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"C.R.T. FOR THE 90's"

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C.R.T'S FOR THE 90'S

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ABSTRACT

The authors present their analysis of developments in modern techniques for graphics displays on cathode-ray tubes. Their point of view is based on the current trends in graphics tools used on the ground. They are convinced that the stroke-writing process used at the present time is not a solution for the future, and that it will be replaced by the raster-scanning technique.

After a brief summary of both display principles, they go on to describe the typical organization of a raster-scan symbol generator and conclude by listing the advantages inherent in this choice.

1 - INTRODUCTION

One of the most important avionics developments in recent years has been the replacement of conventional flight control and navigation instruments by cathode ray tube displays.

First introduced on commerical airliners, this practice is now extended to the whole aeronautical field, including helicopters.

The changeover to electronic displays in the helicopter world seems to be taking place at a very fast rate, in both the civil and military fields, and has led to panel layouts featuring four, five or even six CRT's exactly the same as those on modern long-haul transports.

Parallel to this mass invasion of the cockpit by the electronic image, we on the ground have also witnessed the proliferation of an incalculable number of communications devices, games and tools which also use graphics techniques and color cathode ray tubes. This phenomenon, of which we are all aware, is in fact the first step in an important technical and technological process which should reach its culmination at the end of the century. The last ten-year period will come to be known as "the decade of the image".

This technical progress will lead to a modification in working and reasoning methods, and will also change the way in which the content of an image is perceived.

The present symbologies used for conventional instruments, and which it has been necessary to reproduce on CRT displays, will have become completely outdated and even inefficient.

What will be the new symbologies used in the years to come ?

It is difficult to affirm anything whatsoever in this field at the present time, but the orientation of the techniques used on the ground in the matter of graphics representation may be taken as a certain indicator of what we can expect.

Now, what do we see today if we analyze the developments in graphics tools ?

Basically, two trends :
- graphic images are coming closer and closer to reality,
- the images make intensive use to the surface areas.

In the aeronautical field, these trends will surely be reflected.

The present mode of representation by symbolic lines will gradually be replaced by a representation in which extensive use will be made of colored areas in conjunction with a synthetic representation of the information to be displayed.

This changeover cannot be accomplished effectively by the scanning procedure used today : stroke writing. When this was realized in 1979, SFENA decided to concentrate on a type of scanning which was capable of representing complex images and could benefit from the extensive research and development work conducted in the field of graphics : raster scanning.

On the occasion of this Ninth Rotorcraft Forum, we thought it might be of interest to outline the operation of as symbol generator using the principle of raster-scan image generation for flight control and navigation instruments.

Before discussing the organization of a TV-display instrument, we shall start with a brief resume of the two main scanning modes used at the present time.

2 - CATHODE-RAY TUBE SCANNING PRINCIPLES

Stroke writing

With this type of scanning, an image is traced vector by vector by the CRT spot just as if the line were being drawn on the screen by hand.

The beam jumps from one vector to the other just like aknight in a chess game.

The process which causes the spot to move is an analog control applied to the deflection coils on the horizontal and vertical axes (X and Y), and a CRT "ON/OFF" control (Z axis)

The trace time is longer for a complex image, i.e. one composed of a high number of elementary vectors.

When the surfaces of the image have to be colored, the number of vectors increases considerably and the trace time does not permit an anti-flicker refresh of the image.

It is for this reason that most devices never use only stroke writing alone, but feature a mixed structure (stroke/raster), where the TV scanning principle is used to color the surface.

The resolution of the stroke is excellent without artificial enhancement, and is limited only by the precision of the analog signals which deflect the spot.

Raster Scanning

The image to be shown is broken down dot by dot and stored entirely in a mass memory. This memory is then read, row by row, column by column, by means of a systematic horizontal and vertical scanning procedure. The screen is illuminated each time there is a dot to be illuminated at a row/column intersection.

Owing to this principle, the scan time remains the same whatever the complexity of the image.

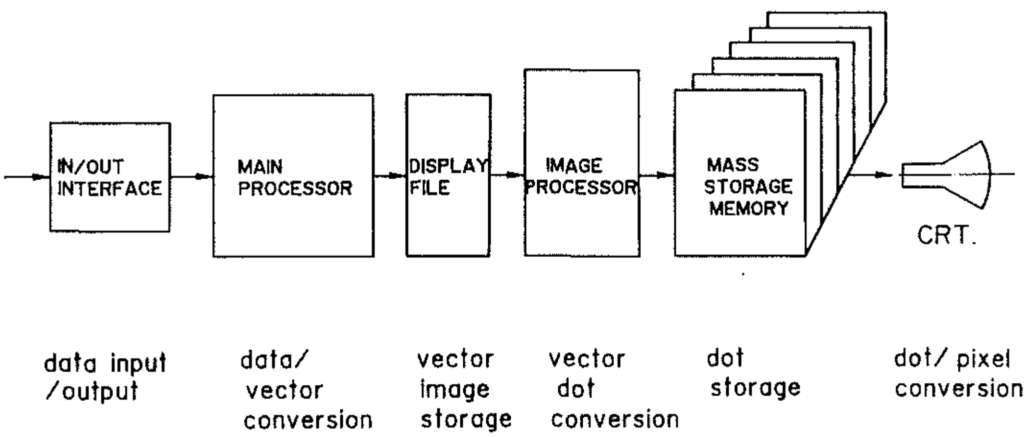
Without special processing, the resolution is mediocre because, as the memory size is finite, the image to be represented is discretized.

This means that a line with a slight horizontal or vertical inclination would appear as a row of "stairs", which is totally unacceptable in instruments such as an ADI or HSI. (This "staircase effect" is very perceptible on color radar tubes on which course indicators have been superimposed).

It is this defect which requires the greatest amount of contemplation and imagination, and is one which SFENA has succeeded in eliminating completely.

This "anti-aliasing" process, which SFENA has patented, makes it possible not only to eliminate the staircase effect completely, but also to bring the resolution up to a level of quality equal to or better than that obtained by stroke writing. As the processes used are digital, they have the advantage over stroke writing that the symbol positions are stable whatever the environmental conditions.

3 - RASTER-SCANNING SYMBOL GENERATOR



Main Processor

The data are received by the interface module which, after matching, transmits them to the input processor.

On the basis of the data received, this processor creates a file of the image to be generated in vectorial form.

For example, as soon as the input processor has received a heading value of 300 degrees from the interface, it immediately generates an image file consisting of the 36 vectors for 10° on the compass card, the 36 vectors for 5° and all the characters giving the heading : N, 3, 6, etc.

All of these vectors and characters are placed in the configuration corresponding to a heading of 300°.

The same is true for all the parameters displayed on the screen. The whole image in vectorial form is stored in a memory located between the input processor and the image processor.

The creation of an image in the file is performed at a fast rate. Typically, a new image replaces the previous one every 50ms, just like photographic snapshots.

This image is a mathematical image written in a trace language. For each vector, the trace scanning typically defines :

- the origin Xo, Yo of the vector,
- the increments ΔX and ΔY,
- the color of the trace.

Moreover, the sequence of vectors constituting the symbols and the symbols themselves are written in a highly-precise order and are stored in the screen memory in the same order.

This arrangement makes it possible to give a relative priority to each symbol, and enables the scanning procedure to solve, in a simple and elegant manner, the problems of superimposing lines of different colors. This interesting feature will be explained below.

The whole of the image file is then read by the image processor which converts the vector-tracing data into their constituent dots and stores them in the screen memory.

Image Processor

The role of the image processor complements that of the input processor and carries on the work of the latter. The input processor has performed a fairly complex mathematical job in a relatively slow manner : basically trigonometrical calculation but also various tasks of display mode control and self-test.

On the other hand, the image processor must - at high speed - convert hundreds vectors transmitted to it by the input processor into colored dots that it will place in the image memory and which will be read and displayed on the screen. Unlike the case of the input processor however, the mathematical operations required to transform the vectors into dots are very simple and consist merely of a sequence of additions and subtractions.

An HSI image in "compass card" mode contains approximately 12,000 illuminated pixels from a total of 256,000. The speed at which the image processor writes into the memory is in the region of 1 pixel per microsecond and therefore makes it possible to trace the images at a rate of more than 80 Hz, which totally eliminates the flicker effect.

Image Memory

The image memory is a representation on the CRT screen. It consists of six planes of 256,000 bits (512 x 512), i.e. more than 1.5 Mbits. The six planes make it possible to encode $2^6 = 64$ levels of colors or priorities.

In fact, as the image memory is written by the image processor and read by the cathode-ray tube (through the slave micro-controller), there is a time conflict between the two accesses. This conflict is resolved by doubling the memory capacity.

While a series of 6 planes is being written by the image processor, the other series of 6 planes is read by the CRT. The planes are then erased and the CRT reads the image prepared beforehand by the image processor while a new image is entered in the erased memory.

The set of dots read in the memory is sent to the CRT according to the sequential raster-scanning principle.

4 - ADVANTAGES OF RASTER-SCANNING : CREATIVE FREEDOM

Unrestricted surface writing

This is the best-known advantage of raster-scanning, as it is currently used in all mixed symbol generators to trace the sky and ground surfaces, and also the clouds in WXR radar.

Surfaces pose an important problem of trace time. If the sky and ground on the ADI had to be "painted" simply by tracing vectors - even if they are out of focus so as to increase thickness - it would be impossible to build the whole ADI picture without it being affected by flicker. Raster-scanning is therefore the only solution to this problem.

Spatial Freedom

Whereas this is one of the least-known qualities of raster-scanning, it is perhaps one of the most interesting. When an image is defined using a raster scan, there is no need to worry about the type of graphical information to be portrayed, the way in which the various symbols will be superimposed, whether the trace length will allow an anti-flicker image, etc.

Let us take the example of symbol superimposition in the case of FD attitude bars. When the stroke-writing principle is used, the following problem arises :

Having traced the blue-sky and brown-earth images on the CRT screen, the yellow FD bars must now be superimposed by stroke writing.

The blue sky will now be written over with the yellow bars, which is in fact made up of the colors red and green. Now, the writing on the CRT and human perception obey the laws of color mixing. Unless special precautions are taken, the bar will appear as a slightly-tinted white.

Stroke-writing systems solve this problem by computing anticipated intersections, by color auto-compensation, and by reserving certain areas. In fact, the possibilities of superimposition are limited to the bare minimum, because the calculations take a long time and restrict the maximum stroke length. This can be seen for example on "compass card" HSI displays where the majority of symbol superimpositions have been omitted.

The TV process resolves these conflicts naturally without supplementary computing and with no restriction whatsoever.

To achieve this, the image to be displayed is written into memory according to a precise order. Thus, in the case of the above-mentioned conflict, the blue of the sky will be written into memory first and then the FD bars. At each point where the FD intersects with the sky, the "blue color" memory will be erased automatically and replaced by the yellow of the bars. The conflict problem is solved simply by the order in which the colors are written into memory.

This last requirement should not be regarded as a restriction. It is necessary because the writing on the CRT takes place in three dimensions : two on the surface and one in depth.

Temporal Freedom

As opposed to stroke writing, where the data acquisition, the various symbol-generation computations and the image display must be performed in a constant period of time, the symbol-generation architecture of the raster-scan system possesses a number of storage elements which at all times make it possible to adapt the input of data to the screen display in the best possible way.

Owing to this, there is no correlation between the complexity of the written image and its refresh rate on the screen. Therefore, there is no need to worry about the trace execution time factor when creating an image by means of raster-scanning.

Interactive Dialogue

Systematic scanning of the whole screen, from top to bottom and from right to left, is the only way to achieve a simple interactive dialogue between the screen and the pilot by means of the light-pen technique. The pilot is able to designate a point directly onto the screen, which makes it possible to create an imaginary waypoint in the case of a map display, or to designate the angle and range of a target, or to select the screen display mode himself if these various modes consist of a number of symbols which are perfectly positioned and present in all configurations.

This feature makes it possible to simplify or even totally eliminate certain control units, thereby saving on weight, cost and power consumption.

Graphic Quality of Alphanumeric Characters

This is a direct consequence of the unrestricted line width.

In a "compass card" HSI display, the number of alphanumeric characters is very high and represents a high proportion of the computing and trace time. With stroke writing an effort is made to reduce this time, but this also leads to a reduction in graphics quality. In fact, the time factor is directly proportional to the number of vectors to be traced : the fewer the vectors used to define a symbol, the shorter the time taken.

On the other hand, raster-scanning makes it possible to define a character by means of a dot matrix which can be as large as you like. Therefore, the displayed character can have the quality of a printed character with unequalled sharpness, with no time penalty whatsoever.

5 - CONCLUSION

The images obtained by the SFENA raster-scanning system, and which make best use of surface representations, are of better quality than those obtained by stroke writing.

During the last Paris Air Show in June 1983, the most difficult task of our marketing team was to convince a large number of people that what they were seeing on the SFENA stand was in fact a CRT image and not an illuminated slide.

This use of surfaces makes it possible to portray softened images. In fact, we have found that images consisting of very bright lines on a dark background tend to cause fatigue over long periods.

The brightness of raster-scan CRTs is comparable to that achieved with stroke writing. This has been demonstrated by tests performed at high altitude on a combat aircraft.

The use of raster-scanning in the tube makes it possible to employ high-efficiency power supplies which are basically equivalent to commercially-available color tubes. On the instrument panel, this means a high saving in energy and lower heat dissipation, which is a significant advantage in the case of helicopter instrument panels which are not generally equipped with cooling systems.

TV scanning is the only process capable of representing either complex real world images :

- LLTV
- FLIR

or images containing a wide range of colors :

- map displays
- synthetic images.

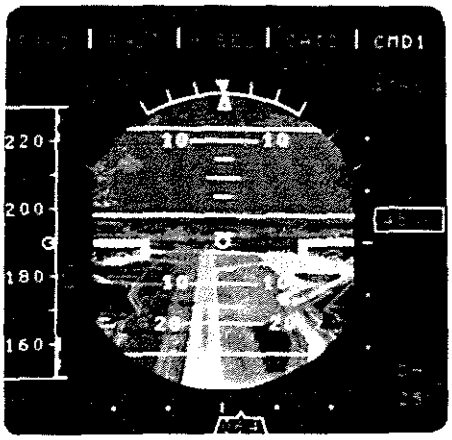
Immediate adaptation to future flat screens, because these use the same scanning principle as television.

Complete digitization of the image generation process, which does not use costly and unreliable digital-to-analog converters.

Infinite trace capability, making it possible to obtain not only complex images but also images on larger tubes such as those incorporated in the basic "T" for example.

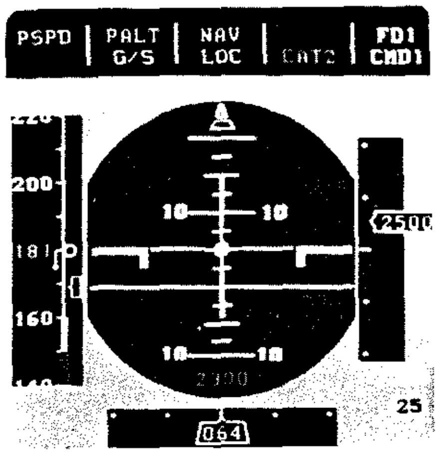
Because of all these advantages, but also because it is the only system to benefit from the extensive research work already being conducted in the graphics field, raster-scanning is destined to become the undisputed leader among display devices in all air and ground applications of the next decade.

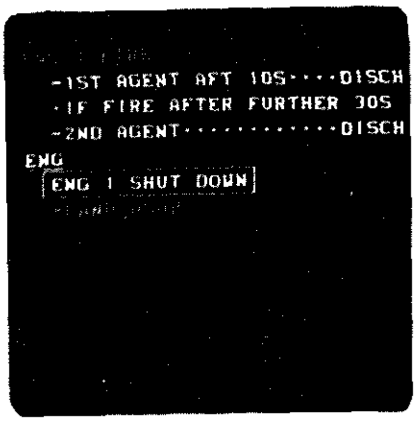
SOME ILLUSTRATED ADVANTAGES OF TV SCANNING



Outside world can be superimposed anywhere in the display

Smoothed picture reduces pilot eye fatigue





High quality of alphanumeric characters

Intensive use of surfaces instead of lines giving a more readable display