A PHOTOGRAPHIC PROCESSING CONTROL METHOD FOR ERTS IMAGERY

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The ERTS NASA Data Processing Facility (NDPF) is required to produce large quantities of film products (transparencies) with extremely high radiometric quality. This required quality (or accuracy) is not only unique to NDPF's Photographic Laboratory, it is also unprecedented in the history of photographic processing. The variation in density range must be limited, and tone reproduction must be uniform and consistent all the time. The stringent radiometric accuracy is necessitated by the fact that significant scientific information is presented in very small changes in radiance, and hence density. Such changes can be as small as 0.03 density units, and must be preserved by the photographic process. In addition, this degree of accuracy must be maintained consistently in order to permit comparison of temporal changes in the observed (imaged) scenes. Production of large quantities of transparencies (approximately 10,000 per day) having the required radiometric accuracy is made possible by the unique processing techniques, and by this processing control method developed and implemented in NDPF's Photographic Laboratory.

The photographic processing control method, hereafter called "the method," was developed to provide the capability of assuring production of high quality film products, detecting processing problems which adversely affect the required quality, and accomplishing these functions very accurately and rapidly to maintain production throughout. Because the information exposed on the actual film is not known in advance, an indirect approach is used to establish system performance and acceptance tolerances. This is based on exhaustive tests and analyses, which were conducted as part of the method development to confirm that the required accuracy would be achieved and maintained for all film products. Thus, special control targets were designed to encompass the required range of performance parameters (also called response variables), measurement and curve fitting techniques were implemented to collect performance data rapidly and accurately, and a feedback procedure was established to indicate what malfunctioned or was set erroneously. Basically, as shown in Figure 1, the method involves two operations: equipment certification, and process verification. Equipment certification exercises the equipment in a standard manner to assure that it is operational over the entire range of required capability before it is used for actual production. This is analogous to the calibration of a telemetry system, where the system is tested at given bit rate and SNR, and its performance is measured in terms of bit error rate. Process verification, on the other hand, is employed with every roll of film (which may be 30 to 45 meters long) to assure that the processing was in control for each particular product. It is noted that production of different products requires the equipment (photographic printers and processors) to be set up differently, thus providing opportunity for error.

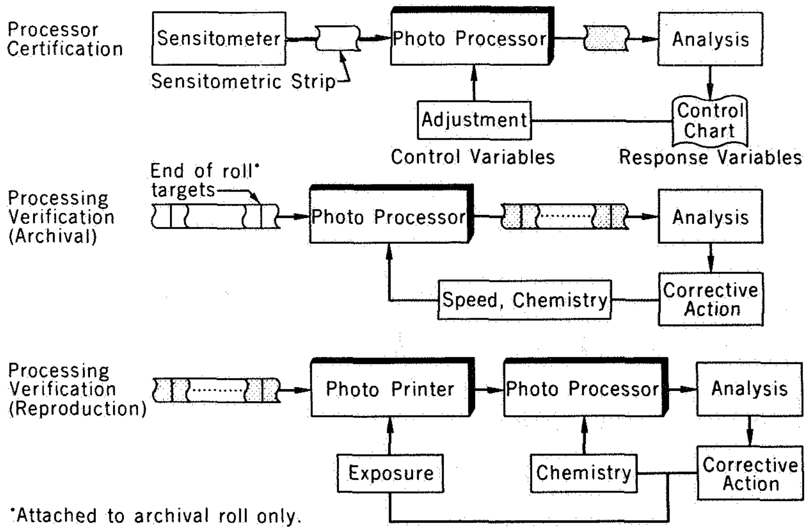

Figure 1. Photo processing control elements.

Both operations make use of control targets, i.e., sensitometric strips for equipment certification and end-of-roll targets (ERT) for process verification. These targets are depicted in Figure 2. They are produced by the sensitometer, which is a precisely calibrated exposing device, in a manner providing discrete levels of exposure, and hence density, to cover the range shown on the characteristic curve. The sensitometric strip is a standard 21-step gray wedge or tablet, whereas the ERTs are made of the same film as that used for archival products. The 22-step ERT is used to provide data on the average gradient, relative exposure, and base plus fog; whereas the five-step ERT is used to provide data on the density range variation and resolution. They are attached to the archival rolls only, and are carried with each subsequent generation to monitor reproduction fidelity. These characteristics or response variables represent and are a measure of the product quality. Therefore, by accurately determining these variables and applying the predetermined tolerances to them, the required quality of the output products can be and is maintained.

The particular target format and shape (circles) were chosen to allow rapid measurements with a standard densitometer. The five-step target contains five equal exposure levels (densities) distributed over the entire 70mm area in order to determine the processing uniformity, so that the measured density range is actually the variation of density over the target surface. The sixth spot is a standard Air Force tri-bar resolution target which is used to determine the processing effects on resolution aspects.

The a priori known target exposure values are stored in a computer. In analyzing the processed targets, the corresponding density values are fed to the computer for curve fitting. This procedure minimizes measurement error. After having correlated the density values with the computer stored exposure values, the actual response variables are determined and displayed in real time. These response variables are then checked against their control limits

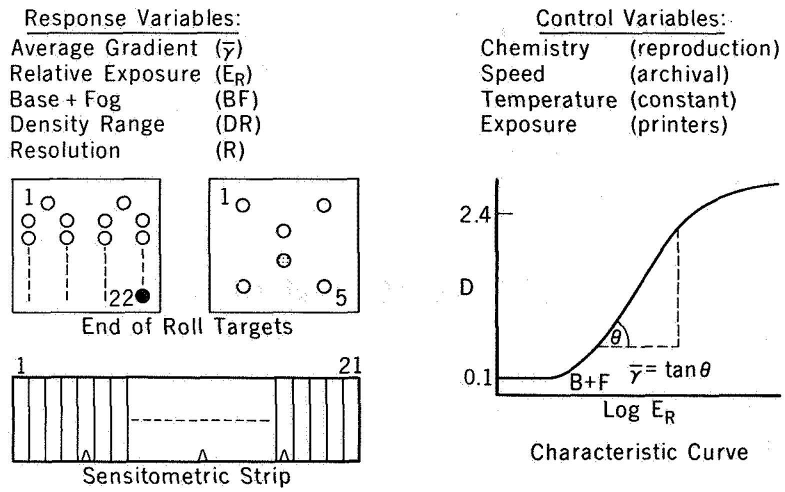

Figure 2. Response and control variables.

shown in Figure 3. It is seen that each response variable corresponds to a control variable (processing parameter) such as chemistry flow rate, processor speed m/s, exposure time, and temperature. Most of the time (90 percent) the response versus control variable relationship holds, and is used in taking corrective action when the control limits have been exceeded. In order to maintain the required accuracy, extremely tight control limits are imposed. This dictates the accuracy with which the response variables must be determined, since erroneous determination thereof will result in adverse reaction. The target analysis is performed in less than five minutes, and the course of action to be taken is determined almost immediately thereafter.

The method described herein proved to be an effective means by which high quality photographic processing could be maintained. The established control limits assure rendition of the required radiometric accuracy so as to preserve the dynamic range of the sensors in the produced transparencies. This method has been in use since launch of ERTS-1, and has been applied thus far to the production of more than 900,000 images. It is interesting to note that virtually no problem affecting the quality of images produced by the NDPF has gone undetected.

CONTROL LIMITS AND CORRECTIVE ACTION

$\bar{\gamma} < \pm 6\%$ ⟶ Processor Chemistry

$E_R < \pm 2.5\%$ ⟶ Printer Exposure

$DR < 5\%$ (0.1) ⟶ Processor Chemistry

$BF < 5\%$ (0.1) ⟶ Film, Printer, Processor

ATTRIBUTES OF METHOD

- Unique targets to match film and density range.
- Rapid measurement of targets and accurate determination of Response Variables.
- Minimum Control and Response Variables.
- Effective Control Limits to maintain required quality.
- Near real-time operation to optimize equipment utilization.

Figure 3. Method characteristics.