user. It does not require complete redrawing of the line. The proposed method can be used in graphical editors and other applications which require interactive graphics.

The results of the method application are shown and discussed. The performance of the algorithm of the proposed method is tested and compared with the algorithm of smoothing based on Bezier curves. It is shown that the performance of the proposed method is 20% higher than the performance of smoothing based on Bezier curves. The ecstatic look of lines obtained as a result of the proposed method is demonstrated as well.

Keywords*: line smoothing, interactive graphics, graphical editor.*

Introduction

The line smoothing is one of the most frequently used operations of raster graphics. It is necessary for enhancing raster images by giving them more ecstatic look. Algorithms of line smoothing are internal part of any graphical editor as well as they are used in various graphical applications. Especially algorithms of line smoothing are important for interactive graphics applications.

Nowadays, the most popular methods of the line smoothing are based on Bezier curves and splines [1-4]. The methods based on splines frequently used for business graphics and diagrams. At the same time, the methods of smoothing by Bezier curves can be applied to various geometric forms, including polygonal paths.

A preferable method depends on the application and requirements to the line smoothing. However, for interactive applications an important task is the insertion of a new point into existing array of raster points. The majority of existing methods require rebuilding of the whole path for the insertion of the new point what takes quite much time.

Research Objective

The research presented in this paper is aimed at the development of the method of smoothing which can be dynamically applied while a user is drawing a line. The method should enable re-drawing of the line during drawing process by updating smoothed line when the new point has been added but without complete redrawing of the line. The method should ensure similar or better quality of smoothing and enable comparative or higher performance of the smoothing algorithm in comparison with the closest analogue – the smoothing based on Bezier curves [1]. The widest angle between line segments of the smoothed line based on the same set of points is supposed to be used as the criterion of smoothing quality. The performance is supposed to be estimated for both algorithms of the line smoothing.

Method Description

The proposed method is based on the physical laws of motion of a body which has its mass [5]. In particular, the motion with constant acceleration is described by the following law:

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$$\bar{r} = \bar{r}_0 + \bar{v}_0 t + \frac{\bar{a} t^2}{2} \qquad (1)$$

Such body being under the action of a force is changing smoothly the trajectory of its motion according to the force acting on the body (Fig. 1).

The proposed method uses the trajectory of the body's motion defined by (1) as a smoothed line. The force acting on the body is directed at the next point of the initial line. The coordinate of this body is changing at each moment of the motion according to the formula:

$$x'(t) = at \qquad (2)$$

In this case, let us consider the value of t, which is iteratively changing by 1, and calculate the value of a proportionally to the distance to the next point.

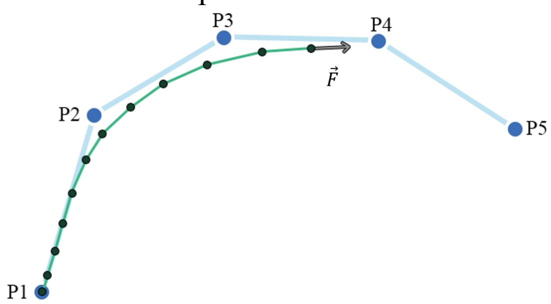

Fig. 1. The motion trajectory smoothly changing according to the force acting on the body

It is possible to find such values of the body mass, frictional force, and speed of points changing at the initial line that the trajectory of the motion is the approximated curve of the initial points set; this curve can be used as the initial smoothed line.

The advantages of this approach are:

1. High performance – the proposed method demonstrates better results than the method based on Bezier curves;

2. Resistance to noise in initial data;

3. Possibility of the motion trajectory calculation separately for one point added into the initial points set; this feature of the method also has positive impact to the performance.

One of the disadvantages of the method is that in certain conditions the quantity of points can be decreased dramatically; as the result the obtained line has too sharp angles. This disadvantage can be overcome by applying the proposed method several times consecutively. However, in this case the performance is reduced.

The initial direction of the body motion is set by its initial speed. The higher mass of the body is, the slower change of the trajectory of the body's motion is.

Tuning of Parameters

The parameters used in this method are the following: the body mass, the coefficient of friction of both the body and the surface, the speed of initial points changing (it is set by the number of steps), and the number of passes.

The mass influences on the motion trajectory – the larger mass is, the lower movement of the body is. If the mass is too small, the point can oscillate around the initial line; if the mass is too large, the point can move too slow and as a result it can cause that the point is not reached the initial line. It has been noticed that the most optimal value of the mass is 10-50 in the most of cases. The example of smoothing for different values of mass and constant values of other parameters (the coefficient of friction is equal to 0.8, the number of steps is equal to 4, the number of passes is equal to 1) is shown in Fig. 2.

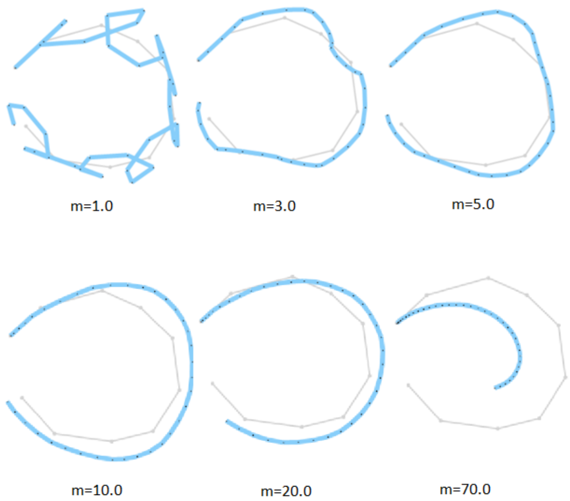

Fig. 2. The example of smoothing for different values of the mass and constant values of other parameters

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The coefficient of friction influences on the motion of a material point and allows to achieve slowing down the point motion while approaching to the aimed point as well as to prevent passing the aimed point. If the coefficient of friction is small, the resulting line does not reach the initial line. If the coefficient of friction is large, the resulting line overtakes the initial line. For most of cases the optimal values of the coefficient of friction is equal to 0.7-0.8. The influence of the coefficient of friction into the resulting line shape, when the mass is equal to 20.0, the number of steps is 4, the number of passes is 1, is shown in Fig. 3.

The number of steps influences on the accuracy of the initial line reconstruction, the smoothness of the final line, and the method time efficiency. A small number of the steps leads to both incorrect reconstruction of the initial line and broken shape of the final line. The large number of steps leads to the accurate reconstruction of the initial line and it excludes broken shape of the final line. Usually, good results of the line smoothing can be obtained in 3-8 steps. Fig. 4 shows the influence of the number of steps on the final line shape.

Sometimes it can happen that the line of the optimal shape is smoothed insufficiently because it is obtained with too small number of points. To avoid this effect the proposed method can be applied in two or more passes. It enables better smoothing of the final line. The example of this approach work is presented at Fig. 5.

The optimal values of the parameters discussed above should be chosen individually for every task. These parameters relate to the following factors: a density of initial points location, presence of noise in initial data, a desired shape of a final line.

Results and Discussion

The proposed method enables achievement of good visual results of the smoothing according to the criteria formulated above. It can be used for a line smoothing in real-time applications. Some examples of the lines smoothing are presented in Fig. 6 and Fig. 7.

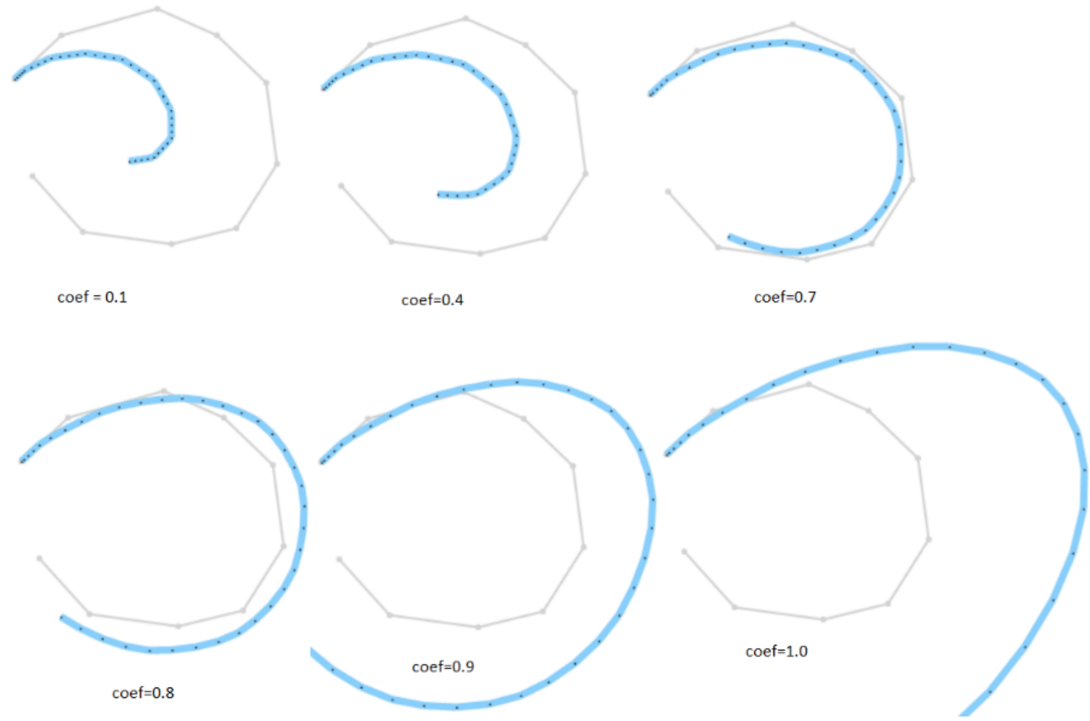

Fig. 3. The example of smoothing for different values of the coefficient of friction and constant values of other parameters

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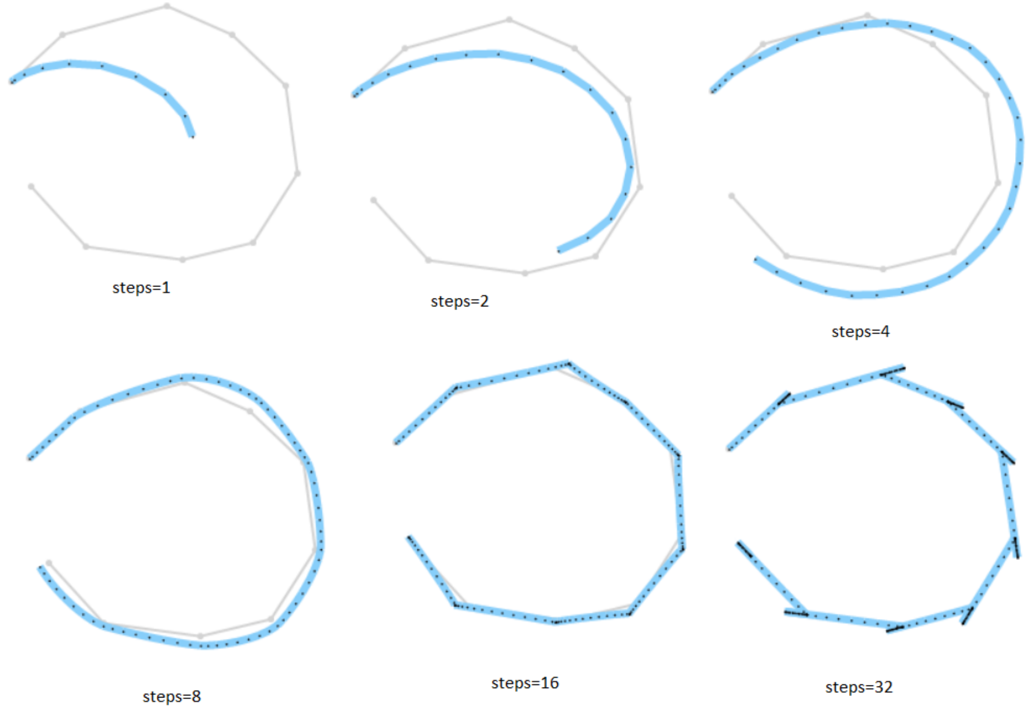
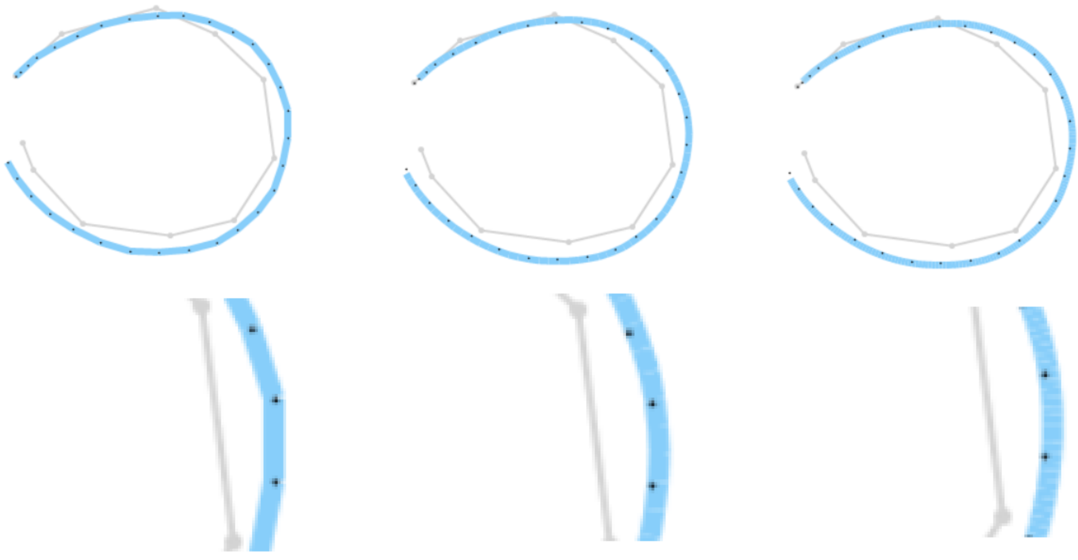


Fig. 4. The example of the smoothing for different numbers of steps



a *b* *c*

Fig. 5. The example of the smoothing for different numbers of passes:
(a) the number of passes is 1, the number of initial points is 11,
the number of smoothing points is 31, the maximal angle is 19.93;
(b) the number of passes is 2, the number of initial points is 11,
the number of smoothing points is 88, the maximal angle is 7.35;
(c) the number of passes is 3, the number of initial points is 11, the number
of smoothing points is 259, the maximal angle is 2.57

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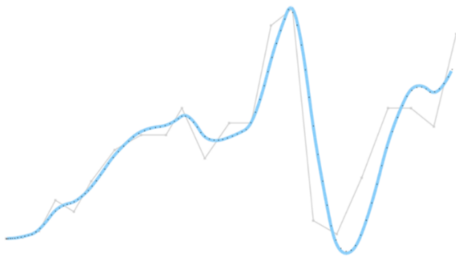

Fig. 6. The example of the line smoothing: an impulse line

Fig. 7. The example of the line smoothing: a cat sketch

This method can be also used for cleaning an input data from noise values. The example of this application of the proposed method is shown on Fig. 8.

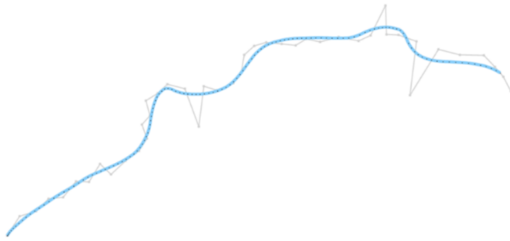

Fig. 8. The example of the smoothing for noise removing

The method enables increasing the data processing speed up to 23% in comparison with the smoothing by Bezier method based on supporting points in centres of basic lines. The test results for these two methods are shown in Table 1. As one can see, the proposed method demonstrates the increasing of the processing time only when the number of points is too small (the number of points is equal to 10). However, the larger number of points is, the lesser time is required by the proposed method for the line construction.

Table 1. Path Reconstruction Time

Number of Points	Proposed Method, ms	Bezier Method, ms	Time Decreasing, %
10	0.07	0.06	–16.67
20	0.11	0.13	15.38
30	0.16	0.20	20.00
40	0.23	0.28	17.86
50	0.28	0.35	20.00
60	0.33	0.43	23.26
70	0.39	0.50	22.00
80	0.47	0.60	21.67
90	0.51	0.65	21.54
100	0.57	0.73	21.92
110	0.62	0.80	22.50
120	0.69	0.87	20.69
130	0.74	0.95	22.11
140	0.80	1.02	21.57
150	0.86	1.10	21.82
160	0.90	1.17	23.08
170	1.00	1.24	19.35
180	1.03	1.32	21.97
190	1.09	1.40	22.14
200	1.18	1.48	20.27

Conclusions

The proposed method enables a raster line dynamic smoothing. It demonstrates 20% decreasing of time required for the line real-time construction on the average in comparison with the closest analogue – Bezier method. The proposed method is appropriate for graphical editors where a user can draw lines by hand. However, it is not recom-

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mended to use this method in the use cases where a high precision of a line reconstruction is required (e.g. exact graph visualization) because the line can be deformed as a result of the smoothing. The changing of the method parameters allows to use of the method in a wider range of applications, depending on availability and intensity of noise in initial data, density and location of supporting points, desirable accuracy and a final line shape.

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МЕТОД ДИНАМІЧНОГО ЗГЛАДЖУВАННЯ РАСТРОВИХ ЛІНІЙ

У статті запропонований метод згладжування ліній, що ґрунтується на фізичних законах руху тіла, яке має масу. Метод робить можливим динамічне оновлення лінії, що згладжується, під час усього процесу малювання лінії користувачем. Він не потребує повного перемальовування лінії. Запропонований метод може бути використаний в графічних редакторах та інших додатках, що потребують інтерактивної графіки.

В статті продемонстровані та обговорені результати практичного застосування методу. Виконано тестування алгоритму реалізації методу з метою оцінки його швидкодії, а також виконано порівняння з алгоритмом, що ґрунтується на застосуванні кривих Без'є. У статті показано, що запропонований метод дозволяє забезпечити підвищення швидкодії на 20% порівняно зі згладжуванням на основі кривих Без'є. В статті також продемонстрований естетичний вигляд ліній, отриманих при застосуванні запропонованого методу.

Ключові слова*: згладжування ліній, інтерактивна графіка, графічний редактор.*

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Киев

МЕТОД ДИНАМИЧЕСКОГО СГЛАЖИВАНИЯ РАСТРОВЫХ ЛИНИЙ

В статье предложен метод сглаживания линий, который основан на физических законах движения тела, имеющего массу. Метод делает возможным динамическое обновление сглаживаемых линий во время всего процесса рисования линии пользователем. Он не требует полного перерисовывания линий. Предложенный метод может быть использован в графических редакторах и других приложениях, которые предполагают наличие интерактивной графики.

В статье показаны и обсуждены результаты практического применения метода. Выполнено тестирование алгоритма реализации метода с целью оценки его быстродействия, а также выполнено сравнение с алгоритмом, основывающемся на применении кривых Безье. В статье показано, что предложенный метод позволяет обеспечить повышение быстродействия на 20% по сравнению со сглаживанием на основе кривых Безье. В статье также проиллюстрирован эстетический вид линий, полученных в результате применения предложенного метода.

Ключевые слова*: сглаживание линий, интерактивная графика, графический редактор.*

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