

## Small Format Photography For Architectural Photogrammetry : A Review

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### Abstract

*Today small format photography have been used widely in many applications of close range photogrammetry. This paper describes the use of small format photography in architectural photogrammetry. A few low cost systems developed for small format photography are also discussed.*

### 1.0 INTRODUCTION

Traditionally most applications of close range photogrammetry have been carried out using metric cameras. These cameras have stable, known and repeatable interior orientation, defined by fiducial marks, and most are equipped with measuring or setting devices to be used for exterior orientation. Metric cameras are also designed primarily for photogrammetric purposes, and thus the obtainable accuracy is high. With the invention of the analytical plotter, the accuracy obtainable has increased due to the ability to correct for various systematic errors (lens distortion, film deformation) and the lack of dependence on optical and mechanical components. There are, however, situations where expensive metric cameras cannot be used. For example often the budget for an individual project will only allow for the use of a low cost camera system. Thus we should be looking for ways and means to free photogrammetry from the restrictions of conventional and expensive hardware. Today, this has largely been done and inexpensive non-metric cameras can be used in many application of close range photogrammetry. To allow this a number of data reduction approaches particularly suitable for non-metric photography have been accepted and these give highly accurate results.

Non-metric cameras are defined as cameras that are not specifically designed for photogrammetric purposes (Karara, 1980, Atkinson, 1989). Faig, 1975a, defined a non-metric camera as a camera whose interior orientation is completely, or partially, unknown and unstable. Non-metric cameras are easily identifiable by the lack of fiducial marks. Off-the-shelf, amateur and professional cameras fall into this category. Non-metric cameras have been used in many applications in close range photogrammetry and have made an impact on a large number of professions when measurements are required.

Nowadays the term non-metric should be questioned as the term implies a negative attribute. It has been shown however that where non-metric photography is combined with an appropriate data reduction system normally an analytical method, it can produce

accuracies close to those given by metric photography (Adam, 1980, Warner, 1989a, Georgopoulos, 1990).

Those non-metric, semi-metric or metric cameras that use light sensitive materials and whose format size does not exceed 80 cm x 80 cm are called **small format cameras**. During the last few years, small format cameras have become popular in photogrammetry. Compared with the larger format and normally metric cameras, small format cameras have the following advantages and disadvantages (Karara, 1979, Atkinson, 1980,1989, Georgopoulos, 1990):-

#### **Advantages**

- a. General availability (e.g small dimension, less weight and many makes).
- b. Some are motor driven allowing for a quick succession of photographs.
- c. Can be hand held and oriented in any direction.
- d. Flexibility of focusing range.
- e. The price is considerably less than that of the larger format metric camera.
- f. A large variety of emulsions is available in terms of light sensitivity.
- g. The process of taking the photographs is generally much faster because camera positioning is not critical. This enables the small format cameras to be used in a wider range of applications and under adverse working conditions.

#### **Disadvantages**

- a. The lenses are designed for high resolution at the expense of high distortion.
- b. Instability of the interior orientation.
- c. Lack of fiducial marks and a film flattening device.
- d. Absence of level bubbles and orientation devices which prevent the determination of the exterior orientation at the time of exposure.
- e. Need more exposures to cover a given area since coverage is limited due to the small format.
- f. Need more control points on the object which prolong the work onsite.

## **2.0 SMALL FORMAT (SF) CAMERAS**

Many types of SF cameras have been used in close range photogrammetry applications. A SF camera can be of single or stereometric form. Examples of SF non-metric single cameras are makes of 35mm cameras such as Pentax, Canon, Olympus, Nikon etc. Examples of SF metric cameras are Hasselbad MK70, Rolleiflex SLX, 6006 and 3003, and Wild P32. There are also SF stereometric cameras such as the Hasselbad SB40,SB120, Nikon TS-20, Officine Galileo Technoster A, Pentax ST-120V, Wild C40, C120 and P32/PBA32 and Zeiss(Jena) SMK 5.5/0808.

Normally, SF non-metric cameras use roll film while SF metric cameras can use roll film, sheet film or plates, depending on the manufacturer. The Polaroid films which allow instant photography can also be used in such cameras (Mustaffar and Newton, 1991) and

their use has been reported in several photogrammetric applications in archaeology and architecture (Waldhausl *et al*, 1987).

As mentioned, SF cameras have a number of disadvantages which have to be compensated for by special data reduction methods. The systematic errors which are caused by physical deviations from the theoretically correct central perspective are usually compensated for at the early stage of the data reduction of metric photography either using a compensation plate in analogue plotters or by photo coordinate refinement in analytical photogrammetry. Unfortunately most of these effects remain unknown for non-metric photography. Thus the compensation has to be integrated into the solution in order to avoid a loss in accuracy. There are several problems associated with SF non-metric cameras that have to be solved. The problems include poorly defined interior orientation, instability, irregular lens distortions, film deformation and unrepeatability of equivalent settings for multiple exposures, which make the analogue approach to data reduction and evaluation not feasible. Thus the analytical data reduction approach, which uses a combination of calibration and evaluation based on mathematical modelling is most suited for non-metric photography. The problems mentioned cannot be solved using the conventional approach of thoroughly calibrating the camera and then using the resulting parameters in the evaluation procedure.

The calibration procedures commonly used are pre-calibration, on-the-job calibration and self-calibration (Faig, 1989, Fryer, 1989). Pre-calibration represents the conventional calibration approach in a laboratory or using a test range. It provides a partial solution only of the effect of lens distortion, which is then treated as a known quantity in further evaluation. This is not suitable for the evaluation of SF non-metric photography. For the on-the-job calibration the procedure is much the same as for metric photography i.e the calibration and evaluation are either combined into one process or carried out sequentially. It requires a sufficient number of known control points around the object. Self-calibration, on the other hand, utilizes the geometric strength of overlapping photographs to determine the parameters of interior orientation plus lens distortion together with object evaluation. Further the geometric strength is used to determine the parameters of relative orientation. For absolute orientation, object space control is required. This is the most suitable method for the evaluation of SF non-metric photography and is used widely in bundle block adjustment with additional parameters.

Bundle block adjustment involves the simultaneous least squares adjustment of all bundles of rays, from all exposure stations, to all measured image points, and simultaneous recovery of the orientation elements of all the photographs and the adjustment to the object space control points (Faig, 1989). Bundle block adjustment requires the use of collinearity equations that ensure that the image point, the perspective center and the object point are all located on a straight line. Unfortunately the collinearity equations are non-linear and have to be linearised by a Taylor's expansion before solution. In addition, parameters must be introduced into the collinearity equations because image coordinate refinement due to deviations from the theoretical perspective projection due to e.g lens distortion cannot be applied. These additional parameters are

unknown for SF non-metric cameras and normally the deviations are variable from exposure to exposure. These additional parameters are therefore referred to as photo-variant. Thus a bundle block adjustment with additional parameters plus an analytical plotter represents an ideal combination for precision measurement of SF non-metric photography.

### 3.0 MEASUREMENT OF SF PHOTOGRAPHY

Close range photogrammetry consists of two major phases. These are : (1) acquiring data about the object to be measured by taking photographs and (2) measuring the photographs to produce maps or spatial coordinates. The SF cameras whether metric, semi-metric or non-metric are used to acquire photographs these cameras have to be calibrated using the calibration method described in the previous section.

Data reduction and evaluation of SF photography involves analytical methods which utilize the concept of bundle block adjustment with additional parameters. This concept is used as the basis for a number of low cost systems. Most of the low cost systems run on personal computers. Examples of low cost systems will be discussed later in this section. Analogue methods are not suitable for data reduction and evaluation because generally the analogue stereoplotter only accepts photography with small tilts. There can also be a problem defining the principal point and the principal distance. At present there are numerous software packages that have been developed for SF photography. Some of these use the bundle block adjustment with additional parameters, and some packages use the direct linear transformation approach. Examples of such software include STAR, CRABS.ESP, GEBAT-V, BINGO, DLT, ORIENT etc. A review of this software can be found in Faig, 1989.

#### 3.1 Low cost photogrammetric systems

Nowadays the prices of electronic equipment and computer hardware are being dramatically reduced. Most of the major manufacturers of photogrammetric instruments have either stopped producing, or stopped developing, terrestrial metric cameras. However, manufacturers have started producing analytical plotters for large format and small format photography. Usually, the analytical plotters are produced along with software for the data reduction process and interface to commercial computer aided design (CAD) packages (e.g AutoCAD, Microstation etc). More recently, manufacturers have started producing low cost photogrammetric systems, which also interface to commercial computer aided design packages.

At present there are a few photogrammetric systems available on the market. These systems are not very expensive compared to the existing systems. In addition, these systems have been introduced since there is seen to be a need for general accessibility to photogrammetry, especially in architecture (Felibaum, 1992). Also these systems offer a low cost solution, as well as being flexible, compatible, versatile and easy to use.

film. These systems can be divided into those which allow monoscopic measurements and those which allow stereoscopic measurements.

### 3.1.1 Monoscopic measurements

Monoscopic measurement allows the image coordinates to be measured using simple devices (see figure 1) and which is helpful for low cost photogrammetric systems. Such systems use self-calibration and also allow multi-image orientation. The orientation parameters are computed using bundle adjustment. Normal and convergent photographs can be used with these systems. Some of these systems use metric photography while others can accept both metric and non-metric photography. Normally measurements are taken from a digitising tablet (i.e using an enlarged photograph). Examples of these systems are FOTOMASS, ELCOVISION 10, ROLLEI MR2, FOTOCAD, PHIDAS and FOTO 3D.

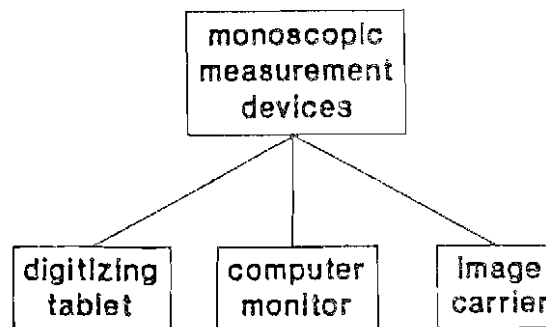


Figure 1 Device for monoscopic measurement (After Fellbaum, 1992)

### 3.1.2 Stereoscopic measurements

Stereoscopic measurement requires more complex measuring instruments and does not offer the option of multi-image orientation (Fellbaum, 1992). These systems can be divided into stereocomparators and analytical plotters. The analytical plotters can be divided into Image-Space-Plotters (ISP) and Object-Space-Plotters (OSP). The ISP works on a similar principle to the stereocomparator. In addition they are equipped with a computer which controls y-parallax compensation and preserves the image orientation. This compensation is calculated several times per second. The OSP works similar to an analogue stereoplotter, only a computer is used to control four servo motors and preserve the image orientation. The servo motors are used to eliminate y-parallax compensation.

In this system the measurement can be done on an image carrier (i.e use diapositive or glass plate), a digitising tablet (i.e use enlarged photograph) and a monitor (i.e use digital image)(see figure 2). Examples of this system are AdamTechnology MPS-2, Leica DVP, Alpha 2000, ASP 2000, FH BO, FM 1 + MR 2, PA 2000, STEREOBIT/20, Visopret 10 and Visopret 20.

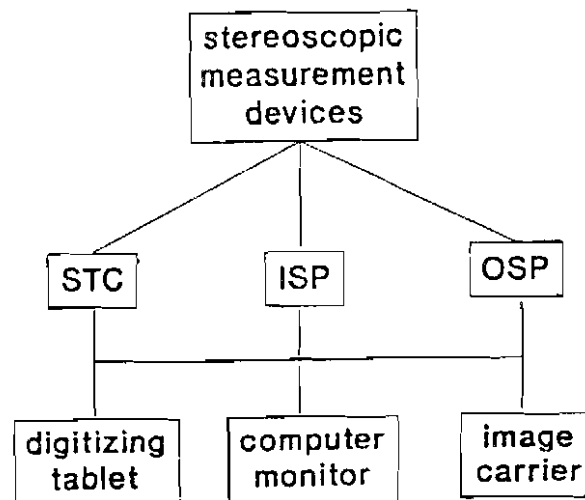


Figure 2 Device for stereoscopic measurement (After Fellbaum, 1992)

#### 4.0 ACCURACY OF SF PHOTOGRAPHY

The main limitations of SF photography are the unstable and unknown interior orientation and the unpredictable film unflatness. Acceptable accuracies can be achieved by calibrating the SF cameras, reducing the data using an analytical method and modifying the cameras themselves. Methods of camera calibration have been discussed briefly under SF cameras. Data reduction using analytical methods involves bundle block adjustment with additional parameters. This method utilized sufficient object space control enclosing the area. At present this method is the most commonly used in low cost systems for SF photography. The camera can be modified by adding fiducial marks or incorporating a reseau glass in the focal plane, thus enabling the user to easily determine the geometry of the camera (eg. Aicher et al., 1974, Gates and Jones 1980, Wester-Ebbinghaus, 1980b, Georgopoulos, 1990). A modified camera is known as a semi-metric camera. Semi-metric cameras can also be used with the software packages that are designed for SF non-metric cameras.

Investigation were carried out in 1976 by Kolbl regarding the accuracies obtained from a number of photogrammetric systems. He stressed that the restitution method should be investigated and not whether a metric or non-metric cameras should be used. Other investigations have shown that acceptable accuracies can be achieved with an appropriate data acquisition and data reduction systems. Karara and Abdel-Aziz, 1974, state that essentially one has to : (a) select a suitable configuration for data acquisition, (b) provide the necessary object space control, (c) counteract possible internal instability of the camera by combining calibration procedures with the measuring process and (d) select a suitable mathematical model to correct for the effect of lens distortion and film deformation. In an investigation, four SF non-metric cameras were used and compared with a metric camera. It was shown from the result that the accuracy was completely acceptable (Karara and Abdel-Aziz, 1974). Thus the SF non-metric cameras can be used in close range photogrammetry. Today the accuracy of SF photography when combined

with an appropriate data reduction system, is capable of producing an accuracy close to the accuracy attained by a system which utilizes metric photography.

## 5.0 APPLICATION OF SF PHOTOGRAPHY IN ARCHITECTURAL PHOTOGRAMMETRY

The term photogrammetry was introduced by Albert Meydenbauer, a German architect. He undertook the first photogrammetric survey of Wetzlar Cathedral. After his finding, photogrammetric methods have continue to evolve. Today the applications of architectural photogrammetry have undergone considerable expansion both in scope and diversity. With the advances in technology of computer hardware and software, nowadays, architectural photogrammetry is not limited to special cameras and special instruments anymore. Most types of cameras with its flexibility can be used in architectural photogrammetry (Waldhausl, 1992).

The main role of photogrammetry in architecture is in the producing line drawings of elevations and sections, preservation and reconstruction of historic buildings and monuments (Dallas, 1980). At present various efforts worldwide are made so that the method of recording and surveying historical buildings and monuments as simple as possible. Digital photogrammetry is being increasingly applied in architectural photogrammetry.

According to the Standard Specification for Architectural Photogrammetric Survey (Dallas, 1988), all photography should be taken using metric camera. Unfortunately, the cost of metric cameras whether single or stereometric cameras are expensive and they are generally heavy and cumbersome. Nowadays, quite often SF cameras are used in many applications of close range photogrammetry including architectural photogrammetry. As mentioned in section 2.4, the accuracy produced by SF photography is close to accuracy produced by metric photography. Also, SF cameras are used because they offer advantages such as light weight, flexible, manoeuvrable, more widely available, cheaper and can be hand held compared to metric cameras. In the following paragraphs, some examples of the use of SF cameras in architectural photogrammetry are cited. In United Kingdom, the first application of architectural photogrammetry was done by E.H. Thompson in 1962. He used the method of photogrammetry in the restoration of Castle Howard's dome. In 1940, the dome was damaged by fire. In his work, he also used non-metric photographs and he worked out the ground coordinates for the original camera positions. Then he measured the coordinates of points in the photographs and the correct dimensions of the dome could be recovered.

Another example of SF camera used in architectural photogrammetry is the surveying of West Window of York Minster (Dallas *et al*, 1983). In this work the drawings of both the interior and exterior stonework tracery. The photographs were taken using Rolleiflex 6006 camera. Also, it have been reported that SF non-metric cameras are used in architectural work for recording simple facade (Shutter and Redelius, 1970, Dallas, 1980). In Australia, an architectural plots and profiles of the sections of a century old

church known as 'Scot's Kirk' was produced (Fryer, 1990). Part of the church main entrance was deemed unsafe following an earthquake and in need of demolition and rebuilding. The photographs were taken using SF Hasselbard 500 ELX non-metric camera with format of 70 mm x 70 mm and observations in MPS-2 were made. A 35 mm Canon AE-1 non-metric camera was also used to record Hadrian's Gate, a simple but important monument of Athen (Georgopoulos *et al*, 1988). The Omayad Mosque and the Citadele of Damacus were recorded using SF non-metric Rollex SLX (Stephani and Eder, 1988).

Most historic monuments are sited in areas of heavy human and vehicular traffic. However, this problem is universal. An example of this case is in the production of Raffles Hotel facade plan (Koo, 1991) (see figure 3). In his work, the photographs were taken using SF Wild P32 metric camera and BINGO software was used. In conclusion, nowadays, SF photography is widely used in architectural photogrammetry. However, SF photography will never be suitable for surveying large buildings.

### 6.0 Summary

In general the accuracy required in close range photogrammetric work can now be achieved by SF cameras. In architectural photogrammetry, SF photography is now being widely used. Due to the limitation of SF cameras, they will never and under no circumstances replace completely metric cameras, especially in architectural photogrammetry. However, the future for SF cameras is bright. Also, SF cameras can be used in cases previously thought not suitable. The wide range of objects, cameras and applications lead to a variety of methods and systems been developed. Hence SF cameras can play an important role in expanding the use of photogrammetric techniques.

At present there are many reports on practical applications of SF cameras for close range photogrammetric work. There are many software packages purposely designed for SF photography and the prices of electronic equipment is decreasing. Many attempts are underway to prove that SF photography can be used in many applications of close range photogrammetry. Today the photogrammetrist is equipped with a relatively cheap, simple, friendly and easy to use system. Other scientists in numerous fields can also make use of the technical and economical advantages of SF photography.

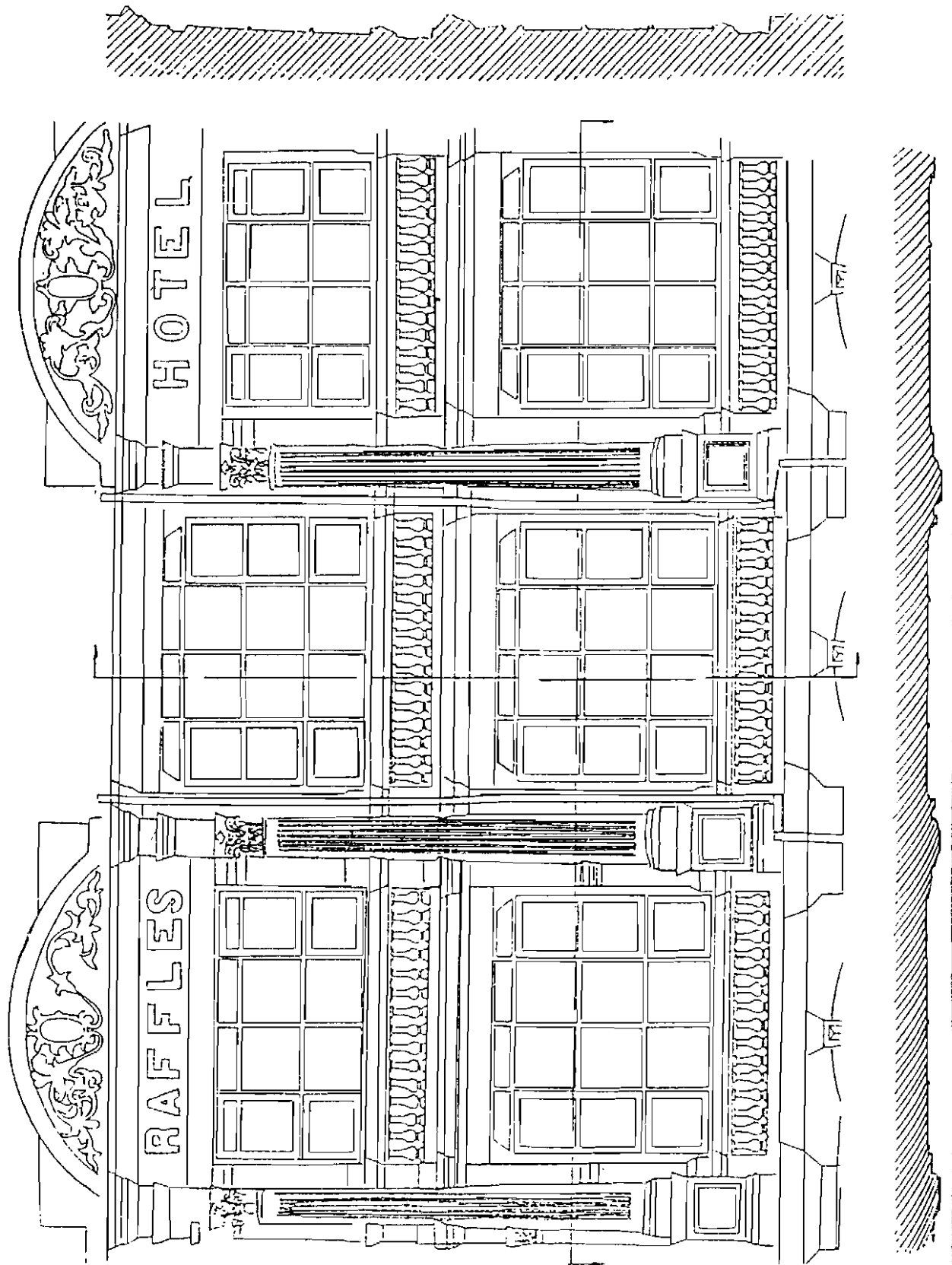


Figure 3 Raffles Hotel facade plan (After Koo, 1991)

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