<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Applications</td>
<td>2</td>
</tr>
<tr>
<td>The Method</td>
<td>3</td>
</tr>
<tr>
<td>Working Examples of the Spline Interpolation Method</td>
<td>4</td>
</tr>
<tr>
<td>Hardware Requirements</td>
<td>5</td>
</tr>
<tr>
<td>Information on Installing the TRANSLATOR</td>
<td>6</td>
</tr>
</tbody>
</table>
**SINUMERIK® Documentation**

**Key to editions**

The editions listed below have been published prior to the current edition.

The column headed "Amendments" lists the amended sections/pages with reference to the previous edition.

<table>
<thead>
<tr>
<th>Edition</th>
<th>Order No.</th>
<th>Amendments</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.88</td>
<td>6ZB5 410-7BA02-0BA1</td>
<td>New edition</td>
</tr>
</tbody>
</table>
Contents

1 Introduction .................................................. 1-1
   1.1 What is spline interpolation? .......................... 1-1
   1.2 What is a spline? ...................................... 1-2
   1.3 What is the approximation method? .................. 1-3
   1.4 What is data reduction? ................................ 1-4

2 Applications .................................................. 2-1

3 The Method ................................................... 3-1
   3.1 Recording the contour ................................. 3-2
   3.2 Approximation using the TRANSLATOR .............. 3-2
       3.2.1 Configuration for the approximation method .. 3-2
       3.2.2 Operating the TRANSLATOR ................... 3-6
       3.2.3 Data transfer ................................... 3-8
   3.3 Spline interpolation ................................... 3-9
   3.4 Working examples of the approximation method ...... 3-9
       3.4.1 Creation of a smooth curve using a small number of spline points .... 3-10
       3.4.2 Creation of a small number of spline blocks from a large number of linear blocks (data reduction) ........................................ 3-13

4 Working Examples of the Spline Interpolation Method .... 4-1
   4.1 Five-axis milling: Backrest of a chair ............... 4-1
   4.2 Free form surfaces: Phone receiver .................. 4-2

5 Hardware Requirements ..................................... 5-1

6 Information on Installing the TRANSLATOR .............. 6-1
1 Introduction

1.1 What is spline interpolation?

The spline interpolation method described in this Guide is used to connect a small number of spline points on a set contour with smooth curves. The individual curve segments are adjoined with the same slope and the same curvature in each case. This results in smooth transitions, thus reducing wear and tear on machine tools. By setting the spline points very close to each other, almost sharp edges can be programmed. Even critical sequences of spline points do not cause overshooting.

The spline interpolation method described in this Guide allows a significant reduction of NC blocks when working on complex workpiece geometries, which is a great advantage compared with spline functions using standard methods. The more complex the surface to be machined and the higher the quality requirements are, the shorter the contour segments described by an NC block become. For numerical controls that use only linear interpolation, this can lead to an immense amount of data which can hardly be processed. The greater the number of elements which can be programmed and interpolated directly, however, the smaller is the number of NC blocks required to machine arbitrary curve paths. Spline interpolation supplies this set of contour elements. The reduced number of NC blocks allows a higher feedrate and thus economical production. The working examples in this Guide show how powerful the method is.

The spline interpolation method is made up of two components: the so-called TRANSLATOR, a program which translates linear NC blocks into spline blocks, and the INTERPOLATOR, which is a function in SINUMERIK controls. Additional knowledge is not necessary. NC programmers create their programs in the usual way and the TRANSLATOR automatically translates the programs into the correct format, which can be interpreted by the INTERPOLATOR.

The spline interpolation method can be applied in the following areas: high-speed and high-precision machining of complex contours, 5-axis milling, machining of free form surfaces, woodworking, laser and plasma machining processes.
1.2 What is a spline?

A spline is a smooth curve, i.e. a curve without any edges and with constantly changing radii of curvature. A spline is made up of a series of 3rd degree polynomials.

Example:

![Spline made of four segments in the x,y plane](image)

Notes for readers who are interested in mathematics:

The spline in Fig. 1.1 is described by the four spline segments \( P_0, P_1, P_2, \) and \( P_3 \). Each spline segment \( P \) is characterized by a 3rd degree polynomial \( P_{nx} \) and a 3rd degree polynomial \( P_{ny} \).

\[
P_n = \begin{cases} 
P_{nx}(i) \\
P_{ny}(i) 
\end{cases}
\]

The polynomials \( P_{nm} \) (\( m = x, y \)) are functions of the path parameter \( i \):

\[
P_{nm}(i) = A_{3m} \cdot i^3 + A_{2m} \cdot i^2 + A_{1m} \cdot i + A_{0m}
\]

Each position within a spline segment is defined by the path parameter \( i \) which is equivalent to the path length to be covered from that position to the end position.

The reason why splines are described by 3rd degree polynomials is as follows:

As already mentioned above, the aim of spline interpolation is to join curve segments of various slopes and curvatures by smooth transitions. 1st degree polynomials describe only curves which have a constant slope, i.e. straight lines. Thus smooth transitions between straight lines of different slopes cannot be produced with 1st degree polynomials. 2nd degree polynomials have a variable slope, but the curvature is constant. 3rd degree polynomials join curve segments of various slopes and various curvatures by smooth transitions, whereas polynomials of higher degrees tend to produce oscillations, which means that the quality of the transitions is not improved.
1.3 What is the approximation method?

In this text, the approximation method relates to the computation of 3rd degree polynomials (i.e. splines), using specific spline points of a set contour. The splines can differ from the specified points by a selectable amount. Two different approximation methods can be applied.

With the **standard spline method**, a spline segment is calculated from two points and two boundary conditions.

![The standard spline method](image1)

Fig. 1.2 The standard spline method

With the so-called **Newton Method of Approximation** a spline segment is calculated from four points.

![The Newton method of approximation](image2)

Fig. 1.3 The Newton method of approximation

For working examples of these methods please refer to Section 3.
1.4 What is data reduction?

Using data reduction methods, spline interpolation can transform a large number of linear blocks into just a few spline blocks. The example in Fig. 1.4 shows how seven linear blocks are replaced by one spline block (a reduction factor of 7).

*Fig. 1.4 Data reduction: Seven linear blocks can be replaced by one spline block*

**The method in detail:**
A tolerance field is defined around the set contour. The width of the tolerance field corresponds to the preset tolerance value. If this value is exceeded when the spline is computed (i.e. the deviation of the spline from the set contour has reached the permissible tolerance limit), the approximation run automatically generates the next spline block. The width of the tolerance field therefore affects the accuracy of the contour and hence the number of computed spline blocks. The more accurately the contour is to coincide with the set contour, the narrower must be the width of the tolerance field.

The graphical example in Fig. 1.5 shows that the width of the tolerance field also affects the number of points which suffice to accurately describe the contour within the required tolerance.

The wider the tolerance field is, the fewer the number of points that are needed to describe the contour. If a minimum of data is specified to describe the contour with the given tolerance, the data stream is said to be coarse. Alternatively, if more data is specified than is required for the description, the data stream is said to be fine.
1.4 What is data reduction?

The tolerance value can also be "zero". In this case, the splines to be computed may not deviate from the given contour points.

Depending on the approximation method chosen, data reduction can still occur even in this case.

Due to its algorithm, the Newton Method of Approximation causes data reduction by a reduction factor of 3 because a spline segment is computed from four points and the fourth point of the first spline segment is identical with the first point of the second spline segment.

Due to the algorithm of the Standard Spline Method, however, no data reduction occurs because it computes a spline between two points.
2 Applications

Spline interpolation opens up new possibilities for the user, especially in the following areas of application:

- **High-speed and high-precision machining of complex contours**
  In high-speed and high-precision machining of complex contours, the same basic problem can occur in each case, namely that the time for processing a block becomes extremely short when programming in the conventional way. In high-speed machining, this results from the fast rate at which NC blocks are processed, and in high-precision machining of complex contours it is due to the extremely short block lengths. Spline interpolation provides solutions to these problems because the higher degree of interpolation significantly extends the traverse described by one block. In other words, fewer blocks are needed to describe any contour. The smooth transitions between the contour segments preclude sudden changes of acceleration. This reduces wear and tear on machine tools. A working example (camshaft) is described in Section 3.4.2.

- **5-axis milling**
  The programming of five machine axes using conventional geometries results in large quantities of data. At the feedrates which are technologically necessary and economical, such quantities cannot always be processed completely within the block cycle times prevailing at present. Spline interpolation and data reduction can reduce the number of blocks significantly and thus increase the feedrate.

- **Machining of free form surfaces**
  Spline interpolation enables machining of surfaces which cannot be described by standard geometries. The necessity to produce these free form surfaces for automobile parts and injection moulded parts for consumer goods results from a combination of aesthetical and functional viewpoints. Free form surfaces are also needed for aircraft construction and shipbuilding because these surfaces are difficult to describe analytically. The number of blocks which were previously necessary to machine such complex workpiece geometries can now be reduced considerably since the introduction of spline interpolation, because larger path sections can be described by fewer spline points and therefore fewer NC blocks. A working example (phone receiver) is described in Section 4.2.

- **Woodworking**
  The description of high-speed machining problems above also applies to the machining of wood. The high speed of the cutter requires very high feedrates. If the feed suddenly drops to zero, there is a risk of the cutter burning loose. A working example of 5-axis cutting in woodworking (backrest of a chair) is given in Section 4.1.

- **Laser and plasma machining**
  Cutting and welding technologies. Laser cutters must be positioned normal to the surface to avoid burrs. This means applying 5-axis machining to curved sheet metal parts. Apart from the geometry the laser intensity can also be controlled.
3 The Method

The spline interpolation method consists of

- recording the contour
- approximation method (TRANSLATOR)
- spline interpolation

The procedure is shown in the diagram below:

Fig. 3.1 The entire spline interpolation procedure

The various steps of the procedure, in particular the application of the approximation software (TRANSLATOR), are explained in detail in the following sections.
3.1 Recording the contour

The contour can be recorded using the following options:

• Play Back
  "Play Back" is a programming method in which the machine tool is driven to different contour points on a master workpiece in the conventional traversing mode. The axis positions of the machine axes can then be transferred to the part program memory. The resulting part program can then be modified or completed and be used to produce further identical workpieces.

• Digitizing
  A scanning device obtains the contour geometry data. The acquired 3D coordinates are either used directly as linear 3D axis positions or converted to linear 5D axis positions by means of a postprocessor.

• CAD programming systems
  e.g. NC 800 -- a programming system for two-dimensional machining.

3.2 Approximation using the TRANSLATOR

The approximation method and handling of the TRANSLATOR (a program for generating spline blocks from standard NC programs) will first be described in general terms. The configuration of the TRANSLATOR is described at the beginning because the programmed axis designations and the machine geometry must be specified before starting the approximation procedure.

Following the description of the approximation method the application of the TRANSLATOR is shown for the following examples:

• Creating a smooth curve from a small number of spline points
• Creating a small number of NC blocks from a large number of linear blocks

3.2.1 Configuration for the approximation method

Before starting the approximation method, the designation of the programmed axes must be declared.

The milling head type used must also be known before the approximation starts because the tool length compensation depends on it.

These can both be entered after selecting the function "Configuration" in the main TRANSLATOR menu.

To obtain the menu, TRANSLATOR must be called by typing the command translat followed by hitting RETURN.
After pressing any key, the main menu is displayed:

```
 Approximation
 Data trans. PC  NC
 Data trans. NC  PC
 Return to MSDOS
 Configuration
```

![Fig. 3.2 TRANSLATOR main menu](image)

Select the function "Configuration" in this menu. (The selected function is highlighted. You can move to the other options by using the space bar, the arrow keys, or the RETURN key.)

After pressing the F2 function key, the following screen form is displayed:

```
Configuration

Models of 5-axis machine:
  1: Nutating head
  2: Gimbal head
  3: Twist and nod head
  4: Inclinable head
Enter your choice: 1
Axis names:
  Linear axes: 1: X  2: Y  3: Z
  Rotary axes: 1: B  2: C
Error constant rotary axis 1 : 1.000
Error constant rotary axis 2 : 1.400
<F1> Last screen page
<F2> Start execution
<F4> Stop execution
```

![Fig. 3.3 Configuration screen form](image)

To make it easier to select the cutter head type, these are shown below diagrammatically and information on the axis constellation is given.

**Note:**

The two constants in the screen form are:

- for 5-axis machines, model 1
  - Error constant rotary axis 1: 0.017
  - Error constant rotary axis 2: 0.024

- for 5-axis machines, models 2, 3, 4
  - Error constant rotary axis 1: 0.017
  - Error constant rotary axis 2: 0.017
Having entered the data, the screen form is exited by pressing F1 or F2 and a return is made to the main menu.

The tool is parallel to the Z axis when \( B = C = 0 \).
The B axis is in the X-Y plane when \( C = 0 \).

The B axis is along the Y axis when \( C = 0 \).
The tool is parallel to the Z axis when \( B = 0 \).
3.2.1 Configuration for the approximation method

The tool is parallel to the Z axis when \( A = B = 0 \).
The A axis is always about the X axis.
The B axis is about the Y axis when \( A = 0 \).

The rotary table (axis C) rotates about the Z axis.
The swivel head (axis B) rotates about the Y axis.
The range of swivel about B is usually between \(-45^\circ\) and \(+45^\circ\).
3.2.2 Operating the TRANSLATOR

- Edit the standard NC program in a file named progxxxx.dat ("xxxx" represents any program number with up to four digits.)

When creating this program, the following conditions must be observed:

a) Up to 5 axes can be programmed.

b) The program may contain Help functions and comments, but no tool compensation may be programmed.

c) Only absolute dimensions are allowed.

d) The NC blocks may be written with or without block numbers.

e) Note that the axis names in the program must correspond to the axis names chosen in the configuration procedure (see Section 3.2.1)

f) All five axes must be specified before the first program section to be translated into spline blocks.

**Note:**

Before starting the approximation procedure, check if the labels of the five programmed axes correspond to the configuration data of the TRANSLATOR (for more details on configuration see Section 3.2.1)

- Mark the beginning of the linear blocks to be converted to spline blocks with the additional functions M50 and the end with M51. Alternatively, the relevant block numbers can also be written into a file canxxxx.dat, where "xxxx" represents the program number selected above.

- Call the TRANSLATOR with the translat command and press RETURN.

- After pressing any key, the TRANSLATOR main menu is displayed.

- Select the "Approximation" function in the menu. (The selected function is highlighted. Other options can be selected by using the space bar, the arrow keys, or the RETURN key.) After pressing the F2 function key, the screen form for the approximation procedure is displayed.

- Select the required approximation method and, where applicable, enter the tolerance value for the endpoints of the spline segments.

  Method 1: Newton's approximation method
  Method 2: Newton's approximation method with boundary conditions
  Method 11: Dynamic natural splines
  Method 12: Dynamic natural splines with data reduction
The four approximation methods are:

<table>
<thead>
<tr>
<th>Method</th>
<th>Boundary conditions</th>
<th>Appropriate data stream *</th>
<th>Reduction factor</th>
<th>Contour/surface quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Continuous</td>
<td>Very fine</td>
<td>Very high</td>
<td>Smooth</td>
</tr>
<tr>
<td>2</td>
<td>Continuous &amp; differentiable</td>
<td>Fine - coarse</td>
<td>High</td>
<td>Smooth</td>
</tr>
<tr>
<td>11</td>
<td>Continuous &amp; 2x differentiable</td>
<td>Coarse</td>
<td>None</td>
<td>Very smooth</td>
</tr>
<tr>
<td>12</td>
<td>Continuous &amp; 2x differentiable</td>
<td>Very fine - coarse</td>
<td>High</td>
<td>Very smooth</td>
</tr>
</tbody>
</table>

\* The term "data stream" is explained in Section 1.4.

The following methods were used for the working examples in this Guide (see Sections 3.4 and 4):

<table>
<thead>
<tr>
<th>Application</th>
<th>Method</th>
</tr>
</thead>
</table>
| Phone receiver    | Roughing 1  
|                   | Finishing 12 |
| Backrest of chair | 11, 2  |
| Shoe sole         | 11, 2  |

- Choose the procedure for checking the tolerance criteria. If procedure 1 (general) is chosen, the positions of the five axes on the spline are checked during approximation, the configured machine geometry and the tool length being taken into consideration. If procedure 2 (axis-specific tolerances) is chosen, the positions on the spline are checked for each of the programmed axes.

Procedure 1 should be chosen, whenever the program to be translated is

a) a 5-axis program for one of the four programmable machine geometries
   (for more details see Section 3.2.1)

b) a program for 2 or 3 linear axes. (Any rotary axis tolerances entered in the screen form are not considered.)

Procedure 2 is advisable in all other cases, in particular if the machine tool has rotary axes, but cannot be configured by any of the four geometries.

- Press F2 for page 2 of the screen form.

- Enter the number of the part program and of the spline program. After entering the number of the part program, the same number is entered automatically for the spline program after pressing RETURN. If a part program is to be translated using different approximation methods, a different number must be chosen for each spline program, otherwise it would be overwritten each time.
• Enter the value for tool length. If a part program is to be translated in which five machine axes have been programmed, and if the general tolerance criterion has been selected, the tool length for which the five axis program was created must be entered here.

• Enter the value for tool length compensation. The tool length compensation corrects the programmed block endpoints according to the type of milling head. **Before starting the approximation procedure, the milling head type used must be specified in the screen form of the “Configuration” function** (for more information see Section 3.2.1).

• Enter the tolerance values for the endpoints of the spline segments. (In Method 1 “Newton’s approximation method”, it is also possible to enter tolerance values for the midpoints of the spline segments. In Method 11 “Dynamic natural splines” no tolerance values are required.)

• Enter values for the maximum deviation on the rotary axes. (In Method 11 “Dynamic natural splines”, no tolerance values are required.)

• Press F2 to start the approximation procedure. Online messages displayed on the screen allow the progress of the procedure to be observed. The approximation speed of complex programs can be increased by simultaneously pressing the “CTRL” and “O” keys to switch off the display of the messages. Message display is reactivated by pressing these keys again. The ”Program executed with success” message indicates the end of the procedure and the main menu is displayed. The approximation procedure can be interrupted and terminated by pressing “CTRL B”.

• The system writes the generated NC program with the spline blocks to the **splnxxxx.dat** file, where “xxxx” represents the spline program number. The header of the spline program contains information on the program numbers of the part and spline programs, the chosen approximation method and the tolerance values.

**Note:**

When the spline program has been edited, it should not be edited further. In particular, the spline points in the spline blocks should not be changed.
### 3.2.3 Data transfer

To transfer data from the PC to the NC unit and vice versa, the appropriate functions must be selected in the TRANSLATOR main menu.

After pressing F2, a screen form appears in which the number of the program to be transferred must be entered.

**Notes:**

The receiving device must be started first before transferring data.

The data transferred from the NC unit to the PC is written into the current MSDOS directory that has been specified. The TRANSLATOR addresses the serial interface by the name LPT1:.

For more information on the transfer of programs from NC to PC please refer to the "TRANS-PCIN/TRANS-PGIN" User's Guide.

### 3.3 Spline interpolation

For the method described here, the control must be equipped with the appropriate interpolator.

The spline function can be executed

- with constant tool path feedrate
- with deceleration and acceleration on the spline
- with effective override switch.

**Some of the contour elements which can be created using spline interpolation:**

- Solid circle
- Ellipses
- Sinus function
- Exponential function
- Root function

### 3.4 Working examples of the approximation method

Application of the TRANSLATOR will be demonstrated below for the following examples:

- Creation of a smooth curve using a small number of spline points
- Creation of a small number of NC blocks using a large number of linear blocks
3.4.1 Creation of a smooth curve using a small number of spline points

The contour of a shoe sole has been chosen as working example for creating a smooth curve using a small number of spline points.

The spline points for the contour are taken from a drawing. A flexible ruler can be used to do this. The spline points are those points where the flexible ruler must be held in position in order to follow the contour. In this example, 10 spline points are needed.

![Spline points of the shoe sole contour](image)

The file containing the NC program which consists of linear blocks must have the file name `progxxxx.dat`, where "xxxx" represents the given program number with up to four digits. The file must be named "prog150.dat" for the following program example.

```
%MPF 150
N10  G10 G90 G01 G64 F5000 S3000 X0 Y0 Z0 B0 C0
N15  G00 X0.3 Y7
N20  G01 Y8 M03
N25  X1.8 Y10.2 M50
N30  X12.4 Y10.3
N35  X18.9 Y12
N40  X25.3 Y10.8
N45  X27.5 Y8
N50  X25.5 Y5
N55  X18.3 Y2.4
N60  X10 Y4
N65  X1.9 Y5.4
N70  X0.3 Y8 M51
N75  G00 X0 Y0 M04
N80 M30
```
The first and the last linear blocks to be translated are marked by the additional functions \textbf{M50} for the beginning and \textbf{M51} for the end of translation.

Alternatively, the relevant block numbers can be written into a second file with the name \texttt{cand\textit{xxxx}.dat}. "xxxx" must be replaced by the program number selected above. This approach is recommended to avoid editing in long NC programs. In our example, the numbers 25 and 70 must be entered in a file with the name \texttt{cand150.dat}.

(In the example: 25 70)

Having finished editing, TRANSLATOR is called by means of the command \texttt{translat} and the RETURN key to confirm the command.

After pressing any key, the TRANSLATOR main menu is displayed.

The function "\textit{Approximation}" must be selected in this menu. (The selected function is highlighted. Other options can be selected by using the space bar, the arrow keys, or the RETURN key.)

After pressing F2, the screen form for the approximation procedure is displayed.

First the required method must be entered. For the given example, Method 11 "\textbf{Dynamic natural splines}" is selected. (In Section 3.2.2 there is a list of all methods.)

As a rule, the procedure for entering the tolerance values must then be selected. Since Method 11 does not require any tolerance values, no further mention of this procedure is needed here.

By pressing F2, the second page of the screen form appears on the display.
First, the number of the program to be translated must be selected, i.e. 150 in our example. By pressing RETURN, the same number is also selected for the translated program.

Finally, the tool length and tool length compensation data must be entered. "0" has been chosen for this example.

After all entries have been made, the approximation procedure is started by pressing F2. The message "\textit{Program executed with success}" indicates the end of the procedure and the main menu is displayed again.

The generated program containing the spline blocks, which was written into the new file with the file name \texttt{spln\textit{xxxx}.dat}, can now be transferred from the PC to the NC.

This is done by selecting the function "Data Trans. PC -> NC" in the main menu, and then by pressing F2. The number of the program to be transferred must then be entered in the screen form which then appears. Finally, the transfer is initiated by pressing F2 again.

To end the TRANSLATOR session instead of transferring the program on completion of approximation, the "Return to MSDOS" function must be selected in the main menu or F4 must be pressed to return to the operating system.
The new program has the following format:

```plaintext
( Generated by Spline Translator Version 3.1 )
( Part program number: 150 )
( Spline program number: 150 )
( Algorithm for spline approximation: 11 Algorithm without data reduction)

%MPF 150
N10 G1 F5000 S3000 X0.000 Y0.000 Z0.000 B0.000 C0.000
N15 G0 X0.300 Y7.000
N20 G1 M03 Y8.000
K38297302 K-191418244 K-167662809
N30 G6 X12.400 Y10.3000000 K11225893 K-25162046 K-273457996
K48595505 K123939431 K-156045
N35 G6 X18.900 Y12.0000000 K-8685768 K11719673 K-257627379
K7424660 K-160932804 K-35810248
N40 G6 X25.300 Y10.8000000 K11225893 K-25162046 K-273457996
K-48595505 K123939431 K-156045
N45 G6 X27.500 Y10.3000000 K-24594846 K-22884017 K238221946
K7708952 K152495968 K186129522
N50 G6 X25.500 Y5.0000000 K-24594846 K-22884017 K238221946
K7708952 K152495968 K186129522
N55 G6 X18.300 Y2.4000000 K-3160504 K-3442601 K261214535
K5298010 K1814280 K5468220
N60 G6 X10.000 Y4.0000000 K-3160504 K-3442601 K261214535
K5298010 K1814280 K5468220
N65 G6 X1.900 Y5.4000000 K-41066769 K164972938 K181672702
K-68518720 K256316753 K-164935188
N70 G6 X0.300 Y8.0000000 K-41066769 K164972938 K181672702
K-68518720 K256316753 K-164935188
N75 G0 M04 X0.000 Y0.000
N80 M30
```

It can be seen that a spline block defining a 2D spline segment consists of 3 blocks (1 coordinate block and 2 coefficient blocks) which the NC unit interprets as one block.

The following applies in the coordinate block:

- **N** Block number
- **G6** G function for spline interpolation
- **X, Y** Endpoint coordinates of the machine axes involved in the path
- **I** Path length (value of the curve parameter at the beginning of the spline segment)

The following expressions are used in the coefficient block:

- **K** Coefficients of the axis polynomials of 3rd degree.

The coefficient blocks are located in the same order as the axes involved in the path. Each of the coefficient blocks contains the coefficients of an axis polynomial in the order \( K_3, K_2, K_1 \). The coefficients \( K_0 \) do not occur because they coincide with the endpoint coordinates (coordinate block).
3.4.2 Creating a small number of spline blocks from a large number of short linear blocks (data reduction)

The following example of a cam contour shows how programs containing vast amounts of data can be reduced in size considerably by converting to a small number of NC blocks using the spline interpolation and data reduction methods.

The procedure:

- After starting the TRANSLATOR, transfer the NC program consisting of 360 linear blocks from the programming system to the PC.

- Call the approximation function.

- Specify the required approximation method. In this case, Method 12: "Dynamic natural splines with data reduction".

- Select procedure 1 (General) to enter tolerance values.

- Press F2 to display page 2 of the screen form.
3.4.2 Creating a small number of spline blocks, from a large number of short linear blocks (data reduction)

- Enter the names of the part program and the spline program. After entering the number of the part program, press RETURN to automatically accept the same number for the spline program.

- Enter "0" for the tool length and tool length compensation values.

- Enter the tolerance value for the endpoints of the spline segments (in this example, 0.01 mm).

- Start the approximation procedure by pressing F2.

- The approximation procedure with data reduction results in an NC program consisting of 18 (!) spline blocks with a tolerance of 0.01 mm. This is a reduction factor >20!

A comparison of a section of the part program and the corresponding section of the translated spline program clearly shows the effect of data reduction.
The first 65 linear blocks of the part program:

```
%MPF 2222
N00 G01 G90 G64 F10000 X0 Y0 Z0 B0 C0
N01 B94.0 X38.494
N02 B95.0 X38.492 M50
N03 B96.0 X38.495
N04 B97.0 X38.460
N05 B98.0 X38.420
N06 B99.0 X38.375
N07 B110.0 X38.325
N08 B111.0 X38.269
N09 B112.0 X38.209
N10 B113.0 X38.144
N11 B114.0 X38.075
N12 B115.0 X38.009
N13 B116.0 X37.092
N14 B117.0 X37.835
N15 B118.0 X37.745
N16 B119.0 X37.649
N17 B120.0 X37.549
N18 B121.0 X37.445
N19 B122.0 X37.335
N20 B123.0 X37.222
N21 B124.0 X37.102
N22 B125.0 X36.975
N23 B126.0 X36.845
N24 B127.0 X36.713
N25 B128.0 X36.572
N26 B129.0 X36.425
N27 B130.0 X36.274
N28 B131.0 X36.119
N29 B132.0 X35.964
N30 B133.0 X35.805
N31 B134.0 X35.639
N32 B135.0 X35.479
N33 B136.0 X35.327
N34 B137.0 X35.160
N35 B138.0 X35.099
N36 B139.0 X34.846
N37 B140.0 X34.679
N38 B141.0 X34.519
N39 B142.0 X34.459
N40 B143.0 X34.201
N41 B144.0 X34.042
N42 B145.0 X33.883
N43 B146.0 X33.724
N44 B147.0 X33.563
N45 B148.0 X33.399
N46 B149.0 X33.239
N47 B150.0 X33.079
N48 B153.0 X32.929
N49 B152.0 X32.768
N50 B153.0 X32.607
N51 B154.0 X32.443
N52 B155.0 X32.287
N53 B156.0 X32.119
N54 B157.0 X31.968
N55 B158.0 X31.807
N56 B159.0 X31.646
N57 B160.0 X31.472
N58 B161.0 X31.327
N59 B162.0 X31.181
N60 B163.0 X31.079
N61 B164.0 X31.023
N62 B165.0 X31.045
N63 B166.0 X31.082
N64 B167.0 X31.034
N65 B168.0 X31.083
```
3.4.2 Creating a small number of spline blocks, from a large number of short linear blocks (data reduction)

By comparison, the equivalent NC blocks of the spline program (65 linear blocks have been translated into 4 spline blocks):

%MPF 2222
N0 G1 F10000 X0.000 Y0.000 Z0.000 B0.000 C0.000
N1 X38.494 B94.000
N5 G6 X38.420 B98.000 I4.001
    K7479172 K-24872128 K13544407
    K138283 K-494686 K-26816468
N12 G6 X38.009 B115.000 I17.011
    K-1092658 K-1255846 K18516670
    K-13440 K-174386 K-267781410
N15 G6 X37.745 B118.000 I3.607
    K1982335983 K-2245320190 K239699980
    K-151548408 K309309875 K-300711934
N64 G6 X31.034 B167.000 I51.515
    K-168507 K3586647 K25742689
    K584696 K-14891629 K-207929854
N65 G1 X31.083 B168.000

Note:

The number of the spline block is always the number of the linear block converted last.
4 Working Examples of the Spline Interpolation Method

4.1 Five-axis milling: Backrest of a chair

Fig. 4.1 Backrest of a chair, made of wood

Notes on the chosen procedure:

- Recording of contour using play back: 16 spline points and mirroring at the axis of symmetry. (Recording a point for 5-axis milling took about 4 minutes. Considering the time required, there is a significant difference between recording only 16 points or more than 100 points.)

- Data transfer NC - PC

- Approximation
  Chosen method: "Dynamic natural splines" (11)

- Data transfer PC - NC

- Use of SINUMERIK spline interpolator in the numerical control.
4.2 Free form surfaces: Phone receiver

Notes on the chosen procedure:

- Recording of the geometry data of the free form surface at the CAD station and generation of the NC program (1300 linear blocks) with a postprocessor.
- Chosen roughing method: “Newton’s approximation method” (1)
  Result: 300 spline blocks
- Chosen finishing method: “Dynamic natural splines with data reduction” (12)
  Result: 480 spline blocks
5 Hardware Requirements

The approximation software, i.e. the TRANSLATOR, can be installed on the following computers:

**PG 685, PC 16-20, PC 32-05**

The TRANSLATOR can be used on other personal computers with MSDOS operating system, but it has not been tested and thus there is no seller’s warranty.

Approximation using the TRANSLATOR should only be used in combination with a SINUMERIK control equipped with the proper interpolator (Spline Interpolation option).

**Example of complete hardware and software for spline interpolation:**

![Diagram showing hardware and software configuration]

*Fig. 5.1 Complete hardware and software for spline interpolation*

You will find a description of the required RS232C (V.24) connection cable and more information on how to parameterize the PC/NC interface in the "Data Transfer TRANS-PCIN/TRANS PGIN" User’s Guide.
6 Information on Installing the TRANSLATOR

The approximation software TRANSLATOR consists of the following files:

- **TRANSLAT.EXE** Program file
- **TEXT.FIL** Text file with the texts for the menu and the screen forms
- **PCFIL.DAT** File containing hardware data
- **PCIN.EXE** Transfer program for transferring data from PC to NC and vice versa
- **CONFIG.FIL** Configuration defaults for certain values can be set in this file. These are then displayed automatically in the screen form. More information on entering and modifying these values are given in the file itself.
- **TRANSIN.BAT** Batch file for installing the TRANSLATOR on a hard disk
- **TRANSRE.BAT** Batch file for copying the TRANSLATOR back to the original diskette

The TRANSLATOR software is copy protected. The original diskette can be copied onto one hard disk. The TRANSLATOR files can be recopied into various directories. If the TRANSLATOR is to be copied onto a different hard disk, it must be copied back onto the original diskette first and then installed again.

If the TRANSLATOR is to be started from any other directory after installation, the following must be added to the AUTOEXEC.BAT file:

```
set transdir = "path to the directory in which TRANSLATOR was installed"
```

**Example:**

If the original diskette is in drive A: and if the TRANSLATOR software is to be copied to hard disk C: in the "translat" directory, the following command must be entered:

```
a:
   transin a:  c:\translat
```

If the TRANSLATOR software is to be copied from hard disk C: to the original diskette in drive A:, the following command must be entered:

```
c:\translat
   transre c:  a:
```

If, for instance, the TRANSLATOR was installed in the "translat" directory, the following must be added in the AUTOEXEC.BAT file:

```
set transdir = \translat \n```