

# Optimized Model And Algorithm For Computation On Storage B-Splines And Their Efficiency For One-Dimensional Parallel Calculation

**Hakimjon Zaynidinov**

Department of Information technologies,  
Tashkent University of Information Technology  
named after Muhammad al-Khwarizmi,  
Tashkent, Uzbekistan.  
tet2001@rambler.ru

**Sarvar Makhmudjanov**

Department of Information technologies,  
Tashkent University of Information Technology  
named after Muhammad al-Khwarizmi,  
Tashkent, Uzbekistan.  
s.makhmudjanov@gmail.com

**Abstract— In this paper, a parallel-pipeline computation structure has been developed for implementation of one-dimensional basic spline-approximation. It allows saving the memory for storage of values of basic splines twice at a limited number of processors. The mathematical B-spline parallel calculation method has been modified.**

**Keywords—B-spline; parallel calculation; spline method, gastro signal, coefficients, cubic splines;**

## I. INTRODUCTION

Parallel programming and the design of efficient parallel programs is well established in high performance, scientific computing for many years. The simulation of scientific problems is an important area in natural and engineering sciences of growing importance. More precise simulations or the simulation of larger problems need greater and greater computing power and memory space. In the last decades, high performance research included new developments in parallel hardware and software technologies, and a steady progress in parallel high performance computing can be observed[3,4,5,8,9].

The modern methods for construction of mathematic models and progress in computer system technologies and complexes are the base for the physicians and engineers studying the complex

multidimensional processes and real time objects in highest efficiency levels[1,2,3].

## II. STATEMENT OF THE PROBLEM

Due to the high noise levels, the empiric multidimensional relationships, produced as a result of experimental studies are considerably processed by being represented as lower level piecewise surfaces, especially in hardware implementation. The tabular algorithmic methods, parallelisation and pipelining principles considerably improve the performance rates in comparison with implementations on general-purpose microprocessors.

## III. MAIN PART

One dimensional signals program module include the following procedures: the procedure of computation of cubic basic spline, the procedure of computation of expansion coefficient and the procedure of approximation of functions and one-dimensional signals.

The cubic basic spline values computation procedure includes computation of the cubic basic spline and, the computed values are recorded in an intermediate data massif for further use.

Similarly to the case of the second level polynomial, the classical third level polynomial on Horner's method can be represented in the following way:

$$P_3(x) = a_3x^3 + a_2x^2 + a_1x + a_0 = (((a_3x + a_2)x + a_1)x + a_0) \quad (1)$$

There is a structure, proposed by Kalyaev A.V., in his work [3] for implementation of this polynomial. However, it not maximally parallel. Basic splines should be used for improving the performance owing

to parallelising implementation of multiplication operations.

According to the formula

$$f(x) \cong S_m(x) = \sum_{i=-1}^{m+1} b_i \cdot B_i(x), \quad a \leq x \leq b \quad (2)$$

the value of function under interpolation at a random point of a given interval is determined by the

values of only  $m+1$  of summands-pair derivatives of basic splines by constant coefficients. For instance,

$$f(x) \cong S_3(x) = b_{-1}B_{-1}(x) + b_0B_0(x) + b_1B_1(x) + b_2B_2(x) \text{ for } x \in [0,1] \quad (3)$$

The rest of basic splines at this sub-interval are equal to zero and, consequently, do not participate in formation of the sum.

Different methods exist for calculation of  $b$ -coefficients: interpolation and "points" formulae, smoothing splines and the smallest quadrates method. However, the "points" formulae should be used for the systems that function in real time. The specific feature of these methods is in the independence of the approximating spline value at the given area from the experimental function values that are remote from the given area. Below are the ready-made "points" formulae for the cubic splines:

*Three-points formula*, in this case the  $r-1$ ,  $r$  and  $r+1$ -th values of the function participate in determination of the coefficient

$$b_r = \frac{1}{6}(-f_{r-1} + 8f_r - f_{r+1}) \quad (4)$$

The structural diagram is shown on Figure 1. and consists of an argument register (ARg), a coefficient memorising unit (CMU), a basic function memorising unit (BFMU) and an outlet summator-accumulator of accumulating summators. For all the basic splines are similar in form, then, using the CMU block as BFMU, it can be limited by memorising the values table of only one basic spline. Basic cubic splines are determined as zero at four areas of cubic segmentation. For selection of four different values of B-splines for the purposes of summing on formula (3), four MU sub-sections will be required, each containing a part of the B-spline curve, given at this area.

Similarly with the parabolic splines case, application of an address of four values of basic splines requires only two additional binary bits, which help determine the one out of the four areas of the carrier of the main basic spline, which hosts the values  $B_{-1}$ ,  $B_0$ ,  $B_1$  и  $B_2$ . The same sub-word of the address that indicates an area of  $h=1$  length, can be used for selection of basic spline values in each of three subsections of PMU, which can be given the following addresses:

11 for  $B_{-1} \quad x \in [-2, -1];$

$$f(x) \cong S_3(x) = b_{-1}B_{-1}(x) + b_0B_0(x) + b_1B_1(1-x) + b_2B_2(2-x) \text{ for } x \in [0,1]$$

the cubic B-splines require four basic summands.

The function value is calculated using the formula

$$00 \text{ for } B_0 \quad x \in [-1, 0]; \quad (5)$$

$$01 \text{ for } B_1 \quad x \in [0, 1];$$

$$10 \text{ for } B_2 \quad x \in [1, 2].$$

For confirmation of justification of the conclusion on applicability of hardware costs as a super large scale integration circuit memory and their slight increase at rise of the number of simultaneously performed functions at one installation, we shall divide the whole task interval of the random, multiple differentiated function  $f(x)$  into areas at  $n \cdot 2^0$ , where  $p$  is an integer number. Then, if the binary code of the argument contains  $l$  bits, one approximation area would have  $2^{l-p}$  values of elements of the basic spline table, while the total scope of the table is determined using the formula:

$$Q = 4 \cdot 2^{l-p} = 2^{l-p+1} \quad (6)$$

Due to the evenness of the basic spline, only half of the table can be recorded in the memory, for instance for the range of argument  $[0,2)$ .

If  $n=32$ , while  $l=16$  of binary charge, then  $Q=2^{16-5}=2048$  words, which at capabilities of modern super large scale integration circuits, can be implemented using one or two micro-chips. The storage capacity coefficients at transformation to one function would be equal to  $n+2m+1$  words.

Reconstruction of a functional relationship to a new shape is done by simple transfer of coefficients to a new storage capacity area. Upon recoding of basic function in PMU, generally, the algorithm of transformation is linear. A parallel structure can be expanded in case of necessity in increase of the basic spline level. However, this leads to complication of data output from memory and increase of the number of multipliers.

Thus, the main advantage of the structure is its high performance, actually top-speed for tabular-algorithmic methods.

In this section every calculation goes right way which is given in previous section. Only  $S(x)$  calculation has been changed.

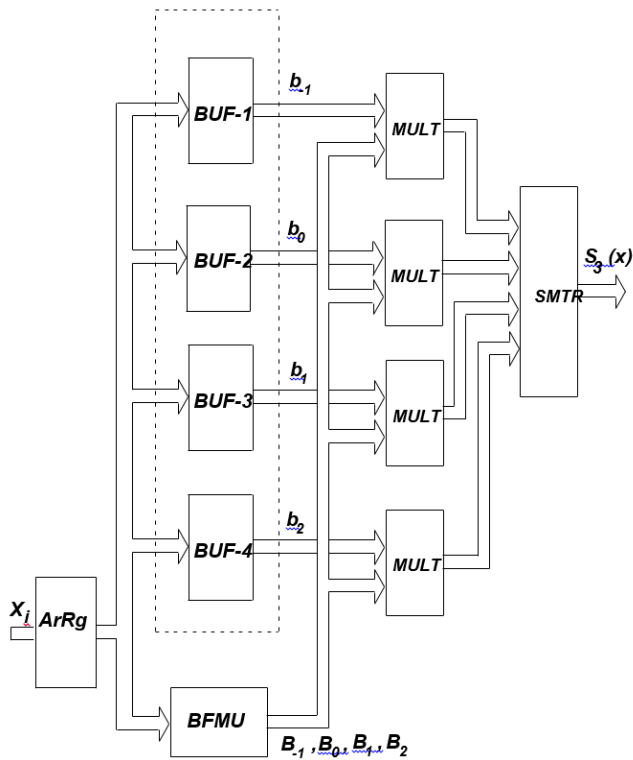


Figure 1. A tabular-algorithmic computing structure for implementation of approximation of function with cubic basic splines.

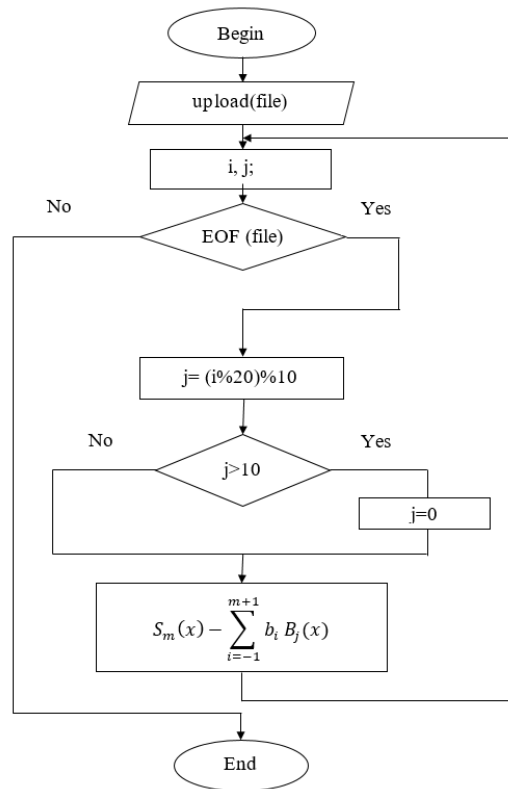


Fig. 2. Block diagram of an algorithm for approximating a function with a cubic basic spline.

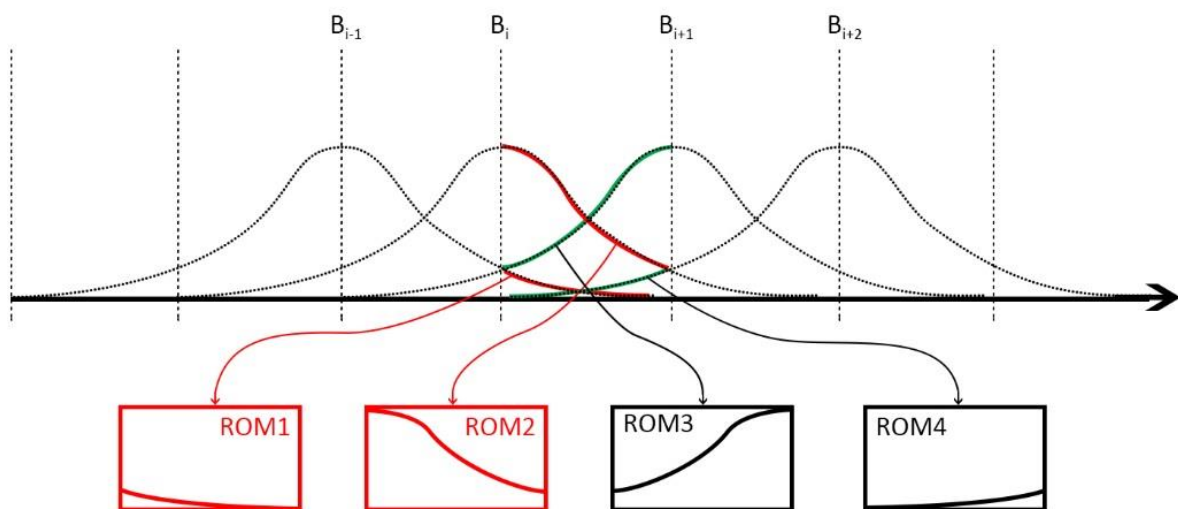


Figure 3. Main structure of restoration bicubic splines in a memory

From this case memory usage decreases two times in parallel computing B-spline functions (Figure 3).

- ROM1 - 00 for an interval ;  $x \in [1,2)$
- ROM2 - 01 for an interval ;  $x \in [0,1)$

As it is given above section there should have been extra requirement for storage memory. But optimized

way there is no need to have extra memory which is blanked with red or vice versa.

ROM1 and ROM2 are actually specular with ROM3 and ROM4. From this point we can skip ROM3 and ROM4, so that to optimize usage of memory.

In this case values of spline function  $x \in [0,1)$ , every value is saved as an element of an array. An array has 20 elements and depending on its values.

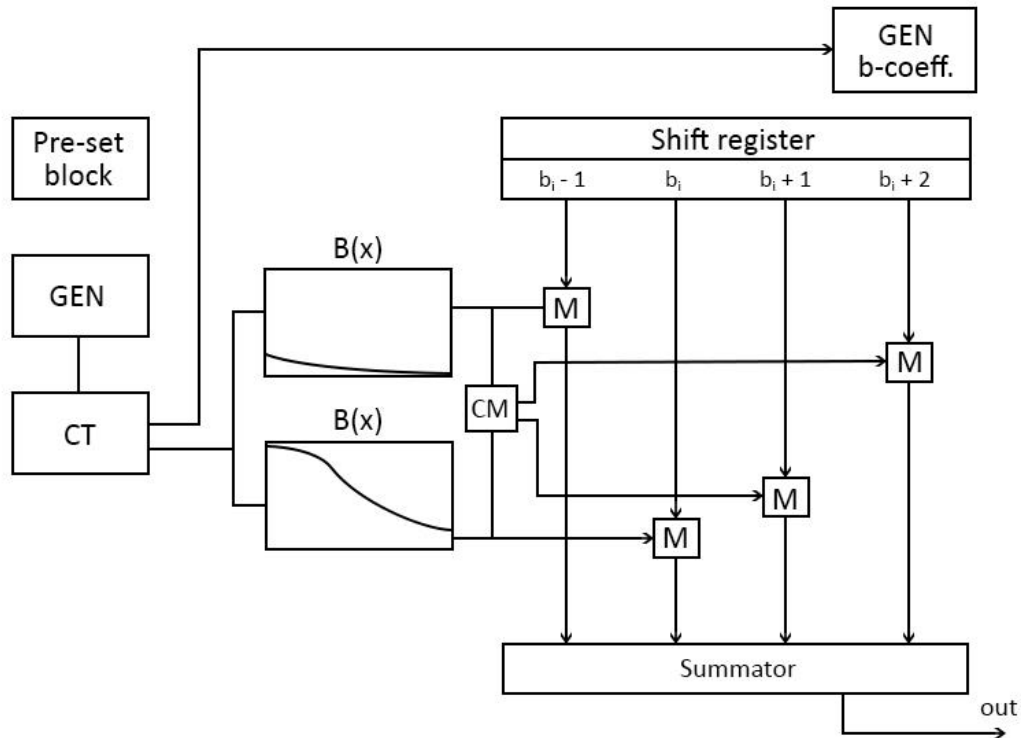


Figure 4. Optimized structure used for method of computation of restored splines

In approximation  $f[i]$  function or any biomedical signals (as an array or any version of it), calling B-spline values are done only once. This is the most effective way when we use parallel processings.

In this new method, it is proved that usage of memory decreased two times but computation speed and accuracy reminds as it was (Figure 4).

Calculations were performed by special software that created in new technologies. First program was created using Java FX and displayed results old version of computation approximation of  $S(x)$ . Second one was created by PHP web technologies and it is provided optimized calculation  $S(x)$  in parallel processing.

A model of parallel computation structure was developed based on cubic basic splines in optimized method (mirroring).

A spline-method of determination of anomalies of complex biomedical signals of experimental data was developed based upon use of the mathematic tool of cubic splines. The use of spline-functions leads to improvement of accuracy of the results and to significant reduction of computation costs.

A spline-method of analysis, processing and determination of cardiosignals of biomedical structures, based upon the use of spectral basic signals was developed. The developed method allows assessing the fatigue and prognosticating the stability and strength of biomedical signals.

The scientific research practice often faces the task, when the experimental data require recovery of the general feature of a phenomenon or a process. A way to resolve this task is the use of spline-methods of approximation of experimental data.

A program complex is prepared as a uniform software package that consists of interrelated programs with determined parameters. At installation of the package, all program modules are implemented simultaneously, which enables the software be a full set product and all possible functions of the complex can be used.

The program complex is intended for use on any type computers that are compatible with any version operating systems and on digital signal processings. The software complex takes external memory to setup and at loading in the operating memory it takes memory based on file size which is being uploaded.

Table I. Approximation of experimental gastro signal based on developed model

| i  | f[i] (gastro signal) | b[i]     | S2[i]        | difference |
|----|----------------------|----------|--------------|------------|
| 1  | 6.102696             | 6.058134 | 5.8863647657 | 0.2163     |
| 2  | 6.637434             | 6.681995 | 6.2766046711 | 0.3608     |
| 3  | 6.904803             | 6.904803 | 6.7576312193 | 0.1472     |
| 4  | 7.172172             | 7.216733 | 7.0551980625 | 0.1170     |
| 5  | 7.172172             | 7.172172 | 7.1861940186 | -0.0140    |
| 6  | 7.172172             | 7.127610 | 7.1690007065 | 0.0032     |
| 7  | 7.439541             | 7.573225 | 7.3896915353 | 0.0498     |
| 8  | 6.904803             | 6.904803 | 6.9877022438 | -0.0829    |
| 9  | 6.370065             | 6.370065 | 6.3774918888 | -0.0074    |
| 10 | 5.835327             | 5.879888 | 6.3263946933 | -0.4911    |
| 11 | 5.033221             | 4.988659 | 5.6678948166 | -0.6347    |
| 12 | 4.498483             | 4.453921 | 4.8492191712 | -0.3507    |

The representation bar consists of graphical demonstration components and this panel helps the software visualize the initial and recovered signal values.

The work of the software.  $F(x)$  is given gastro signals and  $S(x)$  is array of values of the restored function based on spline methods. All programs are interrelated via the program complex interface and they work interdependently with each other (Figure 5.).

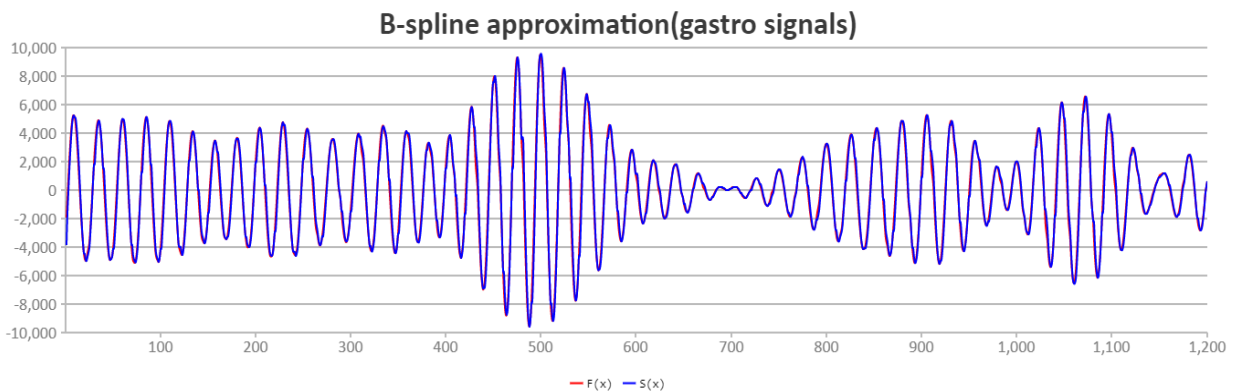


Figure 5. The program complex interface with an example.

One-dimensional signal program module the data entry is performed from external files. At performance of this module, the tabular given data is imported from the file and recorded in the data arrays with respective size.

**SUMMARY**

A spline-method of determination of anomalies of complex biomedical signals of experimental data was developed based upon use of the mathematic tool of cubic splines. The use of spline-functions leads to

improvement of accuracy of the results and to significant reduction of computation costs.

Optimized structure used for method of computation of restored splines in this new method, it is proved that usage of memory decreased two times but computation speed and accuracy reminds as it was.

The graph illustrates that given in Figure 5. those defined by parametric approximation cubic splines given in two colored lines are similar.

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