High Speed Photography 101

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Abstract

This paper describes the contents of a unique introductory, applications oriented, high speed photography course offered to Imaging and Photographic Technology majors at the Rochester Institute of Technology. The course covers the theory and practice of photographic systems designed to permit analysis of events of very short duration. Included are operational characteristics of intermittent and rotating prism cameras, rotating mirror and drum cameras, synchronization systems and timing controls and high speed flash and stroboscopic systems, and high speed video recording. Students gain basic experience not only in the use of fundamental equipment but also in proper planning, set-up and introductory data reduction techniques through a series of practical experiments.

Course Format

This 10 week course meets for 6 hours per week with two hours dedicated to an general lecture period where the theory and application of various high speed cameras, recording schemes and imaging devices are presented. This is followed by a 4 hour laboratory where specialized or improvised instruments demonstrating the lecture material are put to practical use. The primary objective of these lectures and hand-on experiments is for the students to gain an appreciation for the hardware, the applications and data reduction procedures associated with basic high speed techniques and to report their findings in professional quality technical reports.

Topics presented

1. The topic of high speed photography is introduced in terms of basic concepts associated with the measurement of time. This is accomplished by first discussing principles of measurements in general and measurements of time in particular along with and basic calibration concepts. To make the topic relevant to the student's background, the design and operation of leaf and focal plane shutters is presented, focal plane shutter distortion, the moving subject as its own shutter, accounting for magnification and signal-to-noise considerations are topics covered in the lecture portion of the week. During the weekly laboratory students calibrate their camera's shutter basing their work on audio and video standards as the tools of measurement supplemented with a commercial shutter tester.

2. In the next project the application of calibrated timing devices (the camera shutters calibrated the previous week) to solving unknown subject rate of motion problems is presented. The advantages associated with purposeful introduction of blur in photographs is discussed. Introduction of scales in the subject and magnification are addressed in the context of making photographs "magnification" independent. Also, conflicts between image size, measurement accuracy and synchronization of event with available exposure time are raised. During the laboratory portion the students photograph a car moving at various rates to check speedometer accuracy and also determine the falling and rotation rate of a maple or oak seed (propeller seed) with nothing more complex than a regular (calibrated) camera shutter and the introduction of deliberate blur into the photographs.
3. Concepts of sharpness and image resolution, control of subject motion induced image blur are reintroduced in relationship to photographing ballistic and splash phenomena. In the lecture portion of the project, basic theory behind electronic flashes and spark gap light sources, their design and operating parameters, synchronization devices for light, dark or sound activation plus control of delay are covered.

In the hands-on portion of the project the students become acquainted with EG&G Microflash spark gap light sources and apply them in a group setting to photograph the impact of .22 caliber supersonic bullets on various soft subjects such as vegetables, etc. Individually they use their own, powered down, electronic flashes to make photographs of splashes with delay-equipped, dark activated, synchronizers.

4. The theory of animation, the motion picture camera and the video camera are discussed in lecture, demonstration and laboratory format over a period of two weeks. Time magnification is presented as it relates to both time-lapse, video and also high speed motion picture and video photography. Design and operating characteristics of high speed intermittent and rotating prism cameras, comparisons between available photographic, videotape and solid-state or digital instruments, voltage vs. framing rate vs. expended film and elapsed time charts are presented, use of timing lights and event synchronizers, establishment of appropriate lighting levels and power requirements plus safety concerns are covered. Students use high speed cameras such as Fastax, Hycam, Nova, Photosonics, etc. and make a "qualitative" film, and a high speed videotape using a Kodak Ektapro 1000, from which they also are required to make a quantitative analysis of subject behavior.

5. The photographic strip-chart recorder or streak camera is discussed as a potentially useful yet highly underrated analytical tool for precision measurements of elapsed time, simultaneity, velocity and acceleration, frequency, luminance, etc. Streak photography and velocity recording cameras are covered with particular reference to rotating drum and rotating mirror high speed streak cameras and advantages/disadvantages of all camera types are covered. Capping shutters, synchronization characteristics, "always alert", multi-exposure and color systems are mentioned. In the laboratory, students use a simple rotating drum camera to determine the velocity of small gauge rifle bullets of two different calibers. These are fired in succession from a single gun in close vicinity to markers in subject space located a known distance apart.

6. The potential of using a mechanical stroboscope or repeating flash as an industrial visualization or measurement tool is introduced in a general lecture on such techniques. The pioneering work of "Doc" Edgerton is an integral part of this lecture including a demonstration of a "piddler" slowed down with electronic as well as mechanical stroboscopes.
Advantages and disadvantages of the stroboscope as a motion analysis tool are covered and applications of multiple images on stationary as well as moving film are described and illustrated. The "problem" of the dark interval between flashes is given particular emphasis.

The application portion of this technique is demonstrated in an experiment based on moving-film stroboscopy (students use their own cameras, rewinding the film with the shutters locked open while the action takes place) where the subject is a sewing machine operated at various (unknown to students) rates and to the needle of which a small incandescent lamp is attached to positively track the motion of the needle over time.

7. Requirements, design, construction and operating principles behind various ultra high speed cameras is presented by way of a lecture. Included are rotating drum, rotating mirror framing cameras, image dissection techniques and application of image tubes for recording at 1 frame per microsecond and faster. Students work with a rotating drum Dynafax high speed camera to record the passage of a supersonic bullet across a 12 inch diameter Schlieren field and from the record they determine the velocity of the bullet.

8. Finally, expanding on the streak camera, strip photography and line-scan electronic imaging devices are introduced as a high speed imaging solution especially as applied photofinish and synchroballistic photography. The students apply this technique to determine the velocity of self-built model rockets launched in a laboratory-simulated, photo-instrumented, ballistic range using a rotating drum strip camera. The camera is equipped with a capping shutter timed so that it opens just as the rocket's image is about to reach the camera's slit and which closes shortly after it passes the slit. This is to prevent rewrite that would be caused by the image of the exhaust fumes overwriting the image of the rocket recorded in a previous rotation of the drum.

Grades and examinations

There is a midterm exam intended to familiarize students with the course subject matter and the style of questions that are associated with the course. It is simply given as an exercise. In addition, there is the opportunity for students to design and carry out one independent project expanding on any topic included in the course or to investigate high speed topics not covered.

Finally, the course grade is determined on the basis of the completion in a satisfactory manner of class experiments substantiated by the submission of written project reports. The final written exam, covering all the topics of the course, is offered to all students but is not required to pass the course if the reports are of substantial quality. However, the highest course grade can only be earned by opting to take the final exam and turning in an above average performance on this exam.
Conclusion

Students in the Imaging and Photographic Technology program of study at the Rochester Institute of Technology complete an introductory course in high speed photography and photonics which provides them with a general overview of various systems, techniques and instruments associated with the field. It is recognized that not many will become practicing professionals but the experiences gained in solving problems associated with high speed events, handling simple to sophisticated imaging devices, writing complete technical reports, presenting their findings and experiences to an audience, etc. add a dimension to their studies that serves them well in most any technical imaging field they eventually enter.

Bibliography

Davidhazy, Andrew; Tech Directions Magazine, "There is more to a blur than meets the eye!", Vol. 52, No. 6, January 1993, pp. 13-15.