AN EFFECTIVE LOW-COST VISUAL:
Night Scene CGI

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1. Contemporary GCI Night Visual Systems

The CGI Night Visual System belongs to the general technology of computed image graphics, which has been in existence for more than a decade. Computed image graphics has been applied in many fields. A few examples are architecture, mechanical and electrical engineering design and drafting, civil engineering, and the study of multidimensional mathematical functions. The zenith of the state of the art is unquestionably found in the application to the large scale real-time simulation of visual environments for aircraft and spacecraft engineering studies and training. In recent years the trend has been toward expanding the size and complexity of visual environments and the creation of faster and more efficient hardware and image processing algorithms.

If one divides the CGI field into two equipment categories, namely, caligraphic (random stroke), and raster edge generation, the night visual falls into the former equipment class. The CGI night visual system simulates the essential visual environment encountered in nighttime flying conditions by arranging lightpoint patterns into appropriate scenes, with prime attention being paid to a very precise representation of runway and approach lighting patterns. Figure 1 shows an example of a full ICAO ILS runway lighting pattern at a touchdown distance of approximately one-half mile. A random scan graphics unit is usually employed, and this unit differs from conventional computer graphics equipment in that it is designed to permit a much higher degree of beam positioning precision. A display unit with 1000 x 1000 addressable beam positions would not be acceptable in the night visual simulation application, and, in fact, around 4000 x 4000 display locations are usually required to present night scenes with the required degree of resolution and smoothness in image motion. The beam position accuracy is usually attained by employing a beam penetration cathode ray tube, which is superior by far than the best currently available shadow mask tubes. One must, in consequence, accept the limited hue range available from beam penetration tubes. The resolution of a properly designed beam penetration display translates into lightpoint resolution approaching 3 arc minutes. In a well-adjusted CGI night system, the edge lights on a 10,000 x 200 foot simulated runway may be perceived as clearly separated strings at line-of-sight ranges in the order of 12 miles or more.

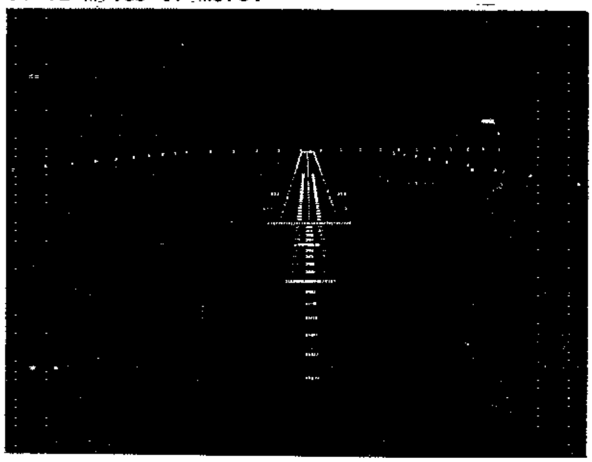

FIGURE 1. ICAO ILS RUNWAY LIGHTING

The total environment size usually varies between 1400 and 2400 lightpoints per scene, with scenes storable for immediate access in the visual computer core, or rapid access from small tape cassette peripherals. A tape cassette unit may easily store 12 scenes with access times in the order of seconds. Large and small scale maps and approach charts are used as source material. User requirements vary quite widely, and in some instances, very carefully prepared scenes of problem airports with non-standard runway lighting have been generated. No detailed work appears yet to have been performed in determining the best distribution of lightpoints in an approach scene. It may, however, be desirable to provide the trainee with vertical height cues during all phases of the approach. Such cues are usually simulations of vertical towers topped with flashing red lights. If a given scene is distributed over an area of say 14 miles square, the maximum useful number of environment lightpoints, including the standard runway approach lighting, appears to be around 2400. Allowing about 1000 points for runway and approach lighting, and distributing the remaining 1400 around the airport, results in an extremely well-defined ground plane.

In common with all other CGI systems, scene perspective and relative motion are computed and therefore exact within the limits of the display data conversion equipment, the CRT deflection correction circuits, and the residual aberrations of the collimating optics. In the latter case, a reasonably good match between the radius of curvature of the cathode ray tube face plate and mirror focal surface is required if reflective optics are used. Without this match, image field curvature may appear and cause observable false parallax and non-uniform image magnification.

2. The Night Scene Concept

CGI night visual systems have, over this past 2-1/2 years, attained an uncommonly rapid degree of acceptance by the pilot community. In spite of this acceptance, one factor is frequently cited as a possible drawback of this type of system as compared with full-day scene systems. This is the limited visual environment. Pilots are naturally concerned about whether training acquired with a night scene environment carries over to the daytime real-life operations. This is a complex question, and it may not be fully answered until all of the conscious and unconscious processes involved in piloting an aircraft through the landing phase are understood.

The relative performance of different types of visual systems may, however, be compared. One method is to measure some of the more important parameters such as the dispersion of sink rate and touchdown point after a number of trial runs on flight simulators equipped with different visual systems. Usually, trials are made with pilots without previous visual simulation experience. Palmer (Ref. 1) of NASA AMES has reported the results of a series of experiments of this kind. In the experiments a group of eight pilots was employed. Repeated trials were made in a TV model and a monochrome-computed image night visual system. The key comparison parameter was the dispersion of vertical velocity at touchdown. As the pilots gained experience with both systems, a progressive reduction in sink rate at touchdown was noted. The results showed that there was little difference between the two systems in the matter of touchdown velocity, and both systems produced results comparable but higher than recorded real-world flight data. Thus, the only experimental data obtained to date indicates that considering one parameter only, sink rate, night CGI and TV model appear to be similar. In other words, the visual cues present in both systems used to control sink rate are approximately equal in effectiveness.

It is therefore difficult to account for the widespread acceptance of the night visual system when we consider traditional attitudes to visual simulation. It has been argued that one should attempt to simulate all of the characteristics of the real world, day, dusk and night, in the hope that all of the cues both essential and desirable would thus be embedded in the scene. Unfortunately, past history has shown that such attempts have necessitated tradeoffs which have affected and degraded all of the visual cues provided. In the case of the present manufacturer, the night scene concept was chosen with due consideration to the specific difficulties of night flying, and realization that computed image techniques offered the possibility of an extremely precise simulation of the limited visual environment. Consider the following selection of illusions and pitfalls peculiar to night flying:

- Runway lights appear to be more distant when viewed through mist and rain, than in clear air.
- Temporary loss of visual contact with the runway due to a low, close-in fog bank.
- Long straight-in approach over water to a runway on sloping terrain.
- A narrow, short runway seen at low altitude may present the same appearance as a wider, longer runway at some higher altitude.
- Breakout over the approach lights, from low ceiling in reduced visibility; is the thousand-foot lightbar ahead or behind?

It has been determined that some, perhaps all, of the above situations have contributed to accidents in both military and commercial flying. In avoiding the pitfalls of these "false cue" environments, total reliance on radio altimeter readings may not be sufficient. Runway altitude cannot always be assumed to be the same as the altitude of the terrain immediately below the aircraft. Therefore, as Litchford (Ref. 2) has pointed out, both the available visual cues and the flight instrumentation must be correctly interpreted. Visual simulation in these hypothetical situations must provide the very limited visual cues with almost eye-limiting detail at extended ranges in order that a lasting and significant impression can be provided to the trainee. This then summarizes the philosophy of the CGI night visual. We believe that current and advanced forms of CGI visuals will be used to explore these phenomena,

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Reference 1: "Touchdown Performance with Computer Graphics Night Visual Attachment", E. A. Palmer and F. W. Cronn, NASA AMES, AIAA Paper 73-927, September 1973.

Reference 2: "Low Visibility Landing", G. B. Litchford, Astronautics and Aeronautics, December 1968.

and perhaps contribute to real-world flight safety.

3. The Economics of Night Visual Systems

In the two years since introduction, around 45 systems have been ordered world-wide. It seems almost certain that by the end of 1975, almost 25% of all visual systems in commercial service will be the CGI type. Since they are hardly more complex than moderately sophisticated computer graphics systems, they are easy to maintain. Required maintenance skill levels are almost always found in normal flight simulator operations, and usually a short training course is all that is required for equipment familiarization, including the construction of new scenes, updating and re-arranging supplier-furnished scenes. The following are some principal economic considerations:

- Initial Cost:

  The initial costs for first generation (lightpoint only) systems range from $150/170K for single display equipment to $400/500K for second generation multiple display illuminated runway systems. Installation and integration costs vary widely depending on the host simulator configuration and condition. Spares costs may be as low as $10K.

- Reliability:

  Due primarily to their almost total use of solid state electronics, reliability and therefore equipment availability is high. Statistics gathered from nine MDEC systems currently in service show an MTBF average per system of a little over 1400 hours.

- Maintainability:

  Average time to repair appears to run in the range of 2.5 to 3 hours. Periodic maintenance consists only of the gain and offset adjustments required to perform color alignment.

Total operating costs including amortization in the range of $10 to $20 per hour are probably not unrealistic, but are subject to the vagaries of accounting methods. Considering that the July '74 reported mean operating costs for DC-10, 747 and L-1011 aircraft is $2000 per hour, the economy of a visually-equipped flight simulator needs no emphasis. Although the additional maneuvers permitted by Federal authorities on visually-equipped simulators can theoretically be performed in less than 30 minutes, the additional aircraft time required to enter flight patterns and set up for maneuvers must, of course, be taken into consideration.

4. Growth Potential

The CGI night visual system is free from the traditional limitations of electro-optical visual simulation methods. Clear lines of advance are opening which will lead to advanced equipment forms providing more complex scenes. Even in the first generation systems, improvements in the lightpoint-only scenes are technically possible. For example, to approach the ideal in the basic night scene, the following real-world characteristics could be simulated -- theoretically at least.

- Elevated street lighting locally illuminates the ground surface and provides a well-defined height cue at low aircraft altitudes.

- Environment lights are not steady. They are randomly occulted by intervening terrain features, building, etc.

- Both point and extended light sources are present in the night scene. Many light sources exhibit strong directionality.

- Environmental conditions may partially obscure the ground plane, merging individual lights into areas of low level glow.

Whether the inclusion of these effects, which would involve additional development costs, would be cost effective seems questionable. Of much more immediate interest is the need to provide the pilot with visual contact with the runway surface during the last few seconds of the approach. The rationale for this is that runway texture and the runway all-weather markings are almost always visible to the pilot either from the aircraft landing lights or the immediate runway lighting or both. Contemporary CGI night visuals provide touchdown zone light strings to avoid a disturbing 'black hole' effect at the instant of touchdown. This measure has proved to be reasonably effective, but obviously less desirable than a clear view of the threshold and fixed distance markings which are always present on an ILS equipped runway. Figures 2, 3, and 4 show recent developments along these lines. The real-time software used to generate these scenes generates a moving band of tapered visibility ahead of the aircraft corresponding roughly to the range of idealized landing lights. A tapered horizon band is also generated. As with the basic night scene the design emphasis has been placed on providing maximum precision in locating and defining the runway texture and markings.

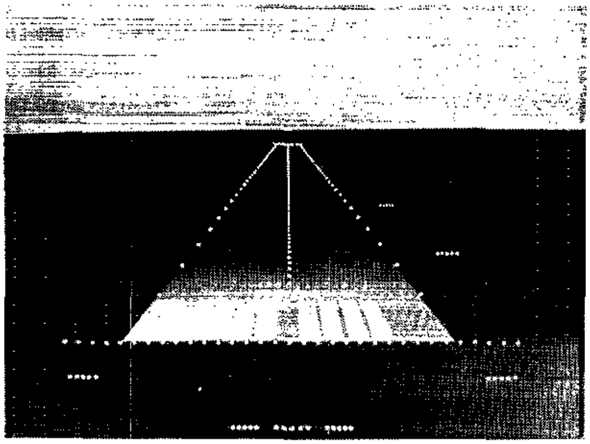

FIGURE 2. RUNWAY SURFACE TEXTURE SIMULATION: VIEW 1

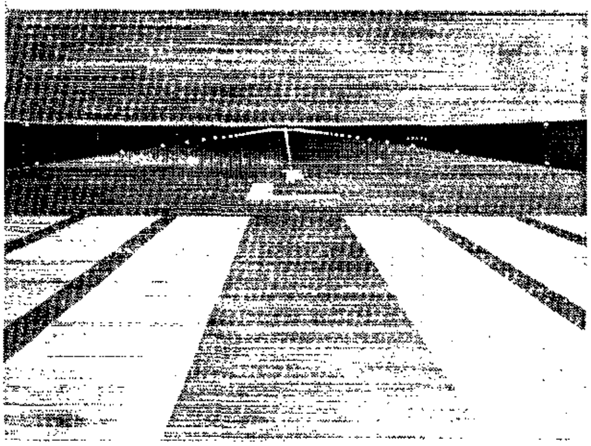

FIGURE 4. RUNWAY SURFACE TEXTURE SIMULATION: VIEW 3

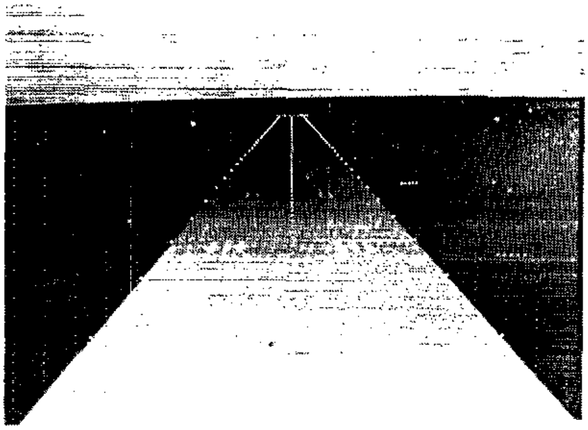

FIGURE 3. RUNWAY SURFACE TEXTURE SIMULATION: VIEW 2

5. Conclusion

The night visual CGI system is not a special, simplified, case of the large, elaborate day scene system which solves the hidden and occulted surface problem and provides complex three-dimensional imagery, but is rather a device developed in its own right to fulfill a specific need in commercial and military applications. In this regard, the evolution of more advanced forms of the system may follow quite different directions and employ different techniques, since refinements, as a matter of expediency and economy, will be closely and perhaps even solely related to specific user needs.

ABOUT THE AUTHORS

MR. JOHN MACKEY is Senior Group Engineer at McDonnell Douglas Electronics Company. Since 1968, Mr. Mackey has been responsible for MDEC's activities in visual systems research and development, as well as new business activity related to visual systems and their electrical, mechanical, and software interfaces with flight simulators. In this capacity, he originated the concept of a night-only computer-generated visual simulation on which the VITAL series of equipment is based. He recently completed a funded study for NASA to define the visual portion of NASA's Space Shuttle simulation system. All continuing visual system research and development work is under his direct supervision. He holds a B.S. degree in Electrical Engineering from the University of Manchester, England, Faculty of Technology. Prior to MDEC, Mr. Mackey was engaged in radar systems engineering with Radio Corporation of America.

MR. THOMAS M. NELSON is a Group Engineer at McDonnell Douglas Electronics Company. Since 1966, Mr. Nelson has held various posts in the simulator engineering department. He is currently responsible for near term and advanced visual system applications and other activities related to visual system/flight simulator interfaces. Previous assignments have included system engineering and software development activities associated with advanced simulator applications, and Company-sponsored research and development on automated training techniques. Mr. Nelson holds a B.S. degree in Physics from Wittenberg University. Prior to MDEC, he was engaged in spacecraft control system design with NASA.