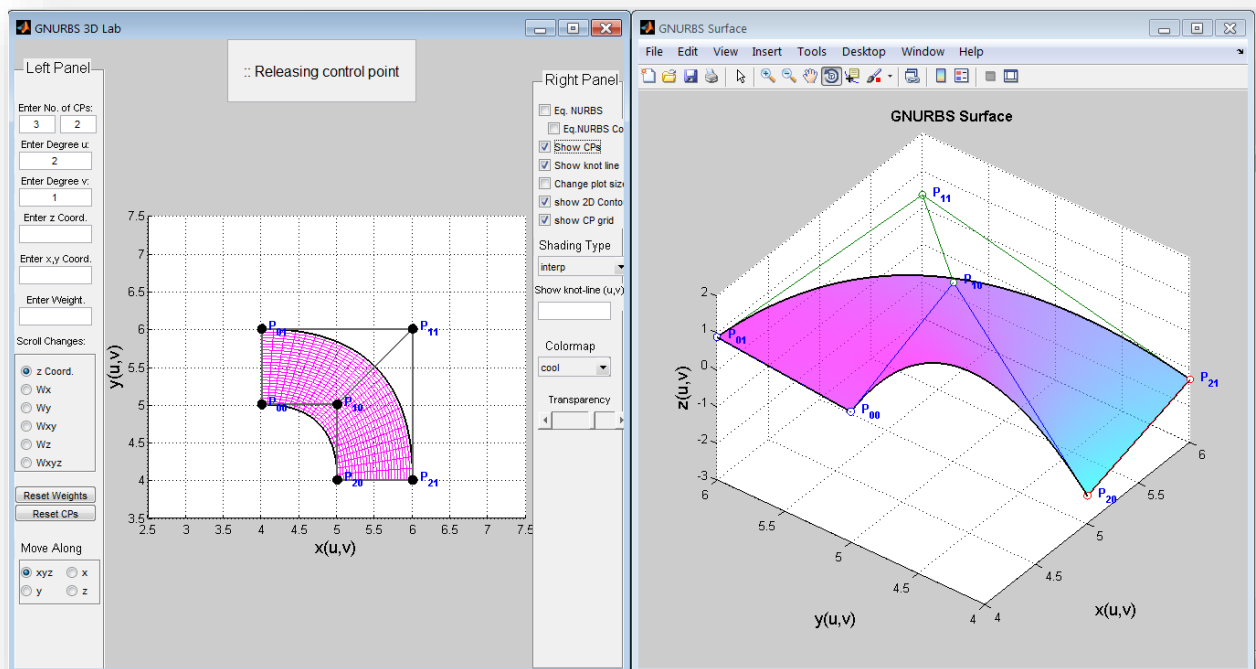


# GNURBS3D Lab

## An Interactive Matlab Toolbox for GNURBS Surfaces



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## A. Introduction

This interactive Matlab toolbox is used to generate and manipulate GNURBS surfaces. We recall that in a NURBS surface, the weights are equal along all physical coordinates. By allowing the weights to change independently along each physical coordinate, a new type of surface is generated which is referred to as Generalized NURBS (GNURBS) surface. Different settings and capabilities of this toolbox are explained in following sections.

## B. Main window

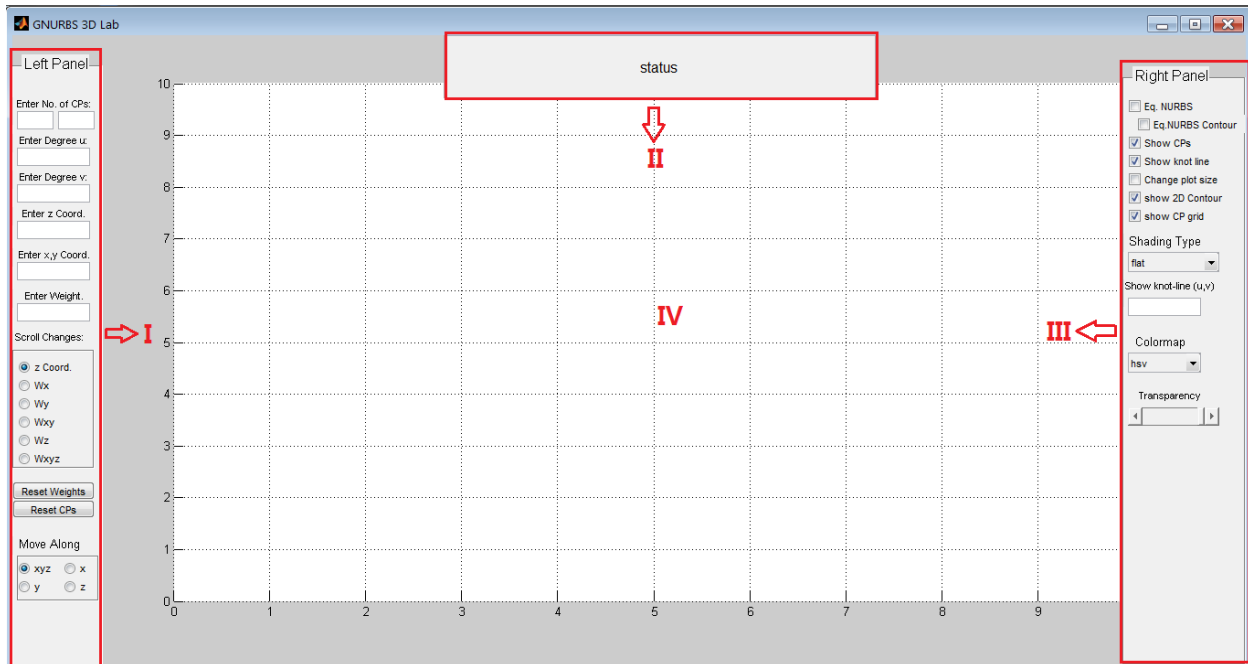
When the code is run, the main window appears. This window, which is shown in Figure 1, is composed of four main sections:

**I: Left panel:** in this panel, the input parameters are inserted, and different settings and selections can be made. The menus of this panel and their function will be explained later.

**II: Status bar:** in this field, the current status of the figure, the actions that are needed to be done by the user and other useful information about the graph and control points are displayed.

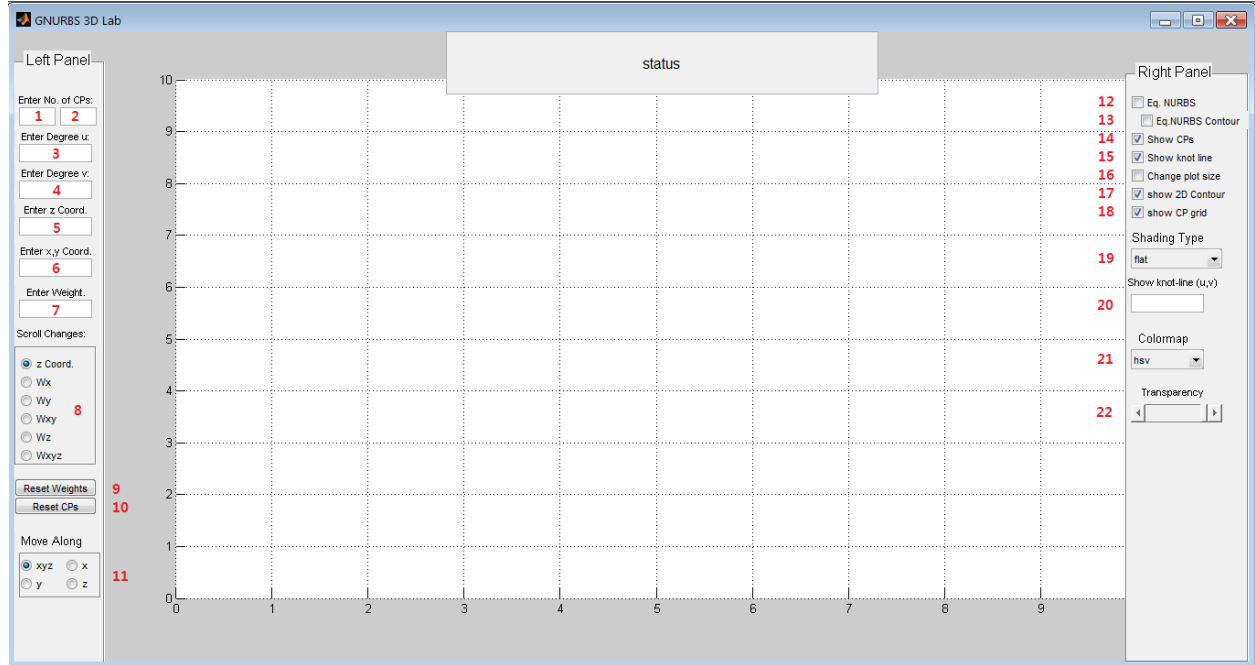
**III: Right panel:** in this panel, another set of settings and selections can be made. The menus of this panel and their functions will be explained later.

**IV: Main graph:** The control points and surface domain are shown in this area.



**Figure 1:** Main window.

Different fields and menus of the right and left panels of the main window are numbered in Figure 2. These numbers will be frequently referenced in the subsequent sections.



**Figure 2:** Numbering different fields and menus of left and right panels.

The toolbox is devised user-friendly and employing most of its features are straightforward. A detailed description of its different features is provided in the following sections. The following table describes the action of different mouse buttons.

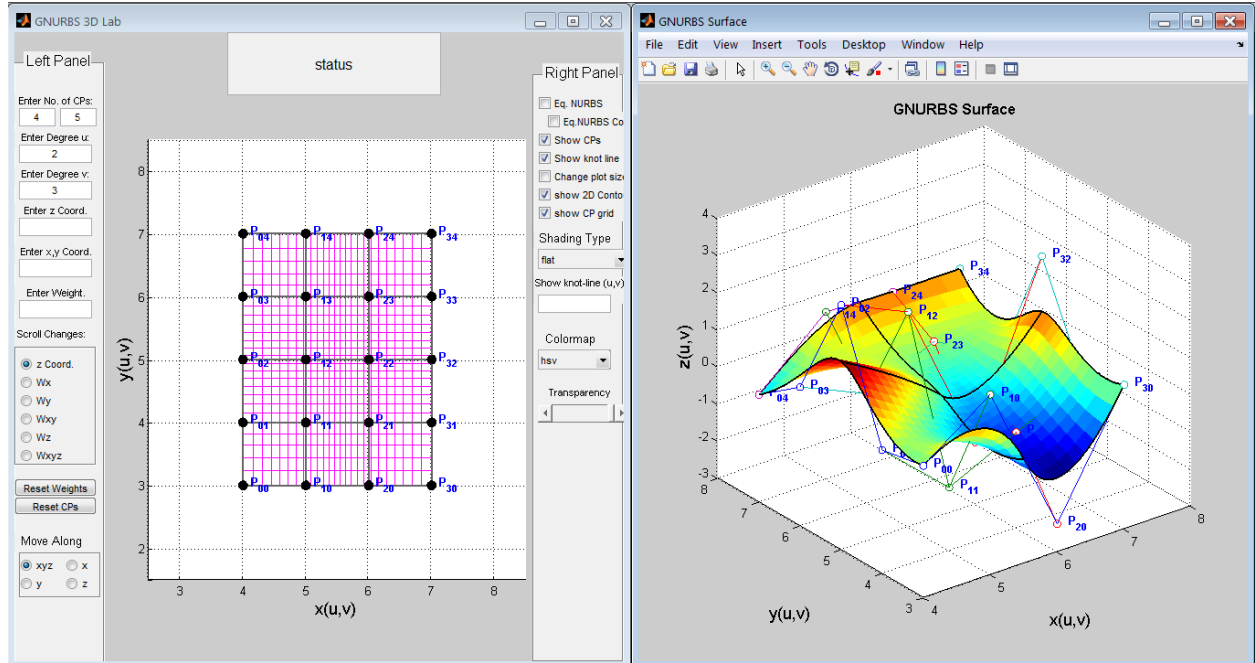
**Table 1.** The actions of different mouse buttons in GNURBS3D Lab.

L-Click	Release a selected control point
R-Click	Select a control point for scrolling ( <i>Scrolling Mode</i> )
Scroll	Change z coordinate of a control point Change weights of a control point
Double R-Click	Move a control point ( <i>Grabbing Mode</i> )

### C. Constructing a GNURBS surface

To construct a surface, first enter the number of control points (CPs) in  $x$  and  $y$  directions in the fields (1) and (2), respectively. Then enter the surface degree  $u$  and  $v$  in the fields (3) and (4), respectively. Now press “Enter” to generate the surface. After pressing the “Enter” button, the generated surface is shown in the right window and the main window resizes automatically to the left. From now on, the left and right windows are called 2D and 3D windows, respectively. The CPs are spaced equally and are shown in the 2D window. Also all the CPs are labeled in the 2D and 3D windows in blue color for better visualization.

In the generated surface, the  $z$  coordinate of CPs are initially assigned randomly, but they can be changed easily. By default, the CP grid and also the 2D contour are shown in the left panel. The initial setup of a GNURBS surface is shown in Figure 3.



**Figure 3:** Initial setup of a GNURBS surface, showing the 2D (left) and 3D (right) windows.

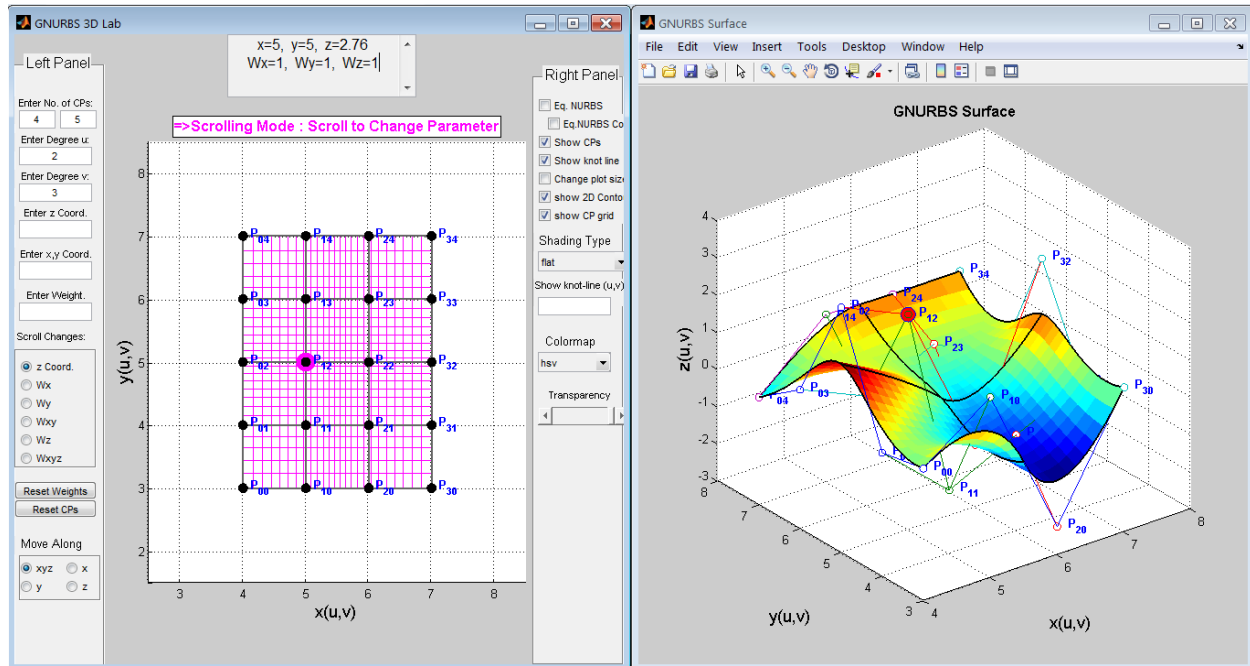
#### D. Changing the parameters of a control point by scrolling

When you right click on a CP in the 2D window, that CP is selected for scrolling (*Scrolling Mode*) and a magenta boundary appears around it. The parameters of the selected CP, such as its  $x$ ,  $y$  and  $z$  coordinates as well as the values of its weights along  $x$ ,  $y$  and  $z$  directions are shown in the status bar. Also, the corresponding CP in the GNURBS surface (3D window) is highlighted in red to track its changes (Figure 4). Now by scrolling, you can change different parameters of the selected CP, such as its  $z$  coordinate and its weights along different directions. First, choose the desired parameter under the “*Scroll changes*” menu in the left panel of the 2D window (8). The default value is “ $z$  Coord”. Now by scrolling, the selected parameter changes and the GNURBS surfaces updates interactively in the 3D window. Also, these changes can be seen simultaneously in the status bar. Here is what happens when you select each of the items under the “*Scroll changes*” menu:

- $z$  Coord. : Changes the  $z$  coordinate of selected CP.
- $Wx$ : Changes the weight of selected CP in  $x$  direction.
- $Wy$ : Changes the weight of selected CP in  $y$  direction.
- $Wxy$ : Changes the weight of selected CP in  $x$  and  $y$  directions simultaneously.

- $W_z$ : Changes the weight of selected CP in  $z$  direction.
- $W_{xyz}$ : Changes the weight of selected CP in all directions simultaneously.

As an example, in Figure 5 the “ $P_{12}$ ” is selected by R-Click and its  $z$  coordinate is changed by scrolling from 2.76 to 6.86. Also, in Figure 6, the  $W_{xy}$  of this control point is changed from 1 to 5 by selecting “ $W_{xy}$ ” in (8) and scrolling. Note that the properties of this CP are shown in the status bar.



**Figure 4:** Selecting a control point for scrolling by R-Click (*Scrolling Mode*).

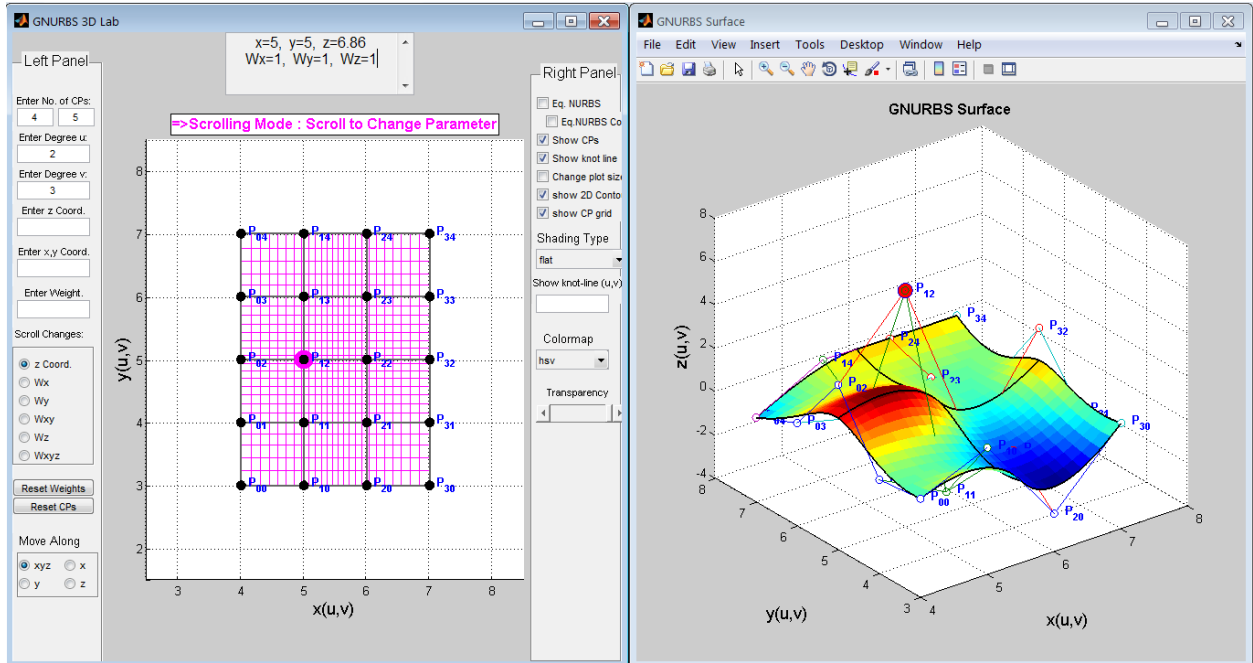


Figure 5: Changing the  $z$  coordinate of “P12” to 6.86 by scrolling.

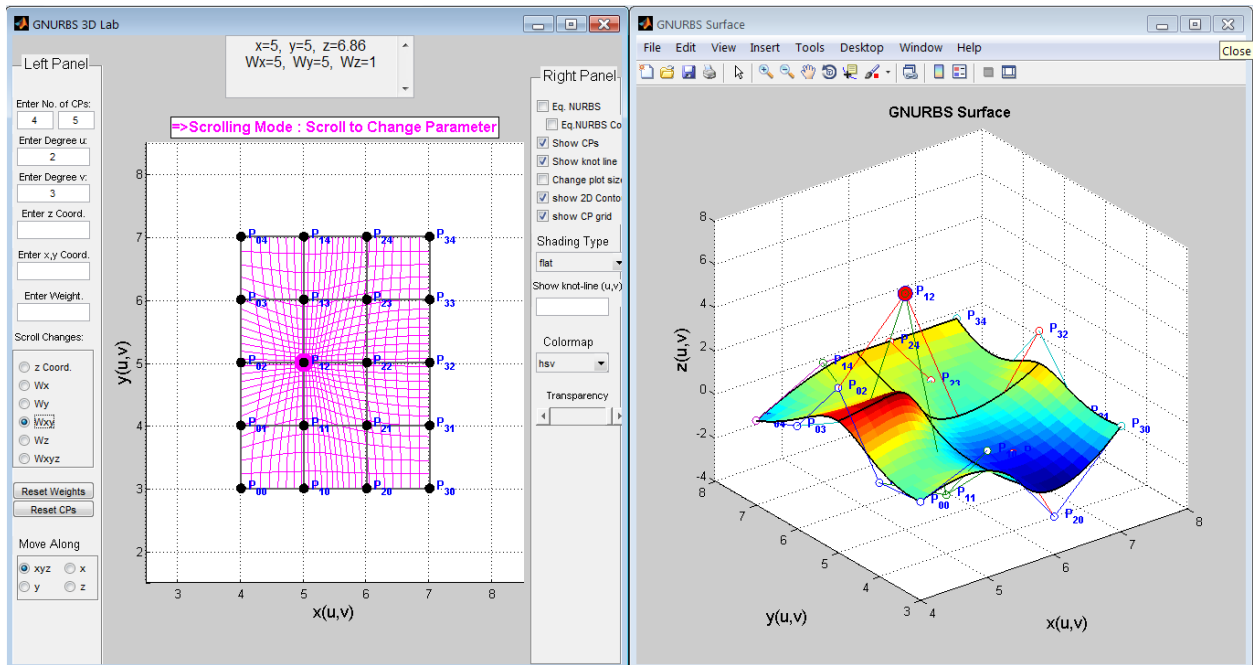


Figure 6: Changing  $W_{xy}$  of “P12” to 5 by scrolling.

### E. Changing the parameters of a control point in the left panel

The parameters of a control point in the scrolling mode can also be changed from the left panel of the 2D window. The  $z$  coordinate of each CP can be changed by right clicking on it in the 2D window (*Scrolling Mode*) and typing the desired value in the “Enter  $z$  Coord.” Field (5). As an example, in Figure 7, the  $z$

coordinate of “P32” is changed to 6 by selecting this CP and typing this value in the “Enter z Coord.” field. Different weights of a control point can be changed by, first, selecting the weight type in (8) and, next, typing the desired value in the “Enter Weight” field (7). For example,  $W_x$  of  $P_{20}$  is changed to 3 in Figure 8.

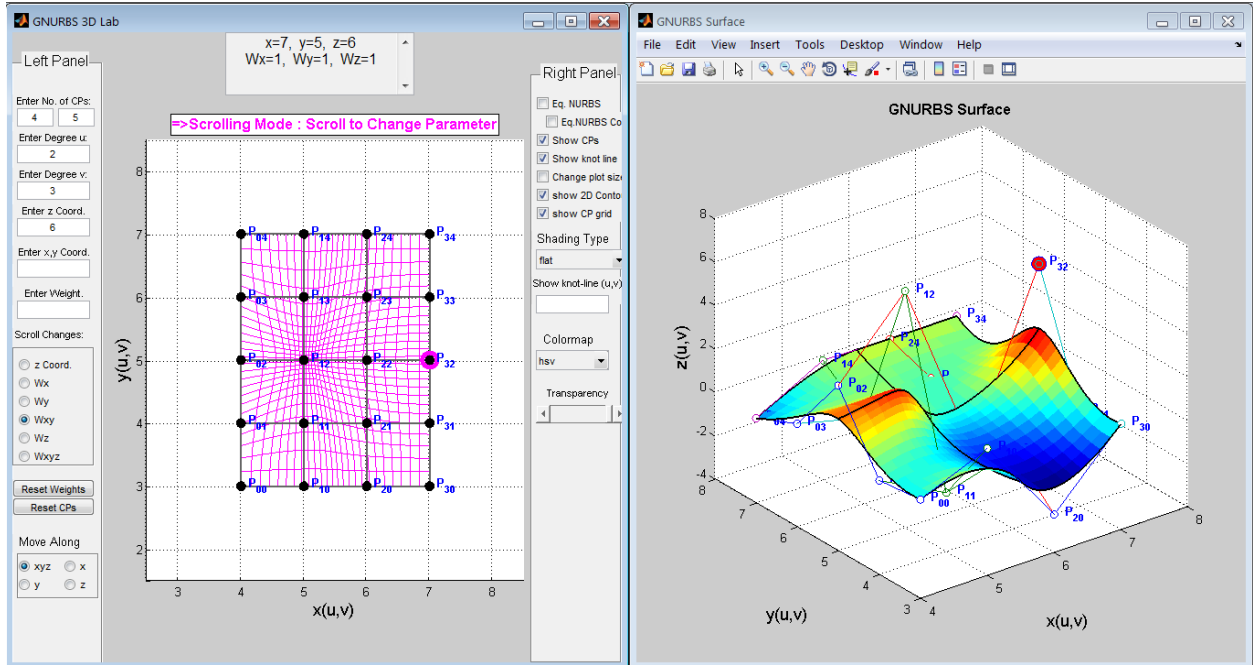


Figure 7: Changing the z coordinate of “P32” to 6.

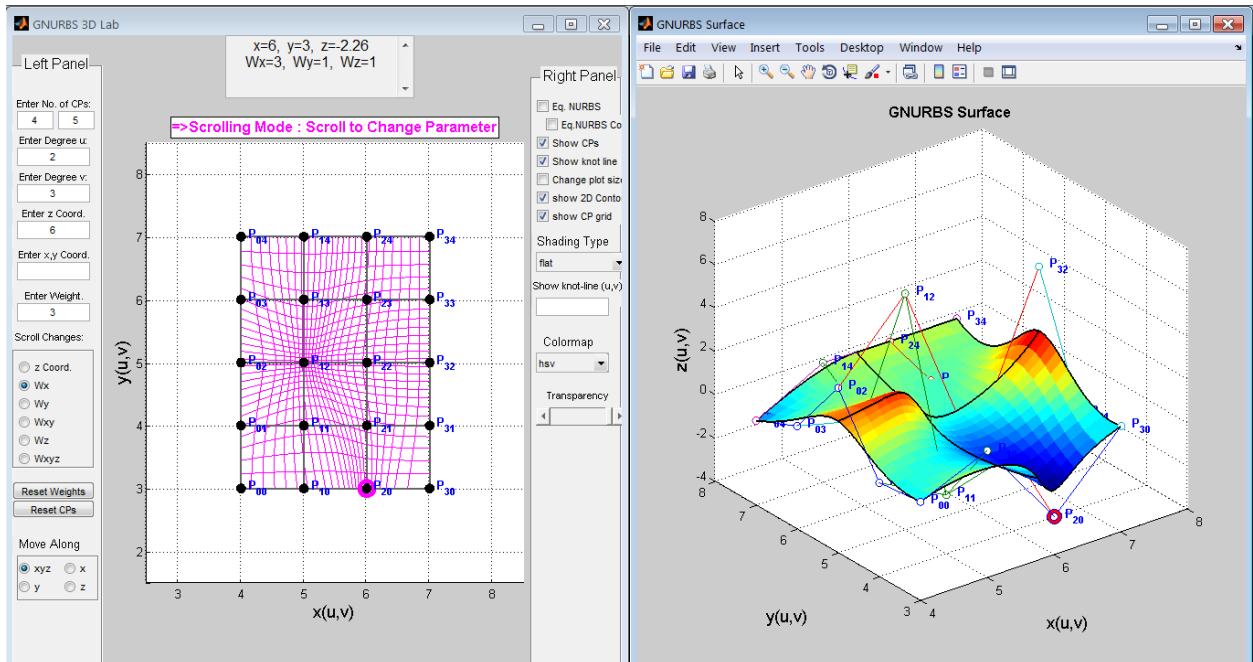
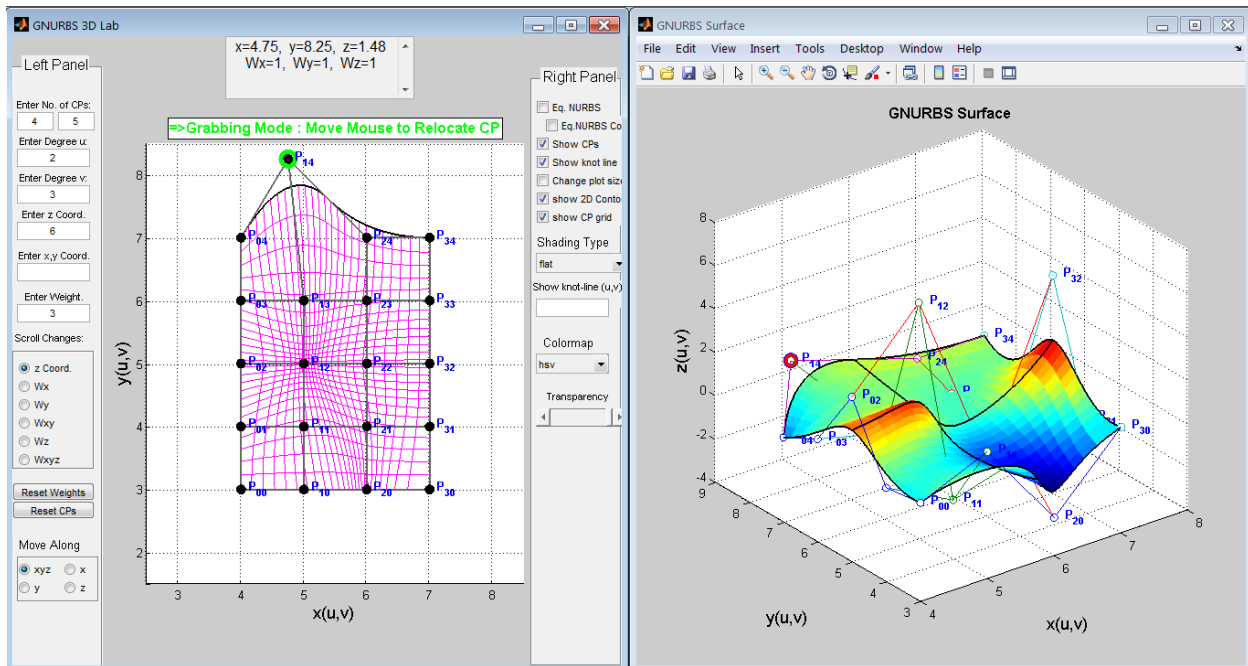


Figure 8: Changing  $W_x$  of “P20” to 3.



## F. Moving a control point in the 2D window

To move and change the position of a CP, first select it by double right clicking on it in the 2D window. When a CP is selected in this way, “Grabbing Mode” is activated and a green boundary appears around the selected CP. Now by moving the mouse, the position of selected CP changes and the GNURBS surface updates interactively to show these changes (Figure 9). Also, the coordinates of selected CP update continuously in the status bar as you move the mouse. To exit from “Grabbing Mode”, left click anywhere in the 2D window. When you do so, the selected CP is released, and the green boundary disappears. Also, the message “::Releasing control point” is shown in the status bar (Figure 10).



**Figure 9:** Changing the position of “P14” by moving the mouse in the “Grabbing Mode”.

You can also change the  $x$  and  $y$  coordinates of any control point from the left panel by right clicking on it in the 2D window and entering the desired values in the “Enter  $x,y$  Coord.” field (6). For example, in Figure (11) the coordinates of  $P20$  are changed from (6,3) to (8,2) by Right-Clicking on it and entering the values “8,2” in field (6).

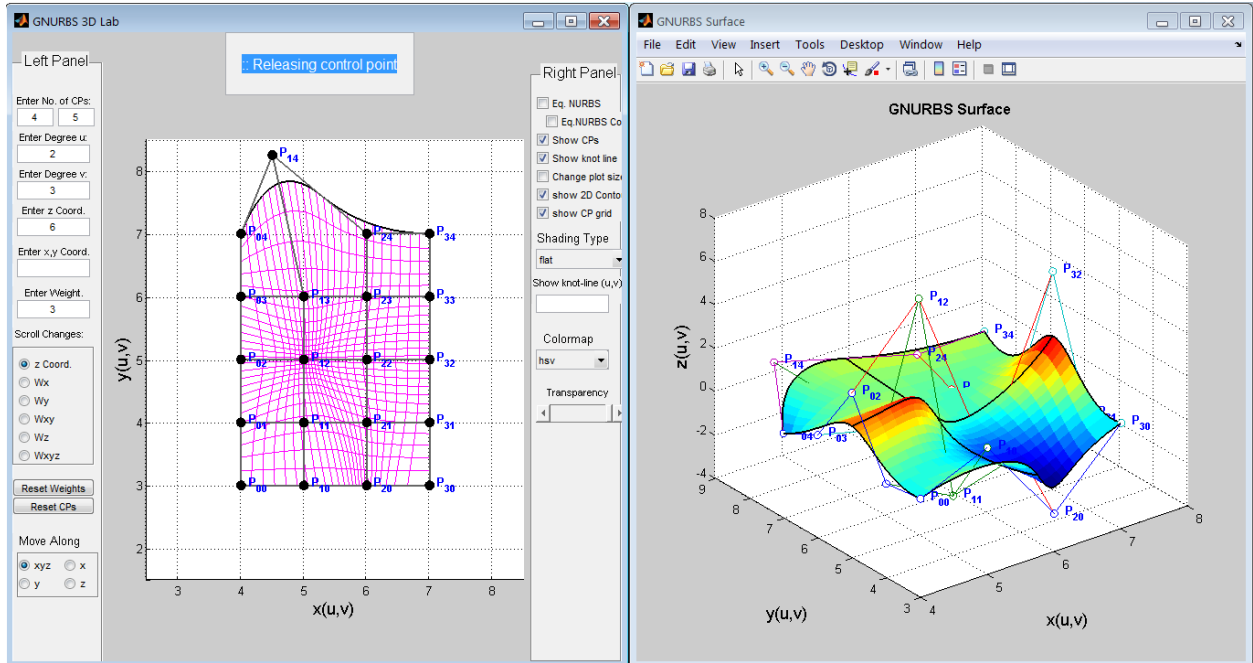


Figure 10: Releasing a selected CP and exiting the “Grabbing Mode” by Left Click.

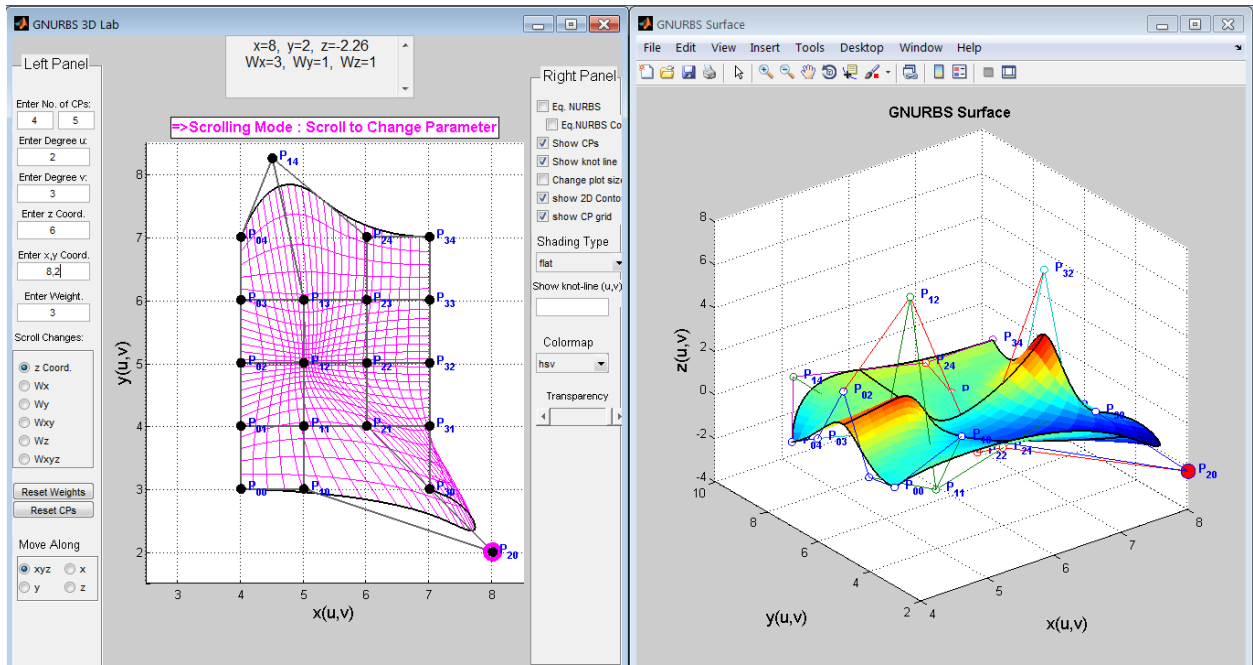
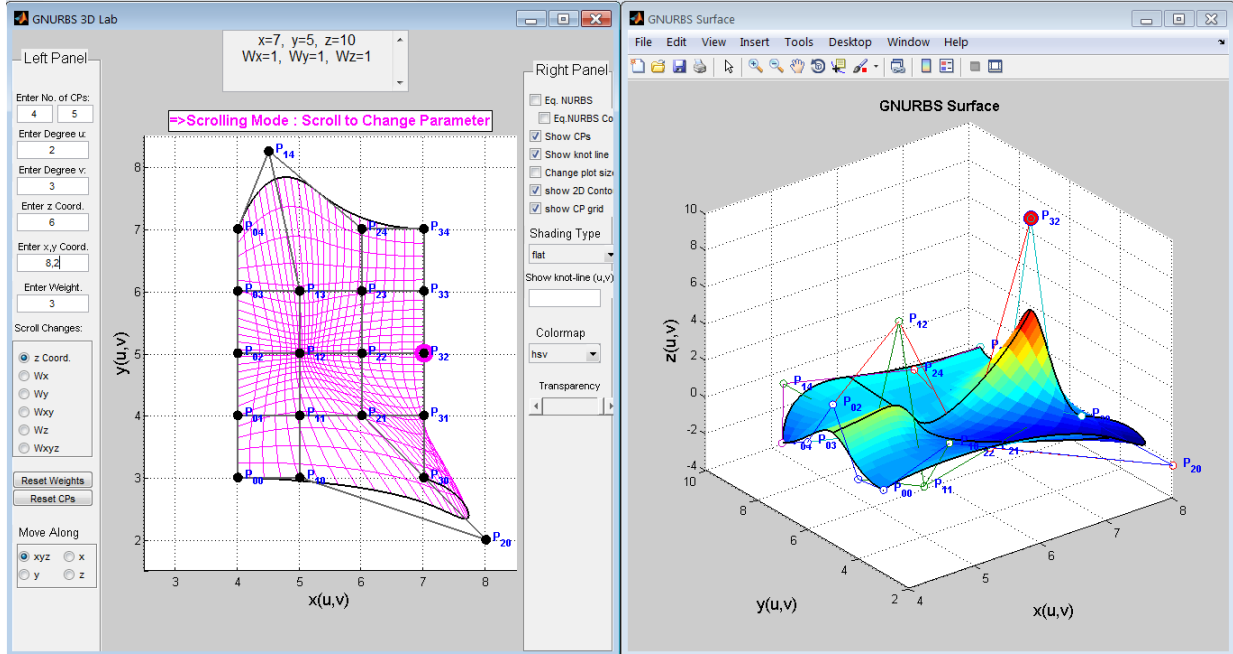


Figure 11: Changing the coordinates of “P20” to (8,2) from the left panel of 2D window.

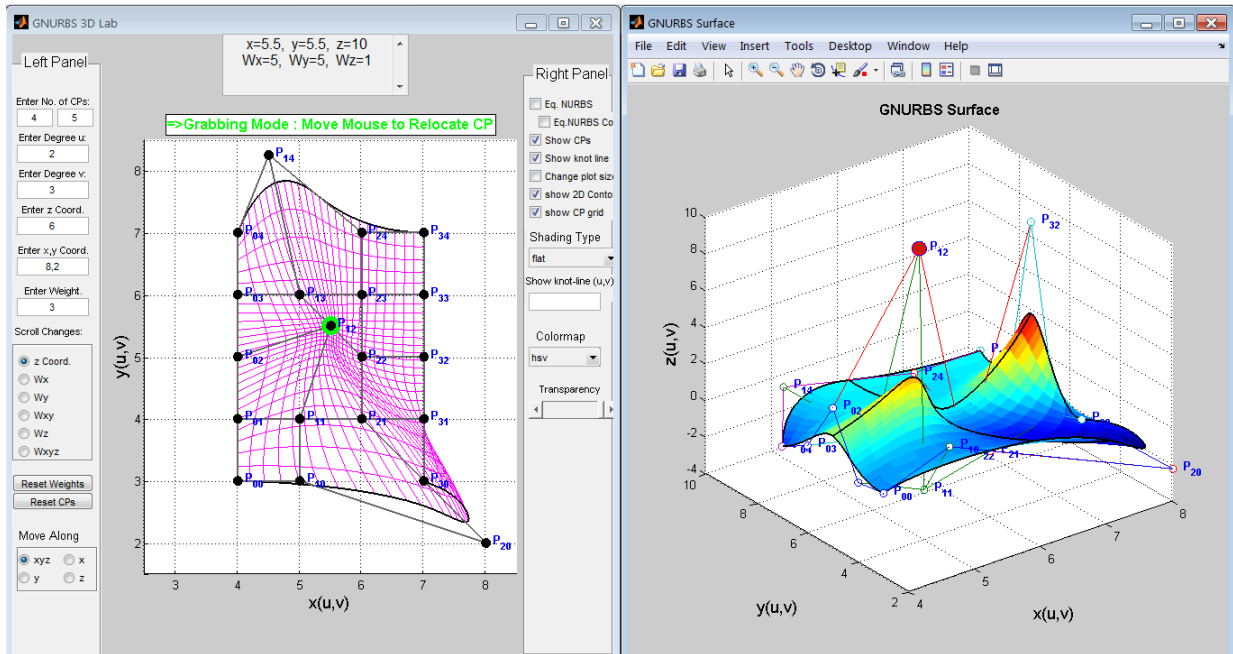
### G. Selecting a control point in the GNURBS surface plot

Control points can also be selected for scrolling or moving in the GNURBS surface plot of the 3D window. As in the 2D window, by right clicking on a CP in the 3D window, the “Scrolling Mode” is activated and by double right clicking on it, the “Grabbing Mode” is activated and the corresponding CP

in the 2D window is highlighted by a magenta or green boundary, according to the type of selection. As an example, in Figure 12 “ $P_{32}$ ” is selected in the 3D window by R-Click and its  $z$  coordinate is increased to 10 by scrolling. Also, in Figure 13, “ $P_{12}$ ” is selected in the 3D window by double R-Click and its position is changed. It is noted that selecting and moving a CP in the 3D window is a little tricky, due to the nature of the 3D plot.

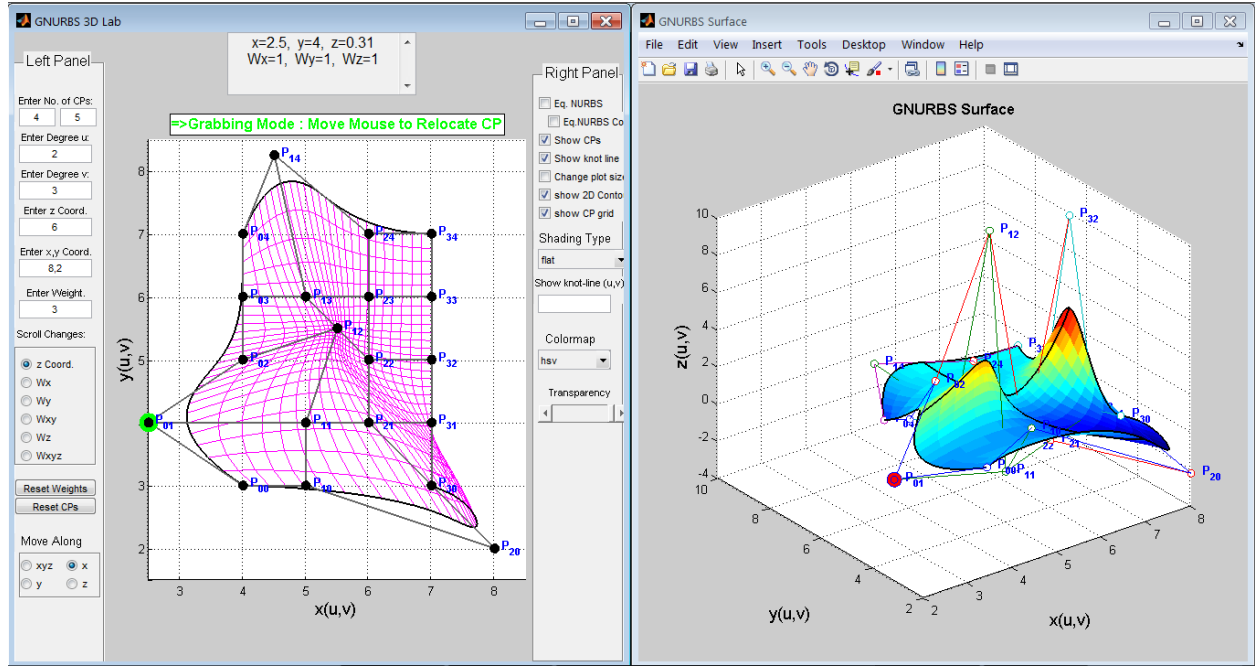


**Figure 12:** Changing the  $z$  coordinate of “ $P_{32}$ ” by selection in the 3D window and scrolling.



**Figure 13:** Changing the position of “ $P_{12}$ ” by selection in 3D window and moving the mouse.

To have more control, when moving a CP in 2D or 3D graphs, you can select the direction in which a selected CP can be moved in the “*Move Along*” menu of the 2D windows (11). For example, in Figure (14) the movement of “*P01*” is constrained to be in the x direction by selecting “x” under the “*Move Along*” menu.



**Figure 14:** Constraining the movement of “*P01*” in the x direction using the “*Move Along*” menu.

## H. Resetting the CPs and weights

You can reset the weights of all CPs in all directions to 1 by clicking on the “*Reset Weights*” button (9) and also reset the position of all CPs by clicking on the “*Reset CPs*” button (10) in the left panel of 2D window. By clicking on these buttons, a message is shown in the status bar for notification and the GNURBS surface updates automatically to show these changes (Figures 15-16).

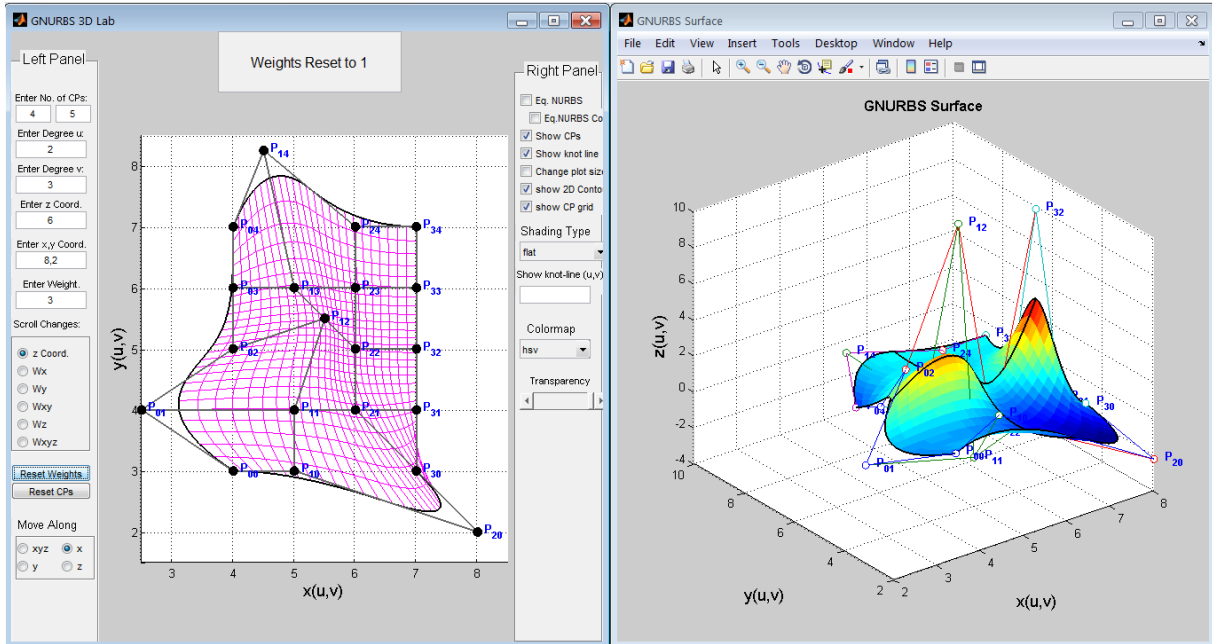


Figure 15: Resetting all weights to 1.

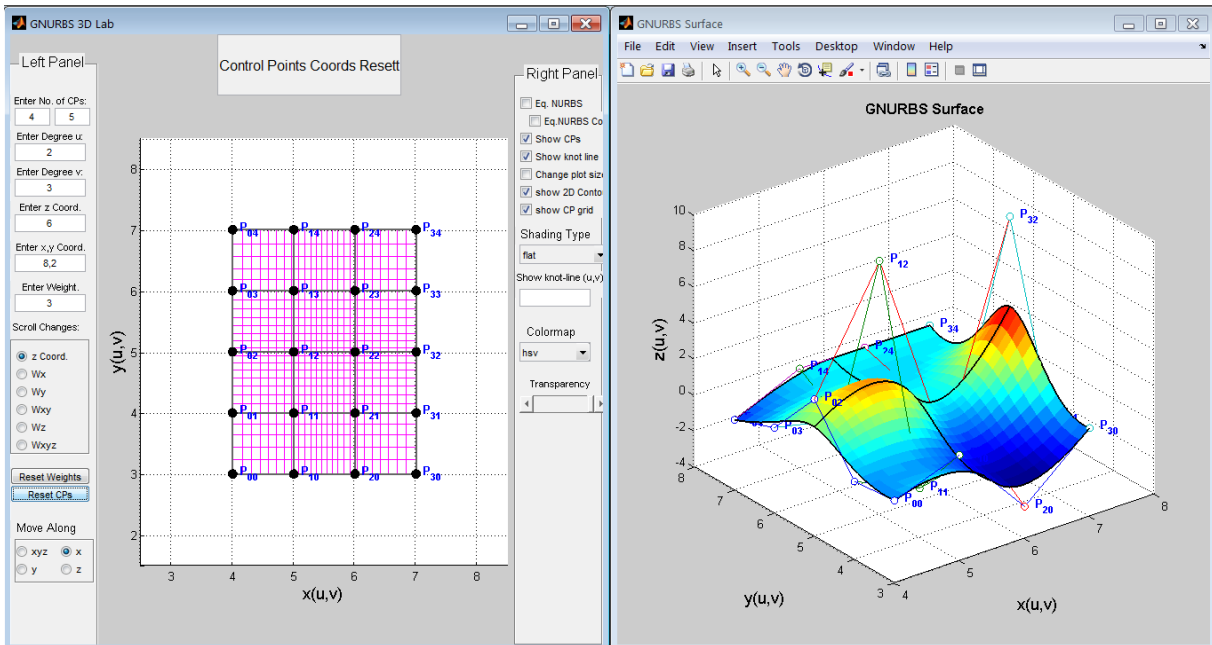
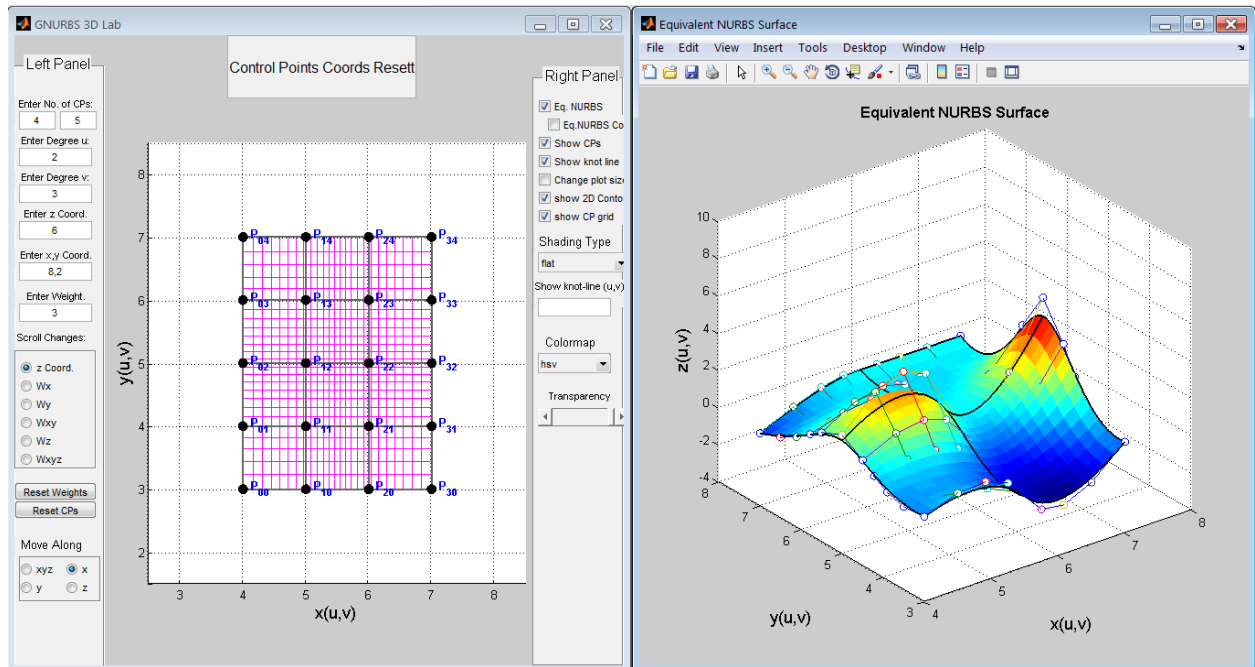


Figure 16: Resetting the coordinates of all CPs.

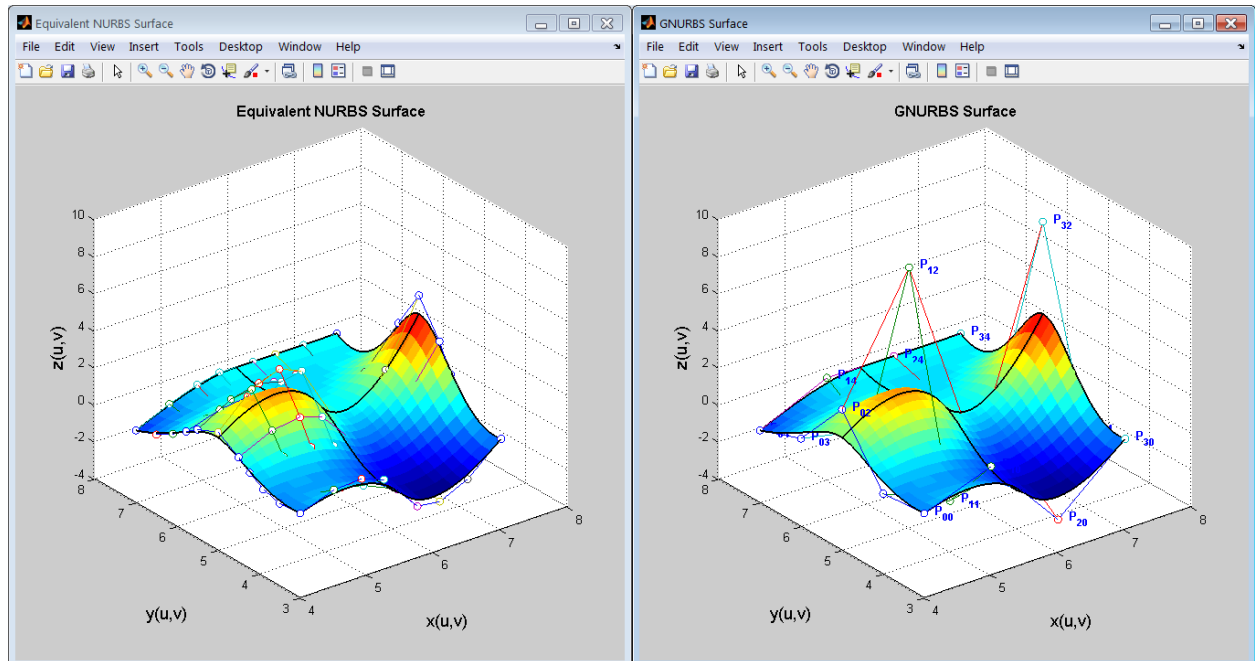
### I. Plotting the equivalent GNURBS surface

In the right panel of 2D window, by checking the “*Eq. NURBS*” box (12), the Equivalent NURBS surface is plotted in the right side of the screen on the GNURBS surface graph (Figure 17). You can resize and move this screen to see both GNURBS and the equivalent NURBS graphs on the screen (Figure 18). The

Equivalent NURBS graph is also interactive, which means that as you do any changes in the 2D or 3D windows, this graph updates automatically. To close this graph, just uncheck the “*Eq. NURBS*” box.



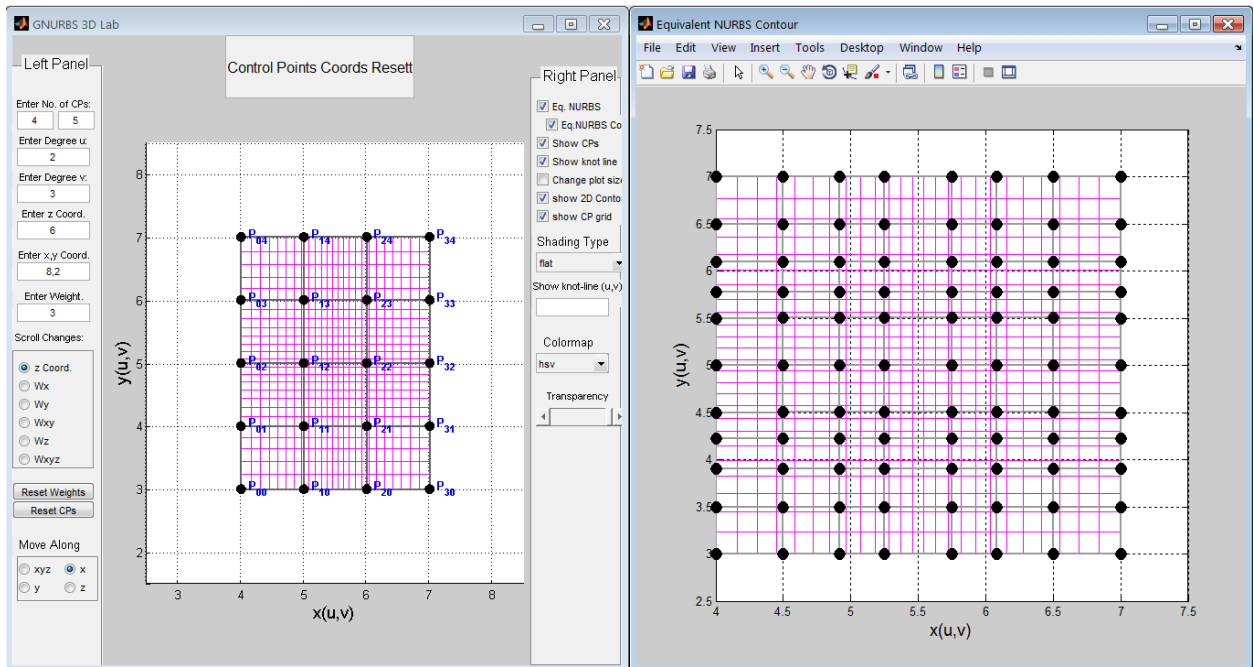
**Figure 17:** The Equivalent NURBS surface is shown on the right by checking the “*Eq. NURBS*” box.



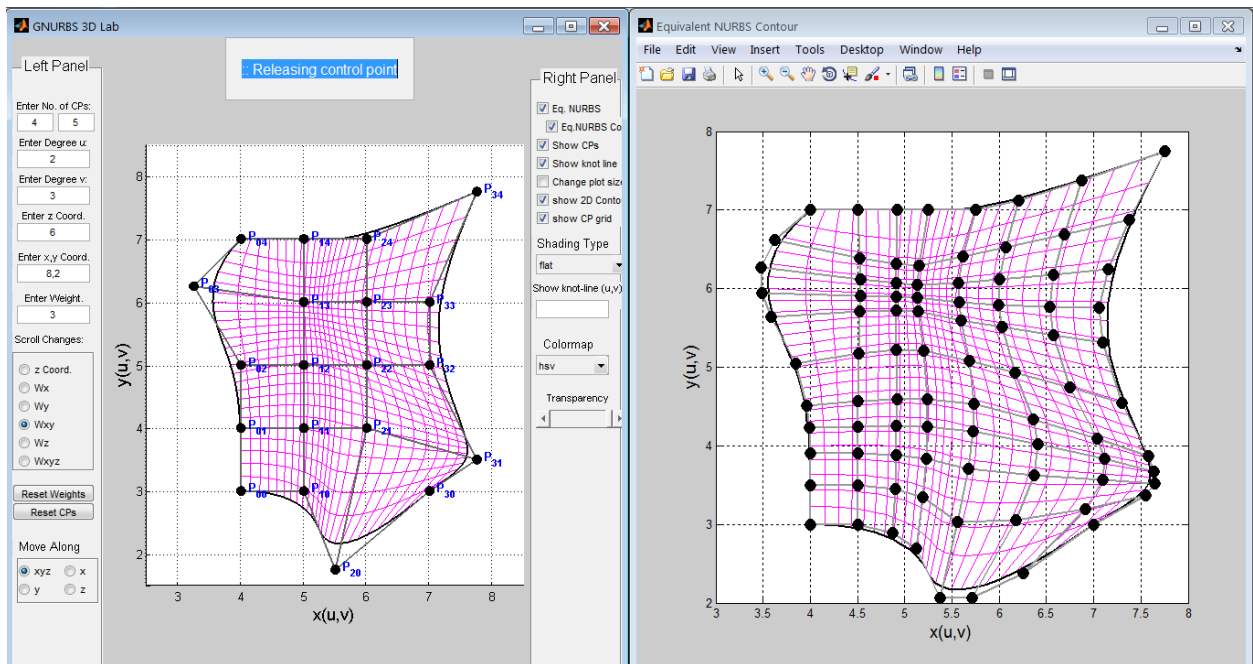
**Figure 18:** Moving the Equivalent NURBS surface plot to the left to see both surfaces on the screen.

As the “*Eq. NURBS*” box is activated, you can also check the “*Eq. NURBS Contour*” box (13) to see the Equivalent NURBS contour in the  $x$ - $y$  plane (Figure 19). When this box is checked, a new graph opens in

the right side of the screen to show the Equivalent NURBS contour. This figure is also interactive and automatically updates as you change weights or CP coordinates in 2D window (Figure 20).



**Figure 19:** The Equivalent NURBS contour is shown on the right by checking the “Eq.NURBS Contour” box.

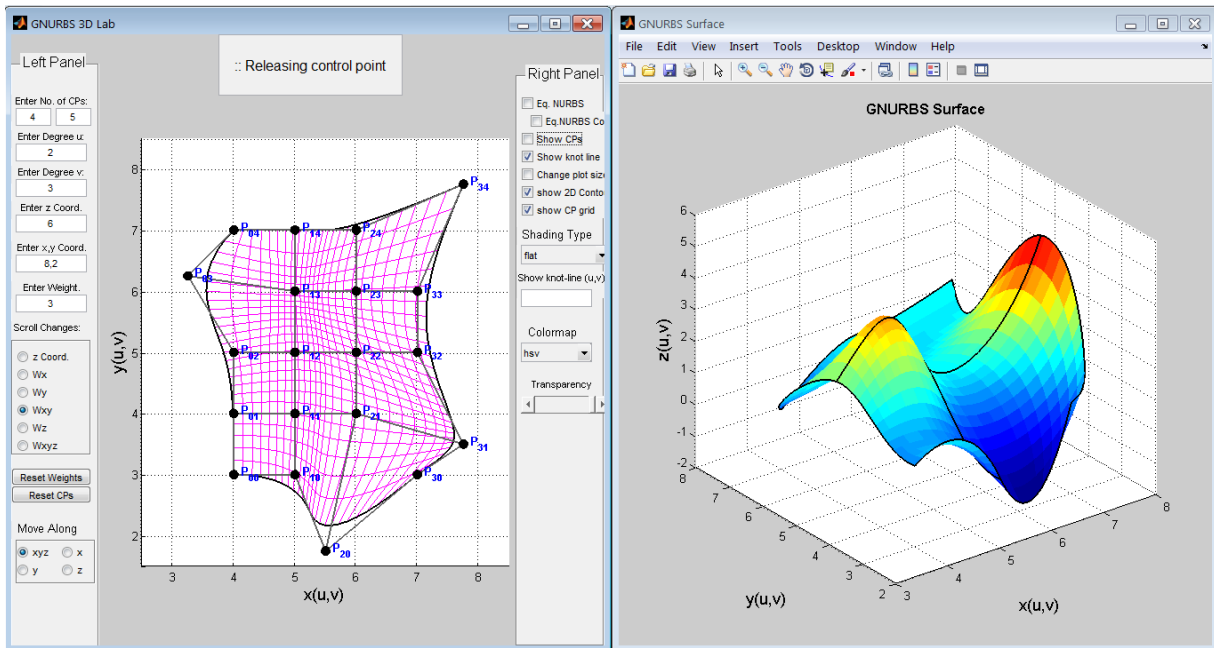


**Figure 20:** The “Equivalent NURBS Contour” graph updates automatically by changing the parameters of a CP in 2D window.

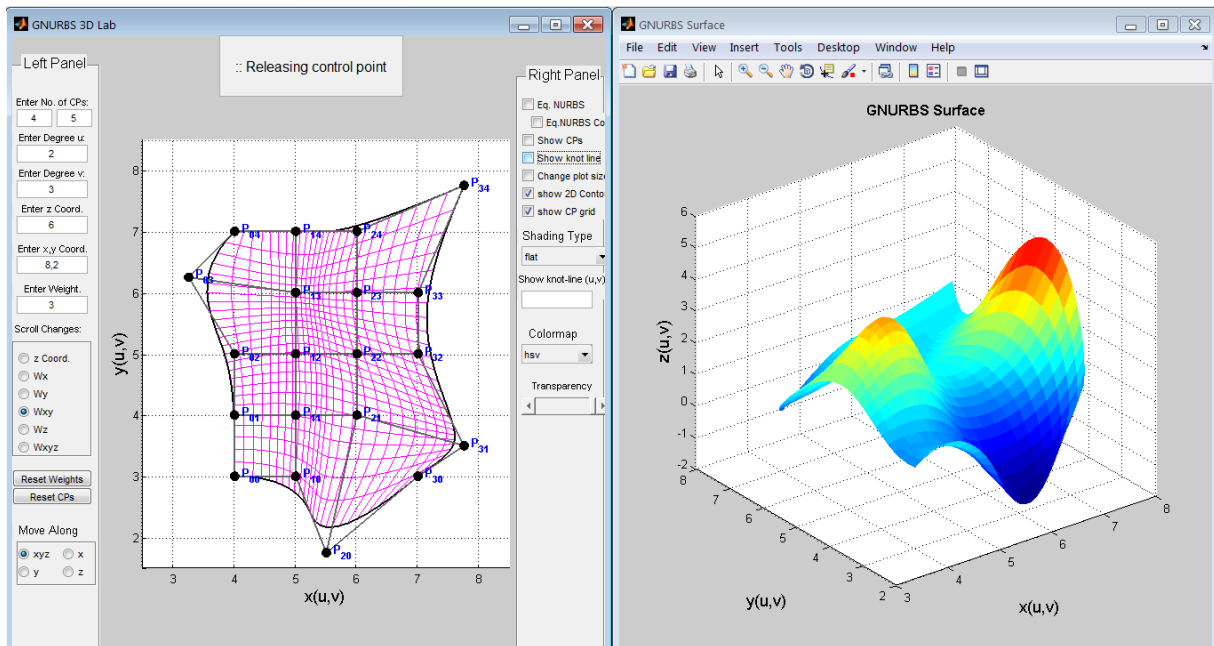


### J. Controlling the display of CPs and knot lines in 3D window

You can control the display of CPs in the 3D window by checking/unchecking the “*Show CPs*” box (14) and also control the display of knot lines by checking/unchecking the “*Show knot line*” box (15) in the right panel of 2D window (Figures 21-22). By default, the display of CPs and knot lines is active when a GNURBS surface is generated.



**Figure 21:** Deactivating the display of CPs in 3D window by unchecking the “*Show CPs*” box.

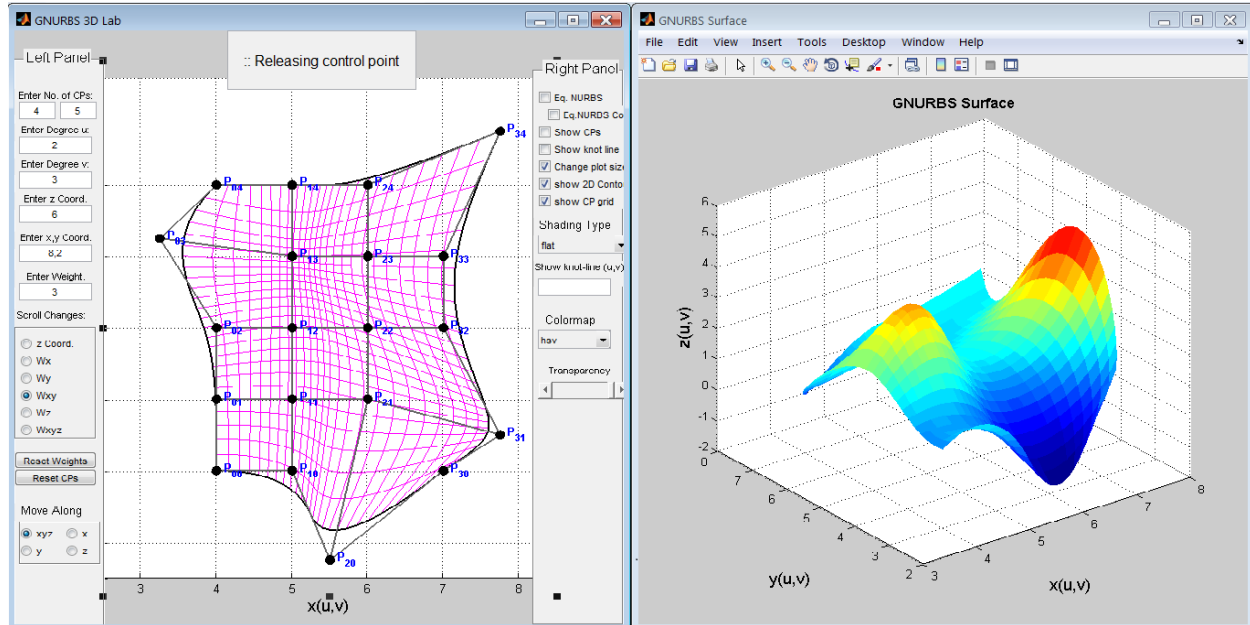


**Figure 22:** Deactivating the display of knot-lines in 3D window by unchecking the “*Show knot lines*” box.



### K. Controlling the display in 2D window

You can move or change the plot size in the 2D window by checking the “*Change plot size*” box (16), which is shown in Figure 23.



**Figure 23:** Moving and resizing the plot area in 2D window by checking the “*Change plot size*” box.

The display of 2D contour and the CP grid is active by default when the 2D window is first initialized. You can control the display of 2D contour by checking/unchecking the “*Show 2D Contour*” box (17) and the display of CP grid by checking/unchecking the “*Show CP grid*” box (18) (Figures 24-25).

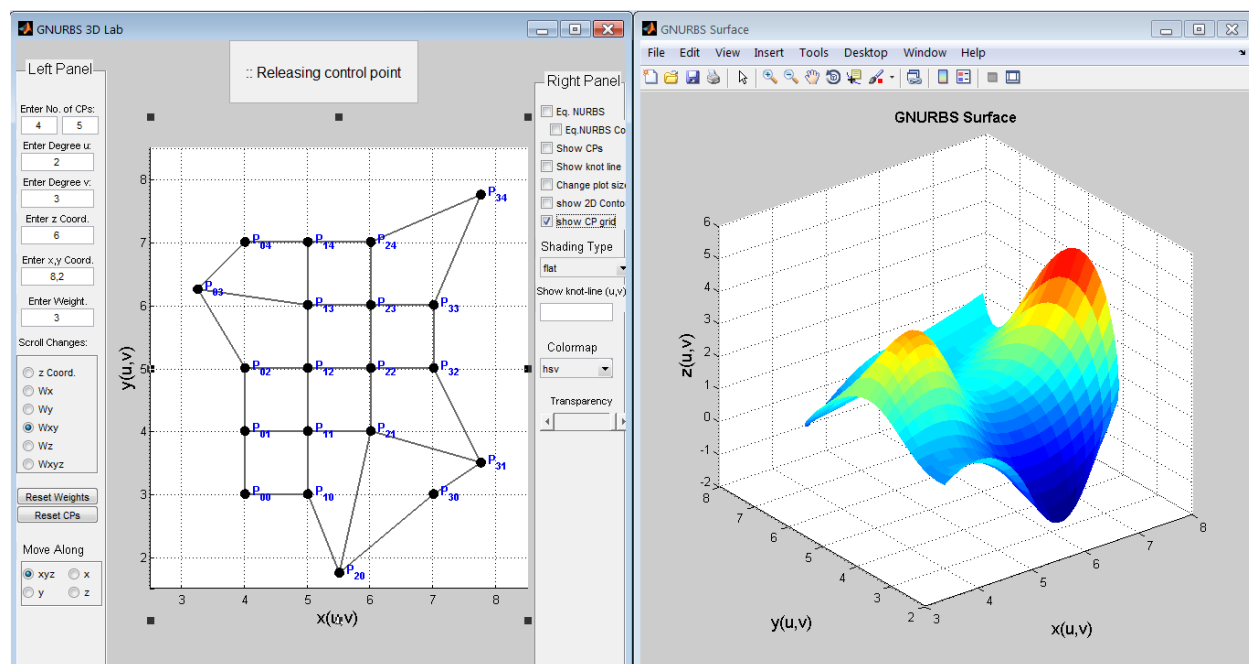


Figure 24: Deactivating the display of 2D contour in the left window.

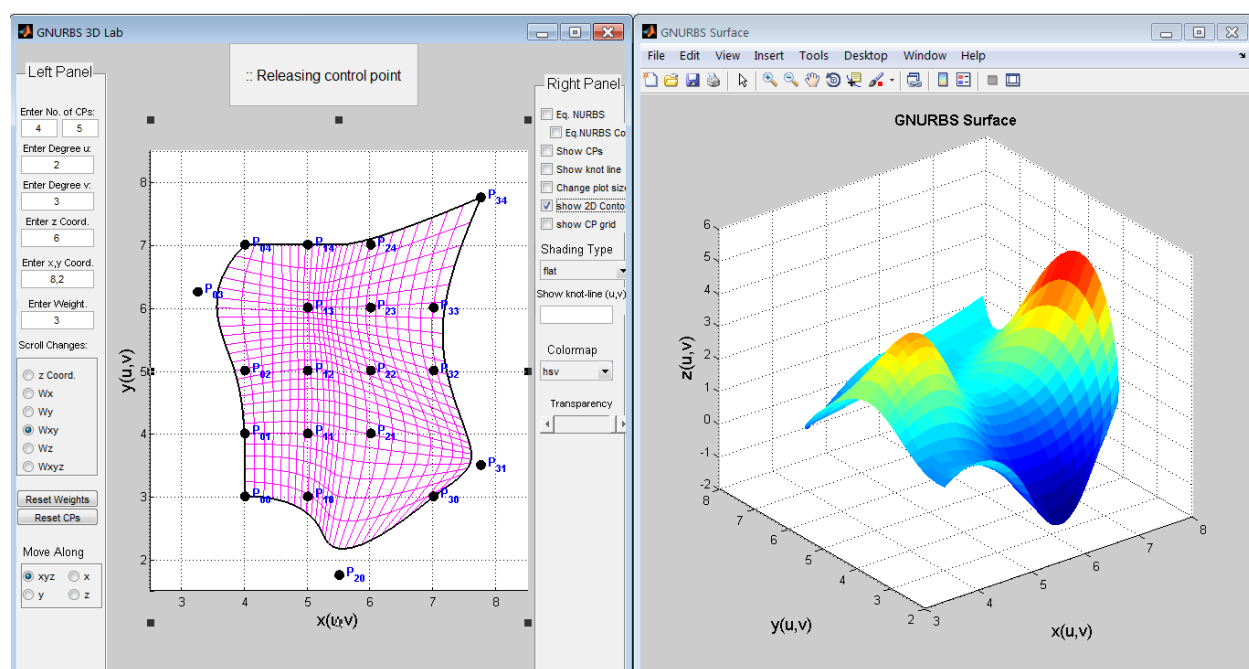
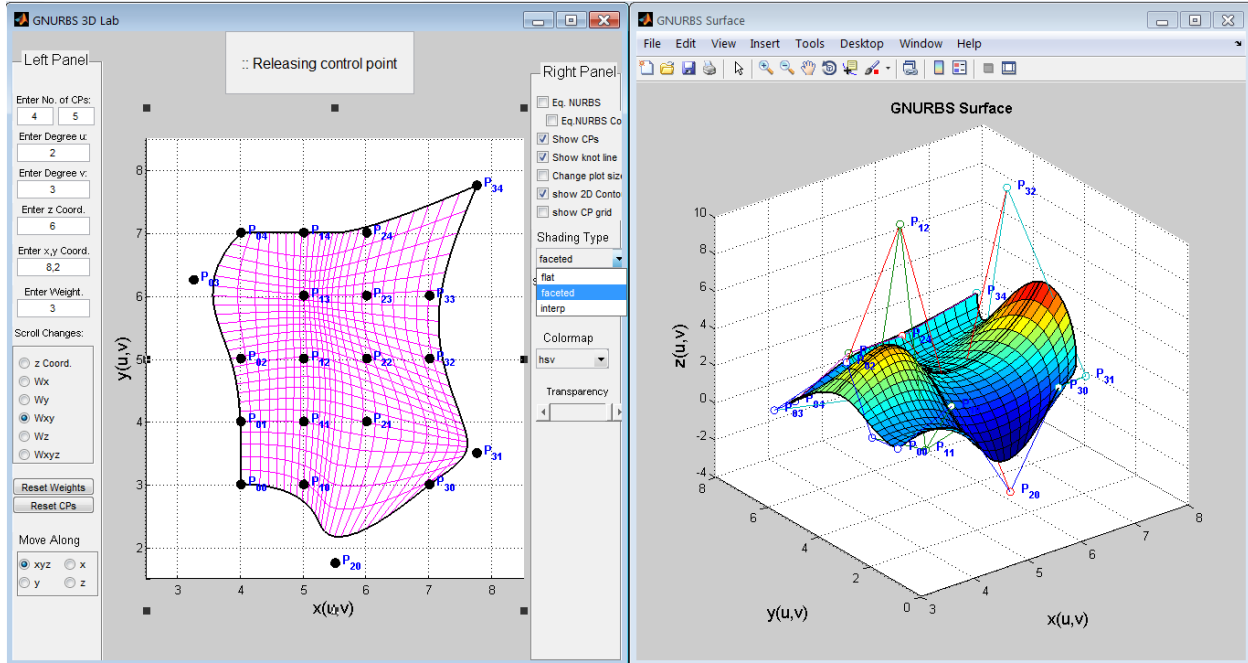


Figure 25: Deactivating the display of CP grid in the left window.

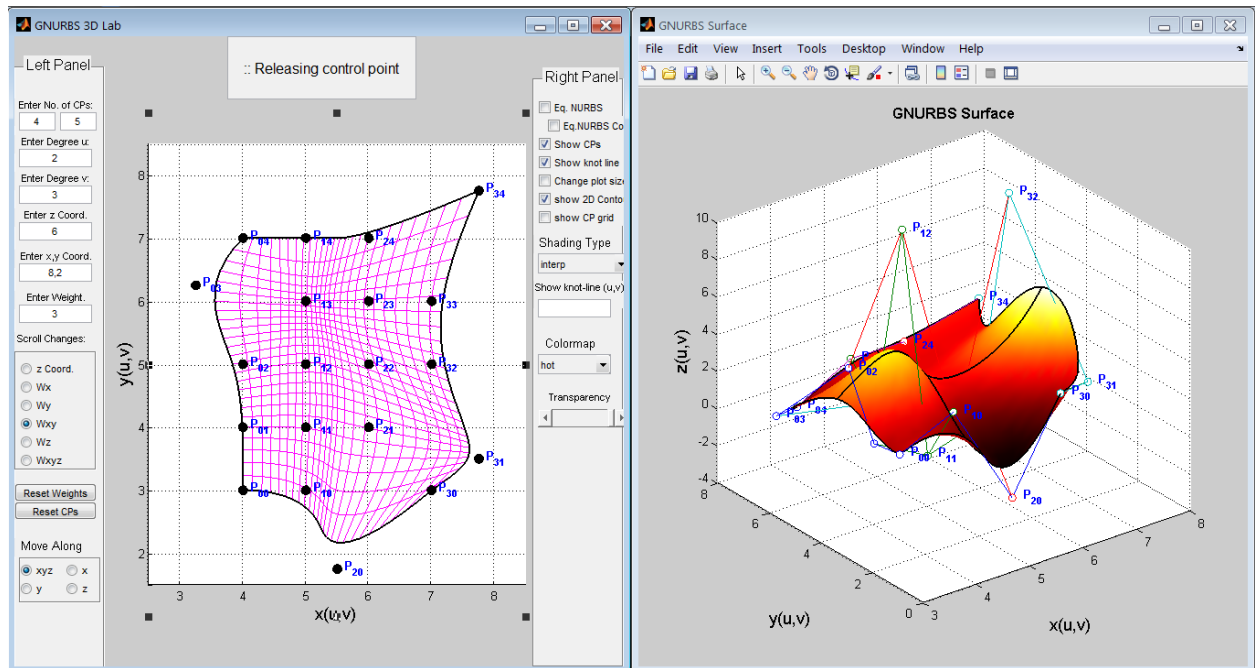
## L. Controlling the display of GNURBS surface

The shading type of the GNURBS surface can be changed by selecting the appropriate type from the “*Shading Type*” dropdown menu (19) in the right panel of the 2D window. There are three different shading types available, namely ‘*flat*’, ‘*faceted*’ and ‘*interp*’ in this menu (Figure 26).

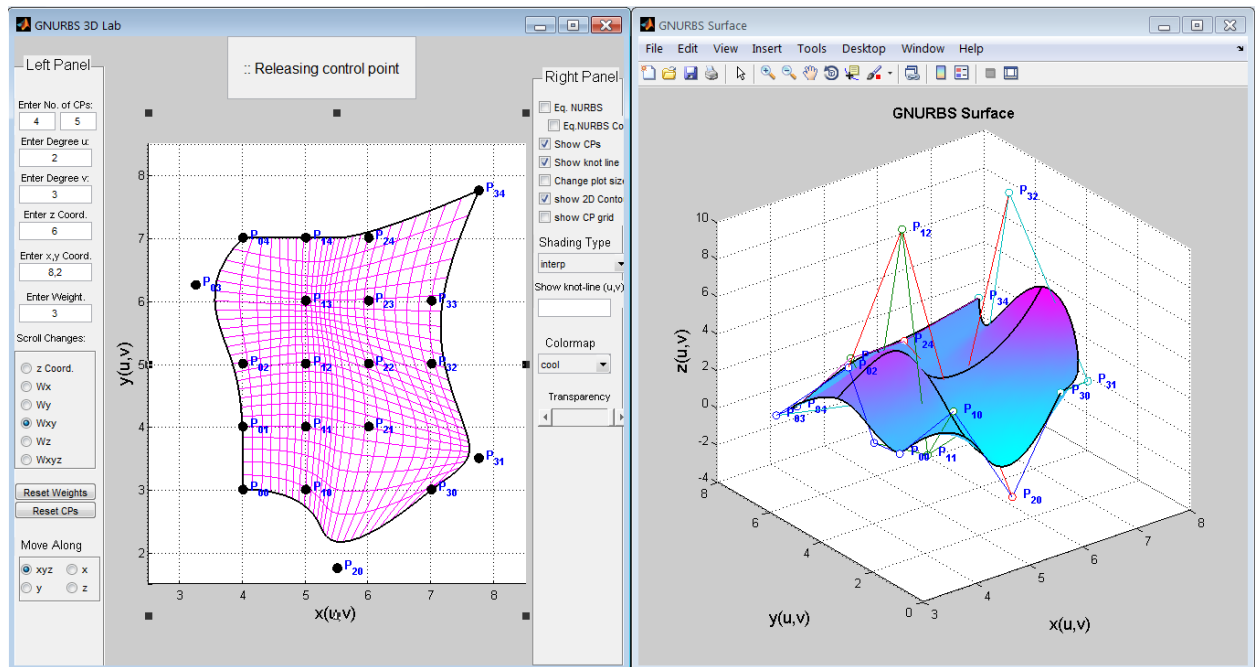


**Figure 26:** Changing the shading type of the GNURBS surface from the “*Shading Type*” dropdown menu.

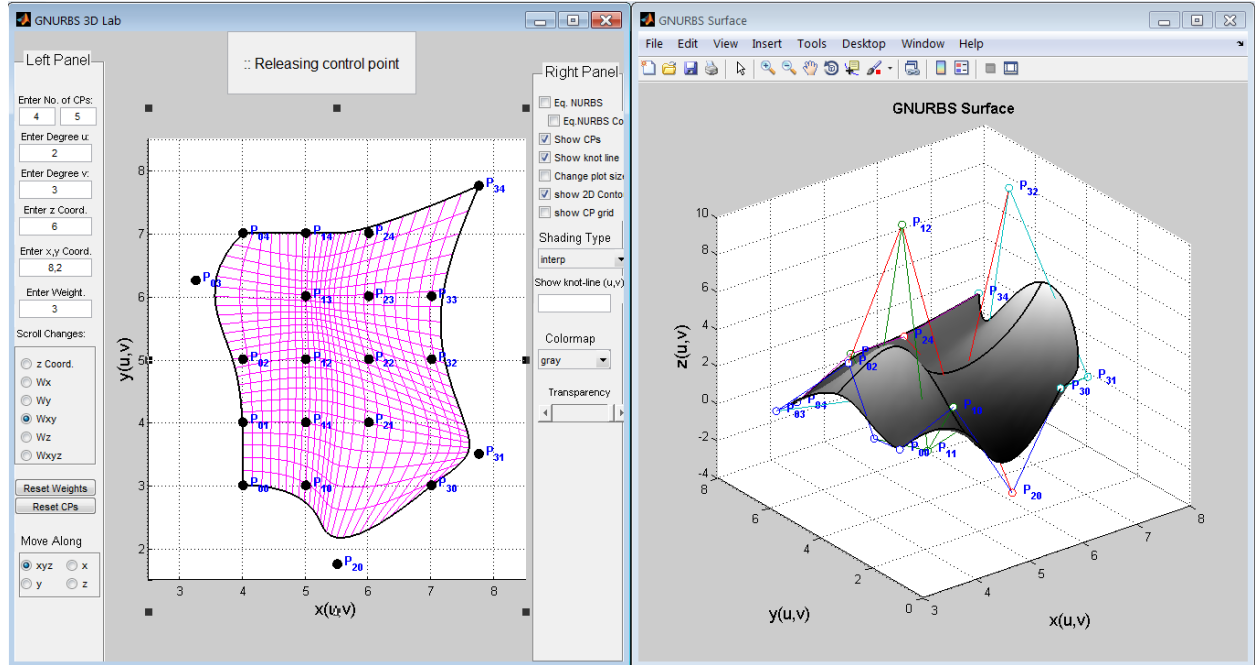
Also, the colormap of the GNURBS surface can be changed by selecting the appropriate type from the “*Colormap*” dropdown menu (21), which is shown in Figures 27.



a) Hot colormap



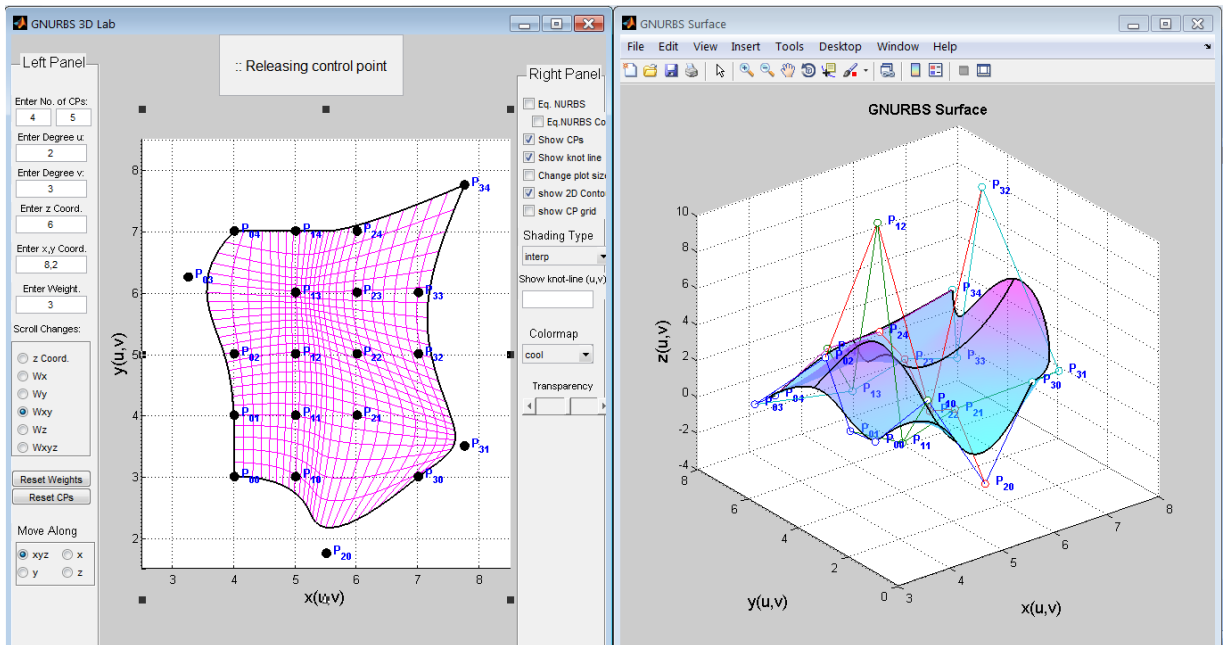
b) Cool colormap



c) Gray colormap

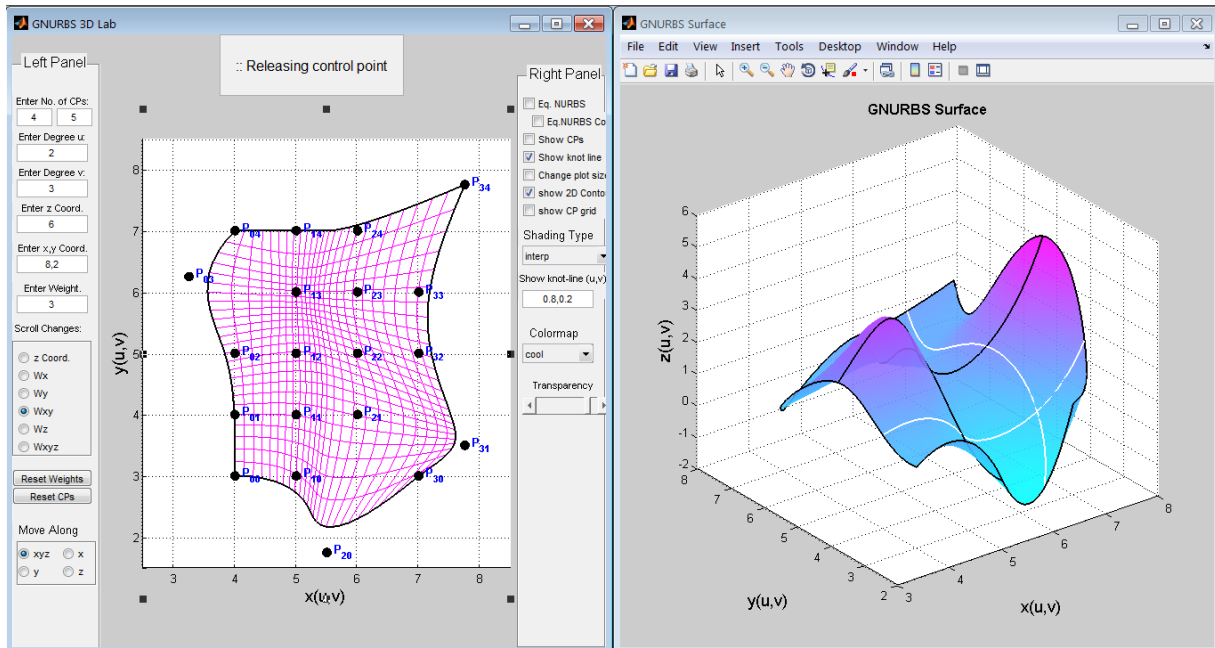
**Figure 27:** Changing the colormap of the GNURBS surface from the “Colormap” dropdown menu.

The transparency of the GNURBS surface can be changed by moving the “Transparency” slide bar (22). This feature is especially useful, because it allows to see the position of CPs which are located behind the surface and cannot be seen without transparency (Figure 28).

**Figure 28:** Changing the transparency of the GNURBS surface by moving the “Transparency” slide bar.

### M. Plotting knot lines on the GNURBS surface

To see the knot lines for a specified knot pair  $(u,v)$  on the GNURBS surface, you can enter the value of  $u$  and  $v$  in the “Show knot-line  $(u,v)$ ” field (20). By pressing the “Enter” button, the corresponding knot lines are shown in white color on the GNURBS surface (Figure 29). It is noted that the values of  $u$  and  $v$  must lie in the 0-1 range.



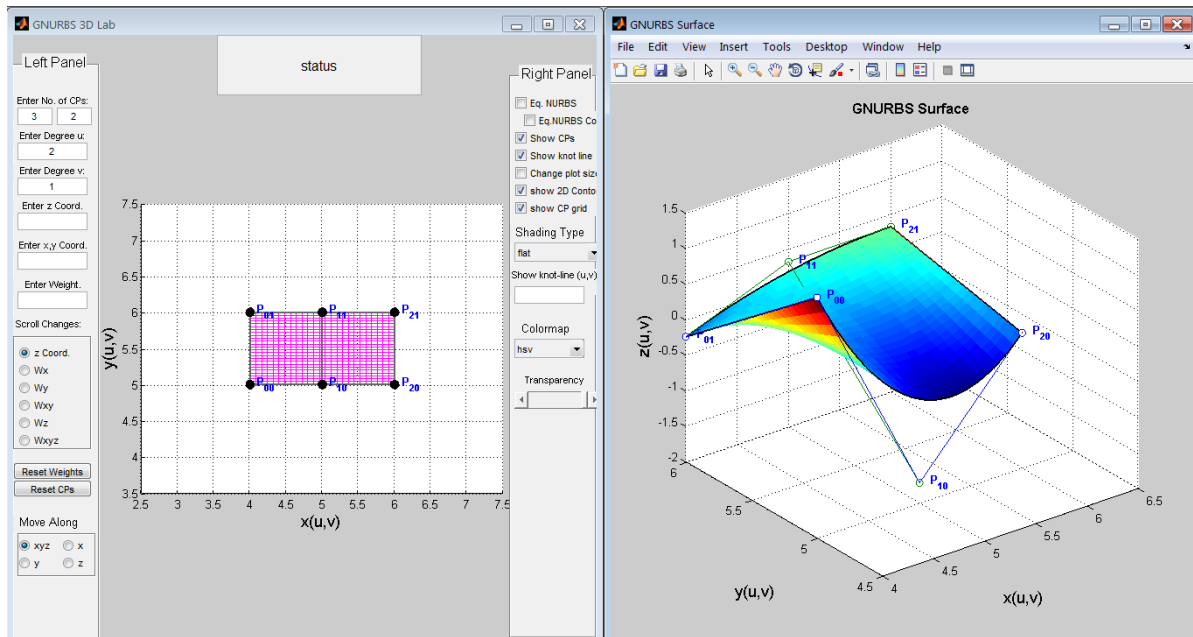
**Figure 29:** Plotting the knot lines for  $u=0.8$  and  $v=0.2$  on the GNURBS surface.

### N. A practical example: Constructing a quarter ring

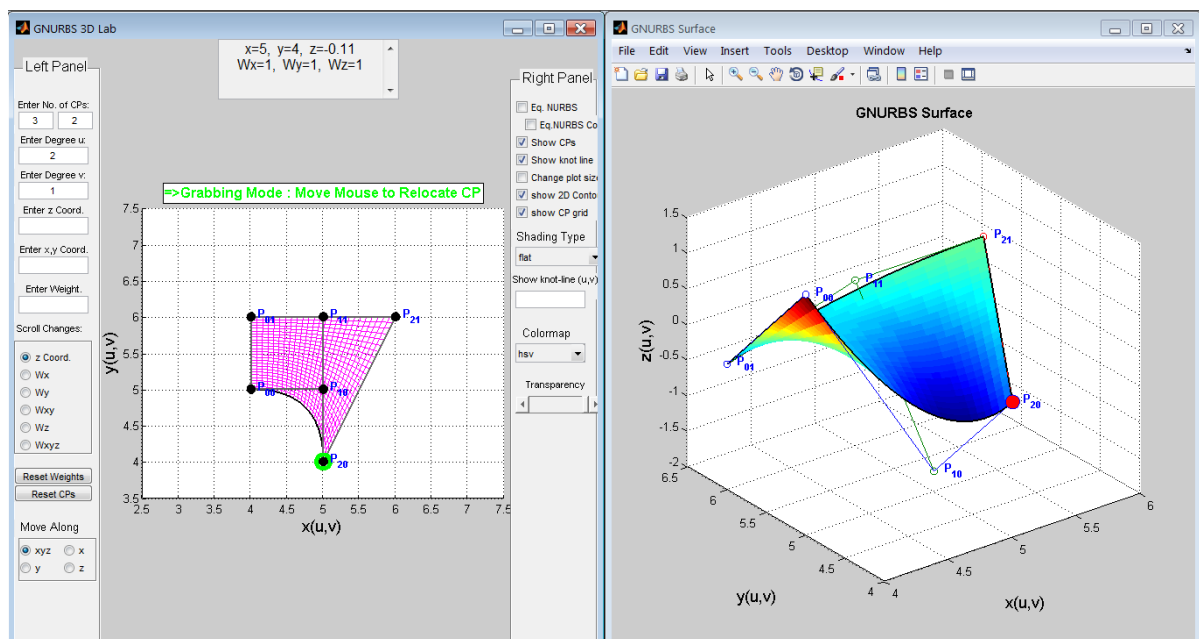
To clearly show the capabilities and flexibility of the “GNURBS3D Lab” in generating and manipulating GNURBS surfaces, the procedure of constructing a quarter ring in the 2D plane and the corresponding GNURBS surface is explained step by step here. These steps are also visually shown in Figure 30.

1. Run the program.
2. Enter **3** and **2** for the number of control points in  $x$  and  $y$  directions, respectively.
3. Enter **2** for degree  $u$  and **1** for degree  $v$ .
4. Move “P20” to the down of “P10” by 1 unit.
5. Move “P21” to the right of “P20” by 1 unit.
6. Move “P11” to the right of “P01” by 2 units.
7. Select “P10” in the 2D window by R-click, then select “Wxy” from the “Scroll Changes” menu of the left window and type the value “0.707” in the “Enter Weight”, then press enter.
8. Repeat step 7 for “P11”.

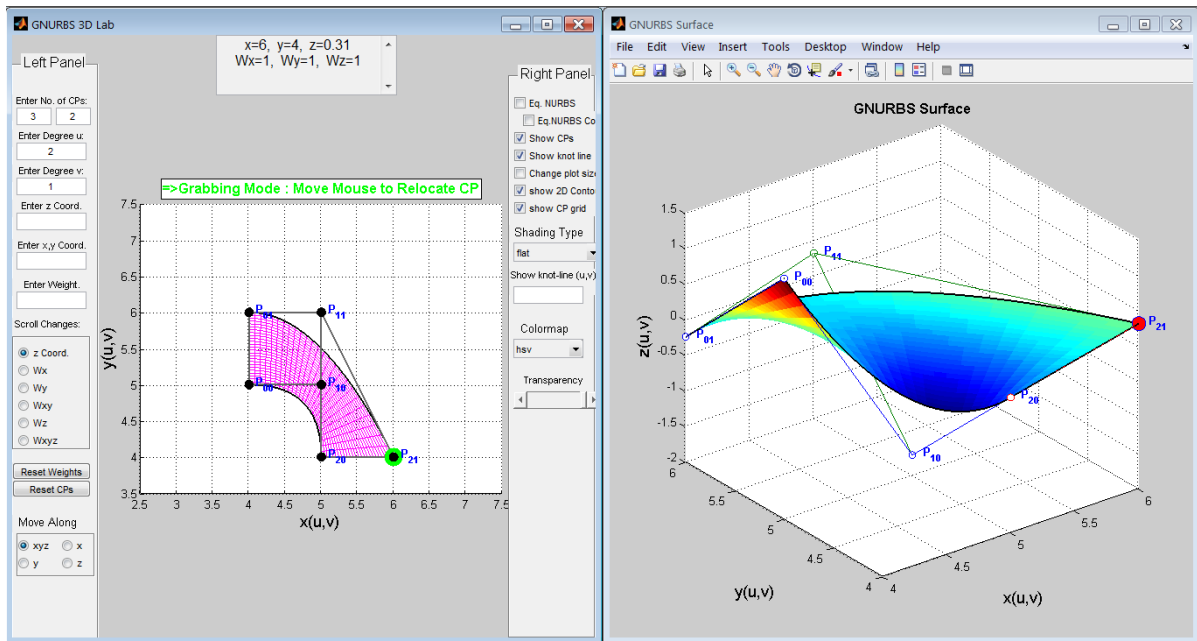
By completing these steps, the quarter ring contour in the 2D window and the corresponding GNURBS surface are constructed.



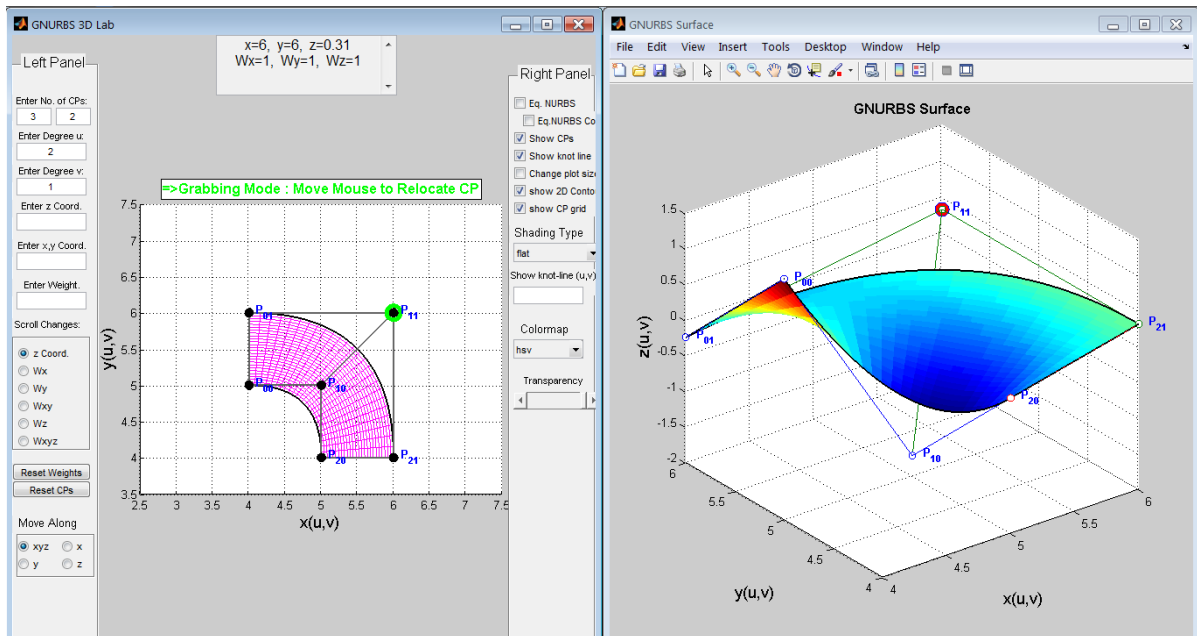
a) Steps 2 and 3: Entering the input parameters



b) Step 4: Moving “P20”

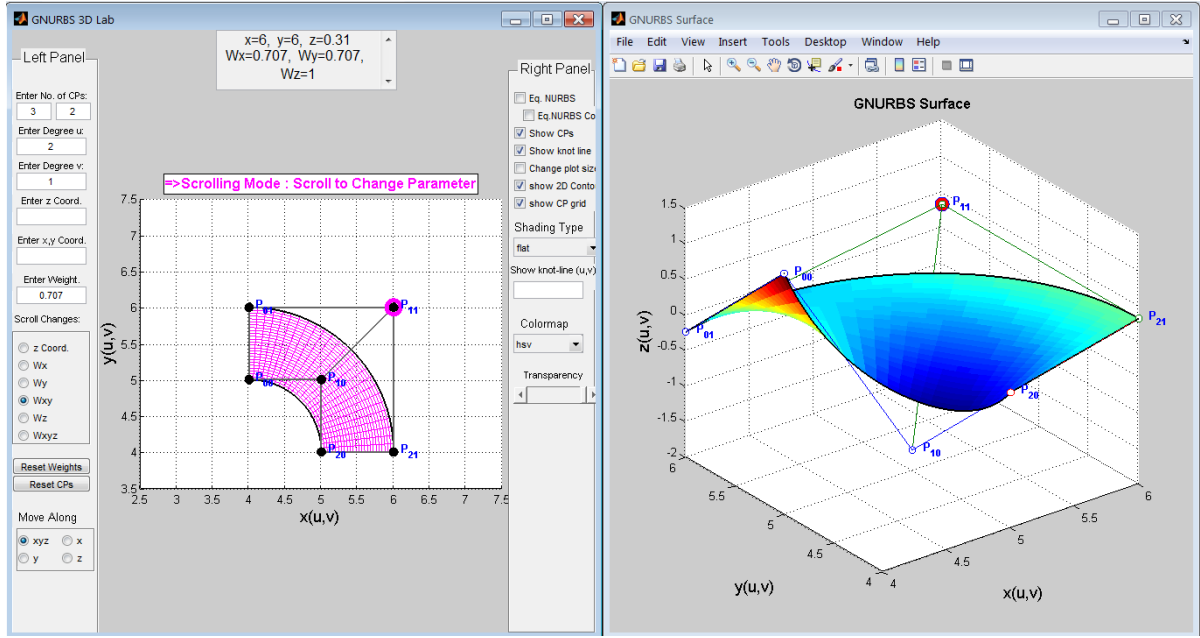


c) Step 5: Moving “P21”



d) Step 6: Moving “P11”

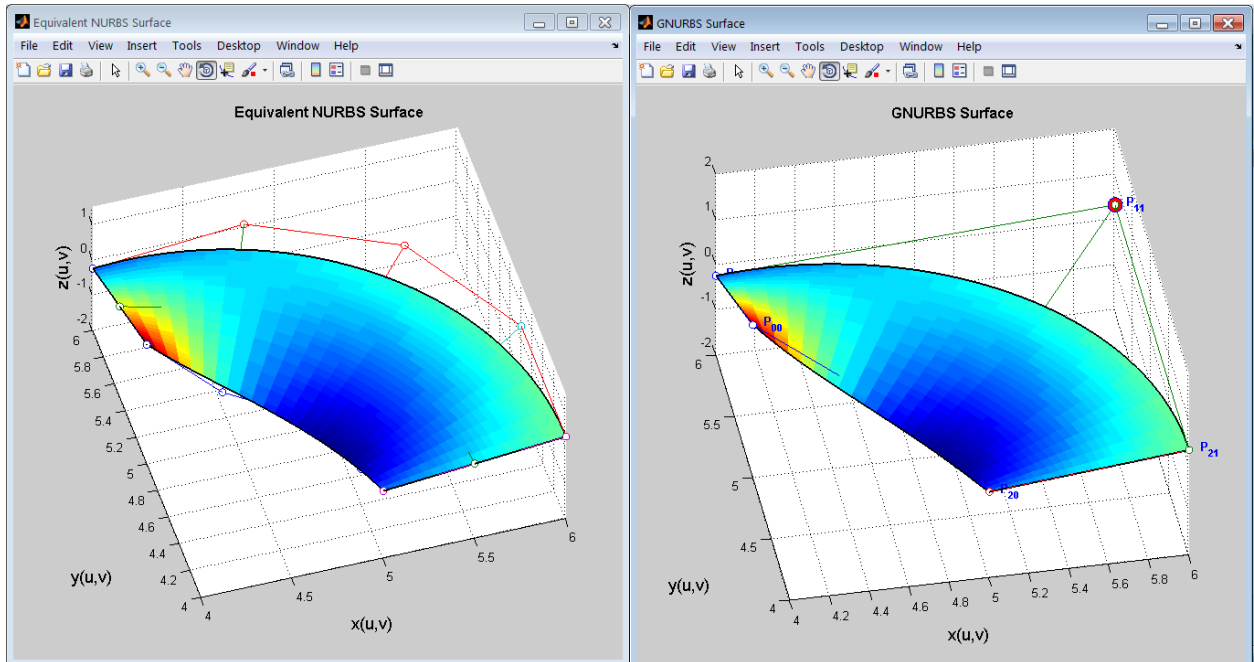




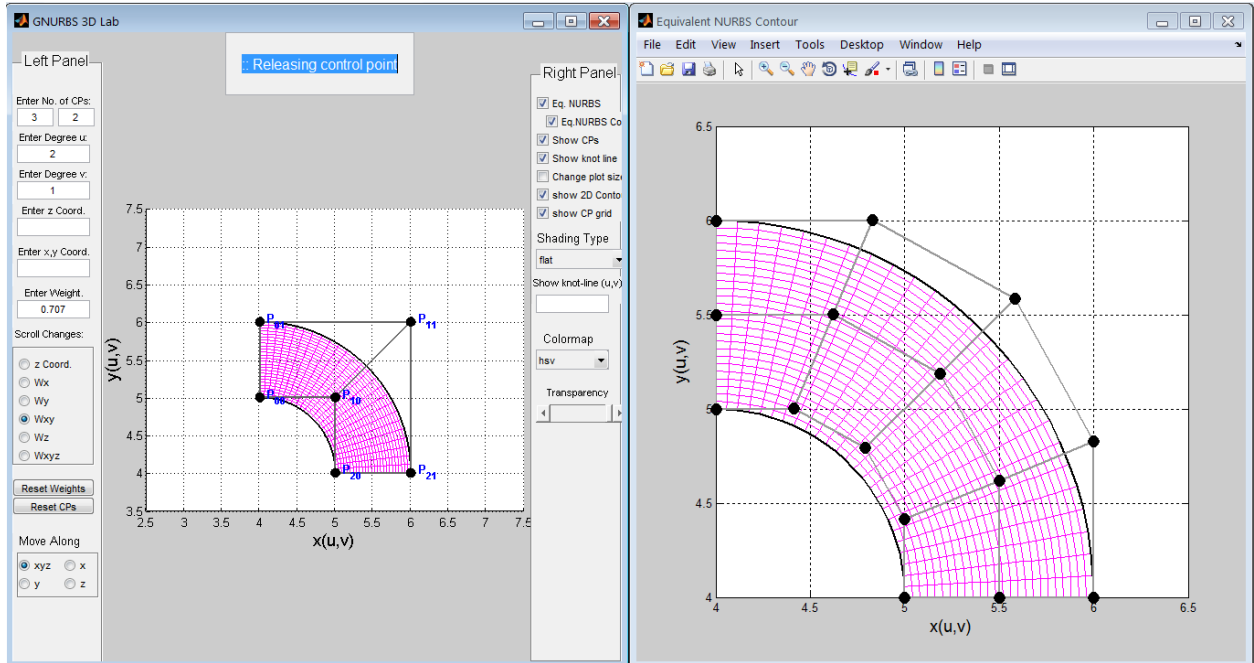
e) Steps 7 and 8: Changing  $W_{xy}$  of “P10” and “P11” to 0.707

**Figure 30:** Steps for constructing a quarter ring and the corresponding GNURBS surface.

After constructing the quarter ring, you can see the equivalent GNURBS surface and its contour by checking the “Eq. NURBS” and then “Eq. NURBS Contour” boxes in the left panel of the right window (Figures 31-32).

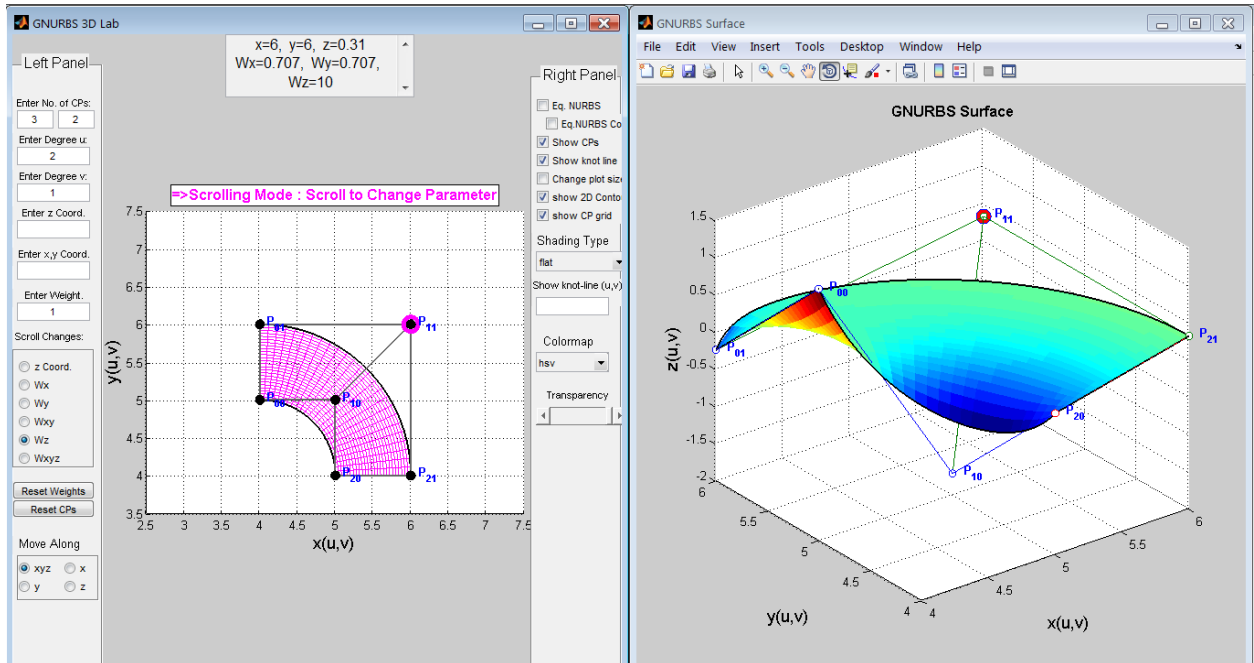


**Figure 31:** Equivalent NURBS surface for the quarter ring domain.



**Figure 32:** Equivalent NURBS contour for the quarter ring domain.

The main advantage of the GNURBS surface is that one can change the weight of any control point in the  $z$  direction without altering the domain shape in the  $x$ - $y$  plane. For example, in Figure 33, the weight of “ $P_{11}$ ” in  $z$  direction is changed to 10 and in Figure 34 the weight of “ $P_{11}$ ” in  $z$  direction is changed to 5, but the in-plane shape of the domain has not changed in the  $x$ - $y$  plane.



**Figure 33:** Changing the  $W_z$  of “ $P_{11}$ ” to 10.

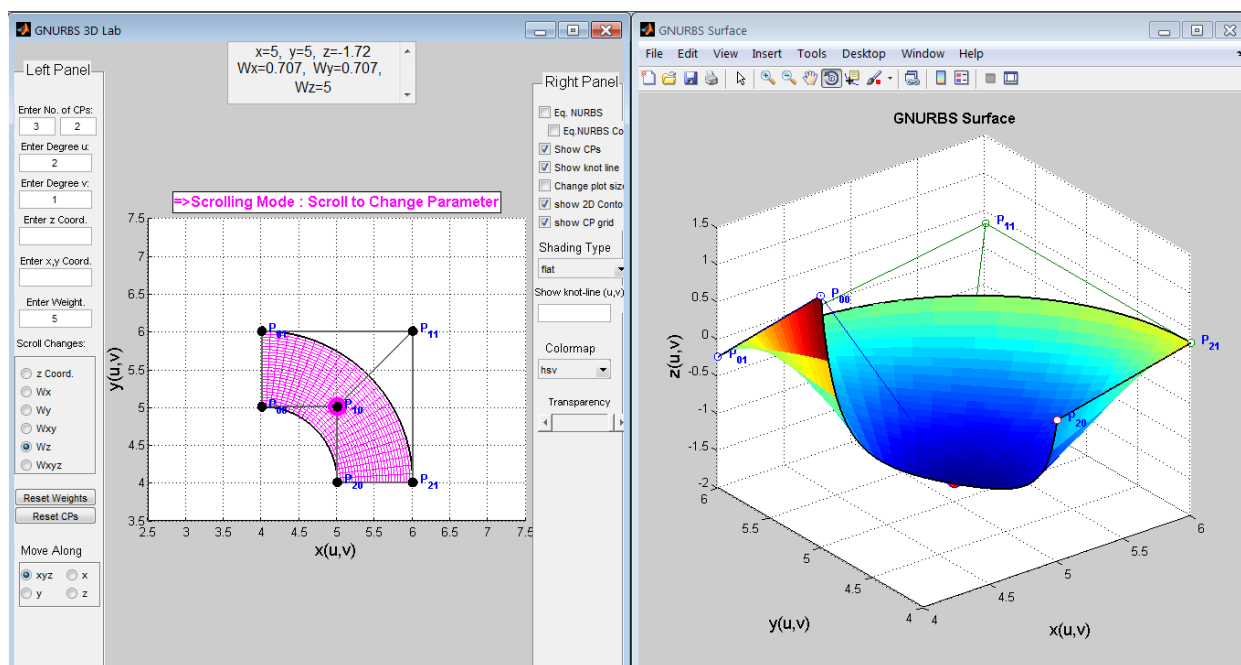


Figure 34: Changing the  $Wz$  of “ $P_{10}$ ” to 5.