

Study 5

Guess the Image

Or

The Matrix Game

The Study will explain you how to get a matrix with numbers from an image (graphic file) and what you can do with this matrix. A new interesting computer game and methods of processing graphic information on a computer are discussed.

Mathematics: matrix, columns, rows, matrix transposition, determinant, inverse matrix, integer, ellipsoid, quadratic equation with three unknowns, Bernoulli lemniscate, Bernoulli "volumetric" lemniscate, triangle, triangle area, cosine theorem, quadratic equation, Pythagorean theorem, similar triangles.

Physics: color.

IT: searching for information on the Internet, storing color and black and white images in a computer, converting an image into a matrix and into an embedded data array, a cycle with a parameter, a nested loop with a parameter, computer animation, image file formats, image manipulation functions.

Art: Alberto Korda "Che Gevara", Andy Warhol "Liz"

Study website: <https://community.ptc.com/t5/PTC-Mathcad/Chapter-5/m-p/606052>

There is a television game called "Guess the Melody". The first notes of a piece of music are played, but the winner is the one who names the work first.

Such a game can be transferred from audio to video — to the visual plane — and called "Guess the image" or, to be more precise, "Guess a person or something else from his incomplete image." The person's portrait in this game needs to be shown on the screen not all at once, but as

a melody — by separate consecutive notes, sorry, separate random dots (raster elements) gradually filling the screen. The more points that are shown, the more likely it is the image will be identified. Below is a description of a program for Mathcad 15 that creates this "portrait melody".

A portrait of a man displayed on a computer monitor¹ is, as a rule, a lot of multicolored points or dots. Such an image is a *matrix* in mathematical terms, each element of which stores an integer from 0 to 256 if we talk about an image with only shades of gray. A color image is comprised of three matrices that store the intensity values of three colors (RGB: Red, Green, Blue).

Recently, information technology has been rapidly developing in the direction of the *recognition of images*. Here are two typical examples of the practical use of this:

A surveillance camera takes a picture of a car that has exceeded the speed on the road or committed another violation, and the computer processes this picture, determines the state registration number of the car and issues a fine to the offender.

At passport control at the border, a digital camera captures the face and / or the iris of the eye of the monitored person, and the computer compares this data with those that are "sewn" into the chip of the presented passport.

Not far away is the time when we will be able to approach the ATM and say: "Give out a hundred rubles!". And this device will fulfil our request, recognizing us in appearance and /or voice.

The game "Guess the image" described in this Study not only helps us entertain friends at a party with an interesting contest, but also reveals some secrets of modern technologies of storage and

¹ Or on the TV screen. But at the present time (the era of digital television), these two devices (computer and television) are increasingly in one "box".

recognition of graphic objects.

In Figure 5.1, you can see "playing" one of the most recognizable graphic objects — the portrait of Che Guevara¹, looking at us from numerous wall graffiti, posters and T-shirts.

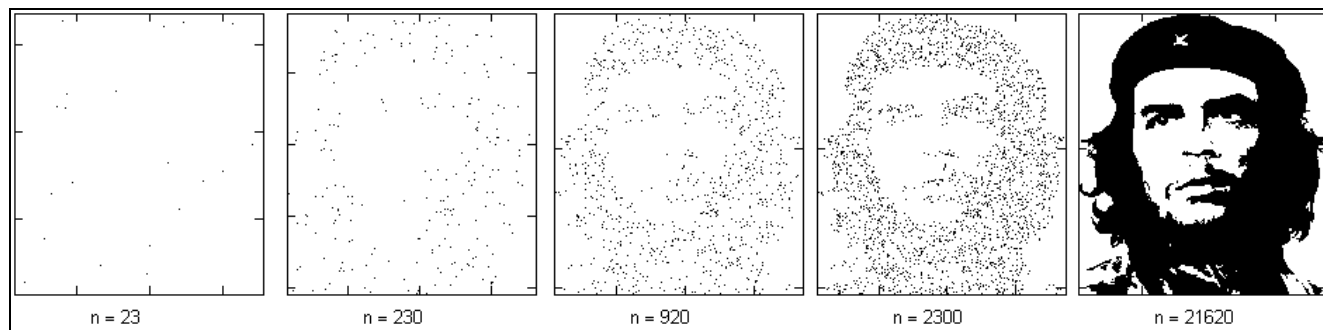


Fig. 5.1. Point drawing of the portrait of Che Guevara

The portrait of Che Guevara, shown in the right image of Figure 5.1, consists of 21,620 black dots on a white background². In Figure 5.1 it is drawn with different number of points (n): for $n = 230$ our hero is not yet recognized, and at $n = 920$ you can already raise your hand and shout: "I recognize it!".

A computer portrait is drawn like this on the Internet. The image of Che Guevara³ is saved to disk in black and white format of the bmp file — see Figure 5.2.

¹ Che Guevara — a very controversial figure. Some consider him a hero, a fighter for freedom. Others are called almost a terrorist. In a word, everyone draws him in black and white colors. We will also do this, but in a literal, not figurative sense — we will draw his portrait only with black and white dots.

² There is such a direction in the art of pointillism — the manner of writing separate smears of the correct point (round) or rectangular shape.

³ In the same place on the Internet you can find portraits and other recognizable people (architectural silhouettes, industrial objects, etc.) for our game "Guess the image."

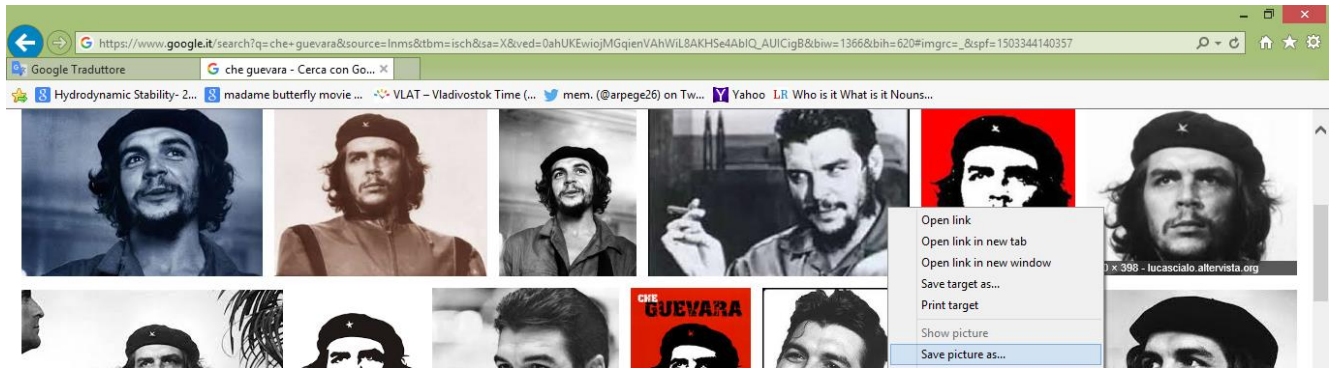


Fig. 5.2. Search for a portrait on the Internet and save it to disk

Figure 5.2 shows a search using the Google portrait of Che Guevara on the Internet. It is saved to disk using the menu command that appears when you right-click. Portraits can not only be fished out from the Internet, but also done by yourself — take pictures of friends and relatives on a digital camera, and save files on a disc for further processing.

In Mathcad 15 there is a command of the insertion menu in the calculation of the figure (Figure 5.3), with which you can draw the selected image in the Mathcad-sheet by specifying the file name. You can just paste the picture from the clipboard into the worksheet with **Ctrl + v**, but in this case the drawing will not be tied to the selected Mathcad variable. In Figure 5.3, it has the name **Che**.

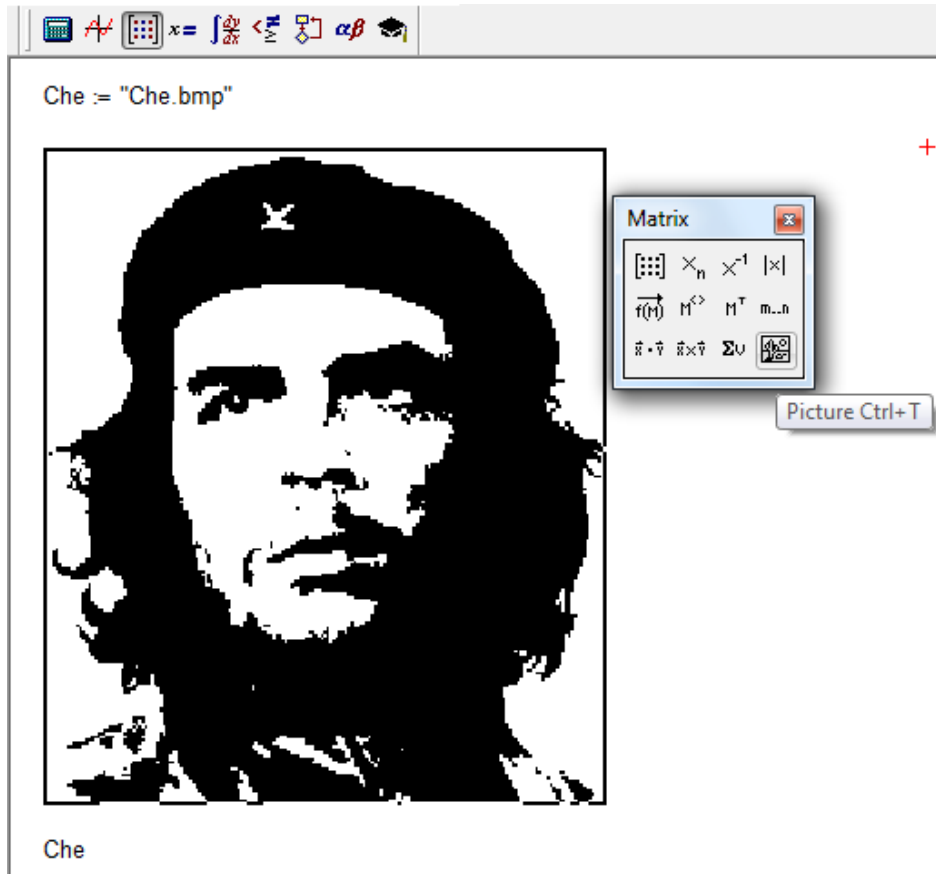


Fig. 5.3. Inserting a picture into a Mathcad document

Inserting a picture into a Mathcad document is in itself a very useful tool. Using the if function (if), you can change the name of the graphic file and load this or that picture depending on the results of a calculation. (For example, this was done by showing the formulas for recalculating the types of concentration as in Figure 1.9 in Study 1).

The black and white picture stored on the disk as a bmp file can be turned into a *matrix*, the elements of which will fix the color of the image point: 0 — black and 256 — white. For this, there is a function READBMP in Mathcad — see Figure 5.4.

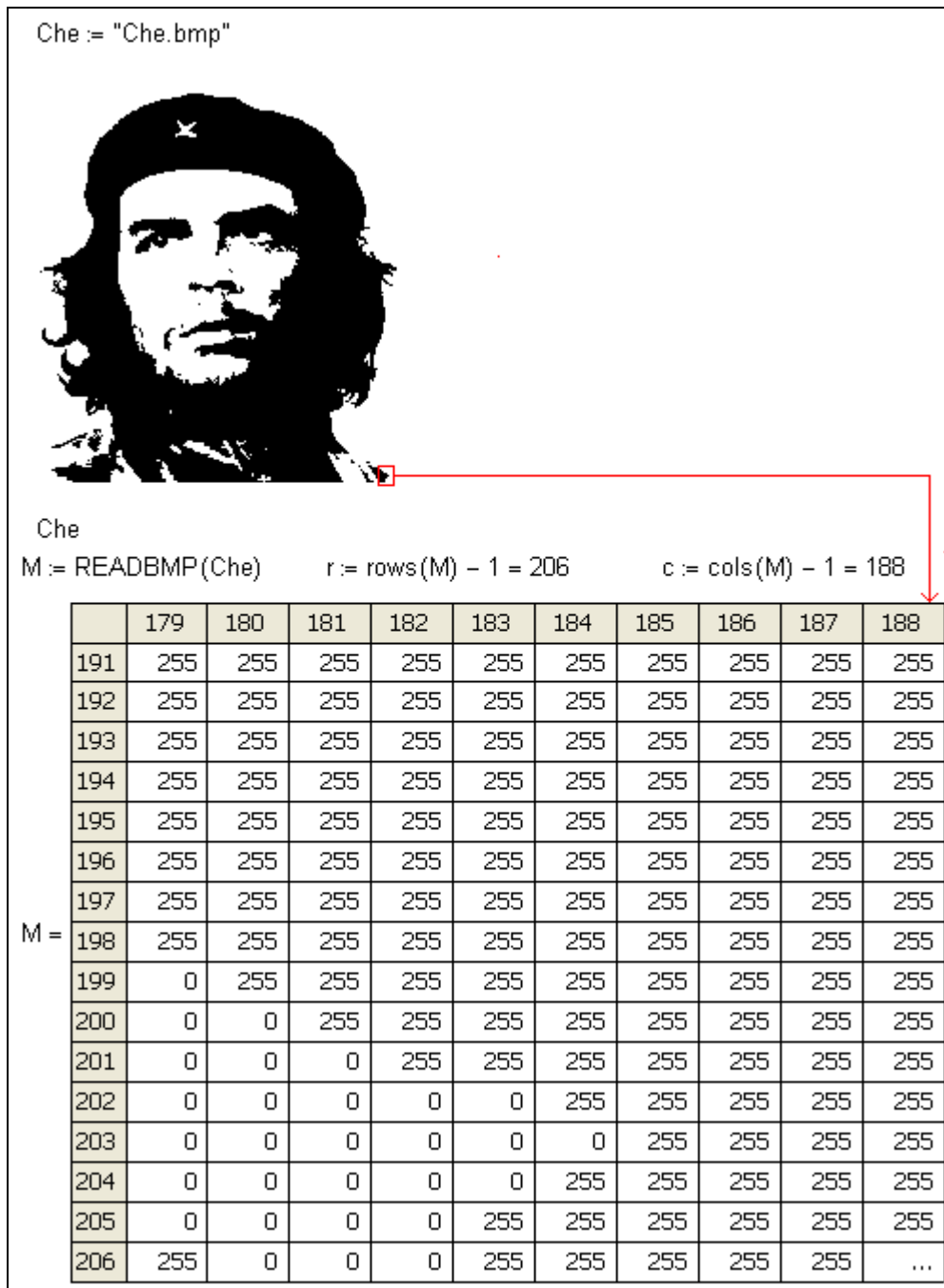


Fig. 5.4. Convert an image to a matrix

In Figure 5.4 we have "printed out" the lower right corner of the matrix M to show how the fragment of the left shoulder of Che Guevara is stored in the matrix. In the matrix, M, 207 rows (from zero to 206) and 189 columns (from zero to 188), store information about 39,123 points of the portrait, of which 21,620 are black. Figure 5.4 shows how, using the rows and cols built-in

coordinates of the black points of our black and white portrait of Che Guevara. This is done in the first program shown in Figure 5.6, with two for loops that sort through the matrix in columns and rows. If the next element of the matrix M is zero (the black point of the portrait), then the number of the given column is written in the vector X , and the number of the row in the vector Y .


```


$$\begin{pmatrix} \text{lon} \\ \text{lat} \end{pmatrix} := \begin{array}{l} n \leftarrow 0 \\ \text{for } i \in 0..c \\ \quad \text{for } j \in 0..r \\ \quad \quad \text{if } M_{j,i} = 0 \\ \quad \quad \quad \begin{array}{l} X_n \leftarrow i \\ Y_n \leftarrow -j \\ n \leftarrow n + 1 \end{array} \end{array}$$


$$\begin{pmatrix} X \\ Y \end{pmatrix}$$


```

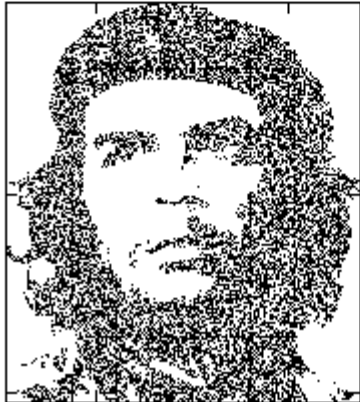
```


$$\begin{pmatrix} \text{lon} \\ \text{lat} \end{pmatrix} := \begin{array}{l} n \leftarrow \text{last}(\text{lon}) \\ \text{for } i \in 0..n-1 \\ \quad \begin{array}{l} \text{RN} \leftarrow \text{floor}(\text{rnd}(n)) \\ \text{while } \text{lon}_{\text{RN}} = "-" \\ \quad \text{RN} \leftarrow \text{floor}(\text{rnd}(n)) \end{array} \\ \quad \begin{pmatrix} \text{lon1}_i \\ \text{lat1}_i \end{pmatrix} \leftarrow \begin{pmatrix} \text{lon}_{\text{RN}} \\ \text{lat}_{\text{RN}} \end{pmatrix} \\ \quad \text{lon}_{\text{RN}} \leftarrow "-" \end{array}$$


$$\begin{pmatrix} \text{lon1} \\ \text{lat1} \end{pmatrix}$$


```

FRAME := 500 n := ceil($\frac{\text{last}(\text{lon})}{940}$) · FRAME i := 0..n



n = 11500

Fig. 5.6. Converting a matrix into two vectors

The second program, shown in Figure 5.6, the core of which is the function `rnd` (it will be the protagonist of Study 17), returning random numbers, mixing the elements of the vectors `lon` and `lat`. After that, it's easy with the Mathcad animation tools to draw our hero point-by-point — see his incomplete portrait in Figure 5.6 and the individual stages of this "drawing" in Figure 5.1. If the vectors `lon` and `lat` do not mix, then the picture will be displayed on the computer screen line by line and you can clearly see image rasters. So you too can play the game "Guess the image". The programs and animations described here are on the site of this Study. In particular, on this site details of the "Guess Image" game with color images were discussed using the example of the famous portrait of Andy Warhol "Liz". In the upper left corner of this figure is a printout of the matrix `M`, which holds a portrait in three vectors, each of which stores an intensity matrix of one of three colors. With these matrices we perform the operations shown in Figure 5.6 and create an animation, the frames of which are displayed in Figure 5.1, but in color.

Childhood, adolescence and youth of the author of the book took place during the birth and flowering of not only cosmonautics (see Study 9), but also of analog television. They remember how parents saved money for the first KVN-49 TV, then a lens was fitted to it (the zoom function — see the last line in Figure 5.5), the announcer explaining how to switch to the second program by switching the lever on the back panel of the TV. In the Polytechnic Museum in Moscow the first soviet color television with three beams in a tube for three colors appeared, as have flat and digital TVs, etc. Many memories are inspired by this Study...

The most recognizable female image is, of course, that of the Mona Lisa. The author of this book has another book with one co-author (see http://tw.t.mpei.ac.ru/ochkov/MC_PC/index.htm). On the cover of that book was a portrait of Mona Lisa, printed with noughts and crosses. By then such printouts were no longer a wonder, but were looked at with interest. The co-author (and he

was a soldier, a signal officer) brought the newly printed book home and showed it to his wife. She asked: "Who is this!?". He replied: "As someone — Mona Lisa or Gioconda". Wife threateningly exclaimed: "What is this Gioconda!? This Raika is your front-line radio operator, with whom you twisted love...". Scandal almost with assault! The co-author told all this and showed Raika's a photo — a complete resemblance. Well, not with a portrait from the Louvre, but with a picture on the cover of the book. See also Figure 15.7 in Study 7.

Guessing not image but melody

The author of the book once proposed to voice... the beginning and ends of all functional program blocks in the system of the European scale:

- functional block — do (C)
- the "until" — re (D)
- alternatives — mi (E)
- the cycle "before" — fa (F)
- cycle with parameter — sol (G)
- Multiple branching — la (A)
- call procedure — si (B)

In this case, the depth of the occurrence of a particular structure is fixed by the duration of the sound. Running the program on a computer with a sound generator and speakers generates a melody, listening to which, you can follow the progress of the solution of the task, fix the loops, etc. You can also play a new game "Guess the program" — the melody created according to the above scheme is played, and the players must guess. What is it: sorting an array, solving a system of equations, numerically integrating, etc. — see <http://twt.mpei.ac.ru/ochkov/128>.

Reader Tasks:

Create a program and/or find a built-in function that calculates the number of points of a different color in the graphic file.

Create a program and/or find the built-in function to create a negative or other alternative image of a graphic file.

Calculate the frequency of meeting points of a color in a graphic file and build a histogram from these data (see Figures 14.19, 14.20 and 14.21 in Study 14).

For the sake of interest and pleasure, let's replace the points in the image matrix with chocolate sweets in the confectionery boxes. Solve this problem. At the confectionery factory there is a machine for packing chocolate sweets. It is a mechanical manipulator, capable of moving along one straight line perpendicular to the conveyor, along which empty boxes with cells for sweets move. Candy instantly enters the cell as soon as the manipulator is above it. Let us consider the motion of the automaton and boxes in the XOY plane. The coordinates of the cells (x, y) are natural numbers, and in the initial position, (all coordinate values are given in inches). The belt of the conveyor starts to move in the direction opposite to the axis OX , with a velocity $v = 1$ inch / s. Simultaneously, the manipulator moves from the origin along the OY axis at a constant speed without stopping. What is the maximum number of sweets that can be placed by the manipulator during a single crossing of the conveyor and at what speed should it move?

Solve problem 4, provided that the manipulator must place the candies in a "gift box" of non-rectangular shape, i.e. The number of chocolates in each row is subject to some dependence.

How in this case to define the speed function of the manipulator?