# Digital True Orthophotos Generation

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**Key words**: Orthoimage, orthophoto, true orthophoto, Z-buffer, occulted area.

## SUMMARY

Orthophoto is a photographic document on which effects of terrain height and camera attitudes are removed. It constitutes hence a document on which precise measurement can be done similar to the map. With the advances in digital techniques, digital orthophotos are becoming very popular within the GIS community. However, as orthophotos do not generally take into account the surface model in the rectification, superimposition of vector data on orthos in urban or sub urban areas is unsatisfactory, mainly when height differences are important. The generation of digital true orthophotos using a digital surface model is the only way to correct these effects.

This paper aims at developing software for the establishment of digital true orthophotos. First, a review of different approaches developed for the generation of true orthophotos is given. The Z-buffer approach that has proved to be efficient in detecting and dealing with hidden and occulted areas on the aerial images is adopted in this paper. The technique is based on the fact that forward features, near to the perspective centre, will hide backward features on the object surface. Therefore, a Z-buffer matrix is built, which memorizes, for each pixel, the minimum distance between the camera and the surface along the perspective ray. Hence only the first point of the surface met by the perspective ray will appear on the orthophoto image; the other points on the surface along this same ray are occulted and will be omitted and their corresponding pixel on the ortho are considered void. The different modules of the software were developed in C language, and experiments were conducted on aerial photos at scale 1/7500 flown on a sub urban area of Meknès region in Morocco. To generate the digital orthophoto, a digital terrain model (DTM) derived by conventional photogrammetric stereo plotting was combined with 3D building stereo plotting to build a digital surface model (DSM) used in the ortho rectification process. The quality of the generated orthophoto was based on the root mean square error computed from differences on check point's coordinates measured on the orthophoto against those determined by conventional surveying methods. Vector data acquired by conventional stereo plotting is also superimposed on the generated true orthophoto and has shown perfect correspondence of features.

**RESUME**

L'Orthophoto est un document photographique sur lequel les effets du relief et de l'attitude de la camera ont été éliminés. Il constitue ainsi un document sur lequel des mesures précises peuvent être faites. Avec le progrès dans les techniques numériques, l'orthophoto numérique est devenue très populaire parmi les utilisateurs SIG. Cependant, comme l'orthophoto ne prend pas généralement en compte le modèle surface dans la rectification, la superposition des données vecteur sur l'orthophoto en milieu urbain ou péri urbain n'est pas satisfaisante, surtout quand les différences d'altitudes sont importantes. La génération de vraies orthophotos utilisant un modèle de surface devient le seul moyen pour tenir compte de ces effets.

Cet article vise à développer un logiciel pour l'établissement de vraies orthophotos. D'abord, une revue des différentes approches pour générer les vraies orthophotos a été présentée. L'approche Z-buffer qui a prouvé qu'elle est efficace pour détecter et prendre en compte les zones occultées dans l'image a été adoptée dans ce travail. La technique est basée le fait que les détails en avant, proches du centre de perspective, cachent les détails en arrière sur la surface objet. Par la suite, une matrice Z-buffer est crée, qui mémorisera, pour chaque pixel, la distance minimale entre la caméra er la surface le long du rayon perspectif. Ainsi, seul le premier point rencontré par le rayon perspectif apparaître sur l'orthoimage ; les autres points de la surface le long du rayon perspectif seront cachés et seront donc omis et leurs pixels correspondants sur l'ortho seront nuls. Les différents modules du logiciel sont développés en langage C++, et une validation a été menée sur des photos aériennes à l'échelle 1/7500 couvrant la région de Méknès, Maroc. Pour générer la vraie orthophoto, un modèle numérique de terrain (MNT) dérivé par méthode photogrammétrique conventionnelle a été combiné avec la restitution 3D pour extraire le modèle numérique de surface (DSM) utilisé dans le processus de rectification. La qualité de l'orthophoto générée est évaluée à l'aide de l'erreur moyenne quadratique calculée à partir des différences de coordonnées sur les points de vérification. Les données vecteur disponibles à partir de la restitution ont aussi été superposés sur la vraie orthophoto et ont révélé une parfaite superposition.

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## 1. INTRODUCTION

The recent advances during the past few years in digital imaging and computing technology have brought significant changes in the mapping domain. This has made the orthophotography an interesting alternative to line mapping that has evolved with the generation of digital orthophotos. Digital orthophoto production provided a larger flexibility taking mainly advantage of computing and digital image processing techniques. The major advantage of orthophotos is that they can be produced rapidly providing thus an eye pleasing and up-to-date document that portrays an impressive and huge display of geographic data.
Orthophoto production nowadays is less expensive than line mapping with shorter production times due to the high degree of automation reached.
Many users are utilizing these images for GIS maintenance, municipal planning, hazard mapping, disaster planning and generally for any urgent planning purposes within short time, whereas line maps would not be at hand due to longer production time. If vector information is necessary, digital orthophotos can still be used to extract this information by a simple head up digitizing, mainly if the accuracy requirements are not too high.
The geometric accuracy of orthophotos depends primarily on the quality of the DTM describing the terrain surface. Therefore, a user of orthophoto data should be aware of the effects inherent to orthophotos such as misplacement of objects that are not modeled by the DTM.
In fact, when the terrain surface is subject to sudden elevation changes, users may notice problems that might limit the user ability to take full advantage of the orthoimage because of discontinuities in data portrayed in some areas. The artifacts are due to buildings that might lean over other areas obscuring thus important data. Bridges also might lean or bend and appear to be displaced from their true location. To sum up, any feature that is does not lay flat on the ground might have a warped or displaced appearance.
The reason is that, buildings, bridges and all man made structures cannot be correctly modeled by conventional Digital Terrain Models, as conventional ortho rectification typically uses DTM with regularly spaced points that do not account for sudden elevation changes and then do not adequately model small features. This results in displacements and occlusions that alter the perfect superimpose of vector data on the orthophoto for checking and change detection purposes. The solution is the generation of true orthophotos using digital surface models (DSM) instead of digital terrain models (DTM).

## 2. PROCESS OF TRUE ORTHOPHOTO GENERATION

True orthophotos are orthophotos on which all the defects are corrected included the leaning due building heights and on which every object is in its correct geometric position on the document.
Several methods have developed to generate true orthophotos. All the methods are based on the same general concepts and principles that go through the following steps:

- Orthogonal projection using a Digital Surface Model that takes into account the sudden elevation changes of man made structures.
- Detection of occulted areas.
- Merging of adjacent images to fill in the gaps and missing parts

### 2.1. Orthogonal projection using a DSM

Having an adequate DSM, elevated features are projected in their correct geometric positions (fig 1.1).

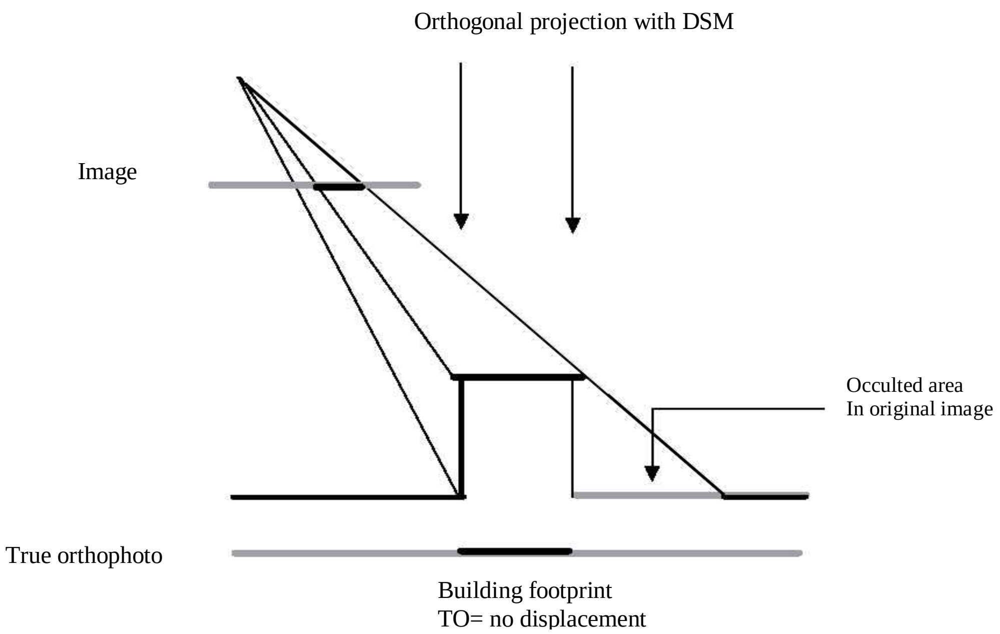


**Figure 1.1:** True orthogonal projection using a DSM

However, even with a precise DSM, a true orthophoto is not guaranteed. In fact, if hidden zones are not detected and corrected accordingly, the gaps are simply filled with the same image leading to a doubling image. Hence, in fig (1.2), the radiometric value of point Q is stored twice: the value is stored in Qo first when rectifying point Q, then it is stored again in Po when rectifying point P.

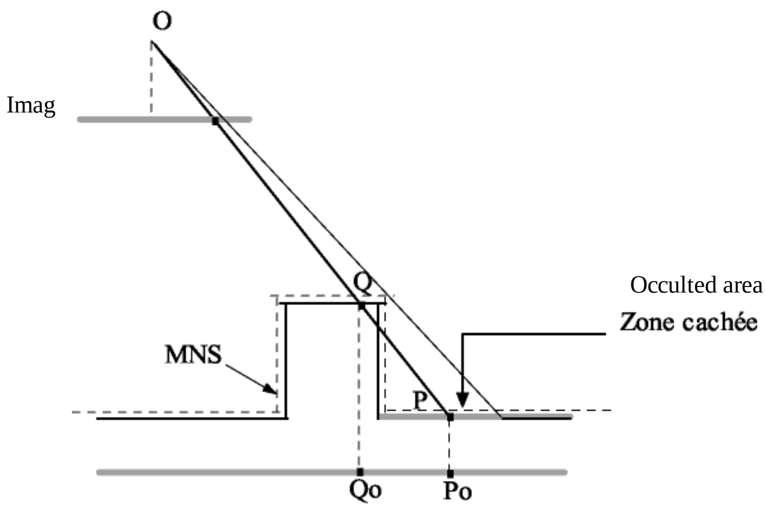


**Figure 1.2:** Ortho rectification in case of occulted areas

## 2.2. Detection of occulted areas

To ovoid double images, occlusions have to be detected. The detection of occluded areas is based on the visibility analysis by tracing perspective rays from the top surface back to the perspective centre.
In general, a widely used method for visibility analysis is the Z-Buffer algorithm (reference….). In this algorithm an image matrix, with same resolution as the image, is created and Orthophoto ith a predefined background value. Each pixel is filled with the corresponding Z distance, but only in cases where the existing Z value is greater than the current value. Hence, only pixels whose rays don't intersect any other feature in their way back to the perspective centre are considered. The occulted areas are also automatically marked as part of the orthophotographic production. The most obvious defect is the double mapping in occluded areas

## 2.3. Merging and mosaicking of orthoimages

When producing orthophotos from individual images, these orthophotos might have gaps and missing information due to occulted areas in the images. The missing information is however available on adjacent orthophotos, it is therefore necessary to merge different orthoimages. One of the approaches generally used is the one based on the view angle rule. In this approach the grey value assigned to a given pixel on the orthoimage is the value taken from the image on which the corresponding point has the narrowest view angle (fig. 1.3) (Yougwel, Peng and Georgy, 2003)

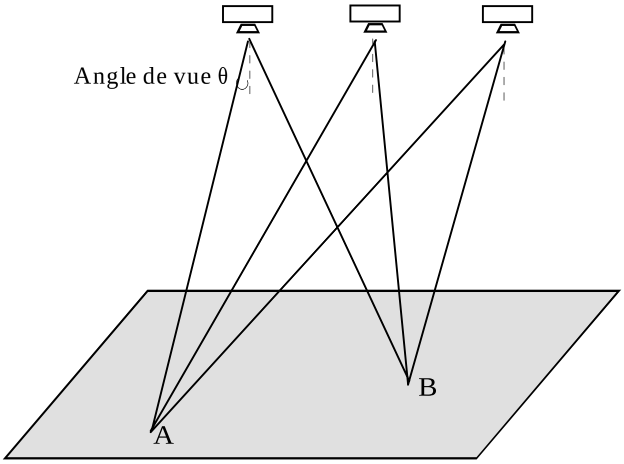


**Figure 1.3:** View angle rule used to merge ortho images

## 3. REVIEW OF METHODS USED TO GENERATE TRUE ORTHOPHOTOS

True orthophotos are photographic documents on which all the defects are corrected, including the leaning due building heights; and hence every object is in its correct geometric position on the document. Several methods have developed to generate true orthophotos, some of which are reviewed hereafter.

### 3.1. Method based on Z-buffer

The Z-buffer algorithm is a technique based on the fact that objects in lesser depth hide those with greater depth with respect to the observer. Hence, when processing, for each pixel we compute its depth and we compare it to the depth previously computed for this location. For that location, only the pixel with the lesser depth is retained. To detect the occulted areas, this algorithm is integrated in the indirect method (top down method) of the collinearity for the rectification using a digital surface model. A digital Z-buffer matrix, with the same resolution as the original image, is created for the image and stores the minimal distance between the perspective centre and the surface for each pixel (Yougwel, Peng and Georgy, 2003).

### 3.2. Method based on dense digital terrain models

This method was introduced by Ecker (1992) and further investigated by Skarlatos (1998) and uses digital terrain model with fine resolutions. The principal disadvantage of this method is the acquisition of very dense DTMs which has to be done manually as the automated methods produce bad effects.

### 3.3. Method based on the merging of terrain and buildings orthophotos

In this method, the digital terrain model (DTM) and the digital building model (DBM) are processed separately. Buildings are correctly rectified using the DBM, leading to a true orthophoto of building and that does not show any information regarding the surrounding terrain. On the other hand, a DTM is used with the original image, but where buildings are masked, to create a conventional orthophoto with areas corresponding to building are filled with the mask value. The merging of the two orthophotos will give the final true orthophoto (Amhar, 1998). In case building occult each other, in depth visibility analysis using digital surface model (DSM) resulting from the combination of DTM and DBM becomes necessary.

### 3.4. Method based on a segmented digital surface model

The method is part of automated method for the generation of true orthophotos (Boldo, 2003). It is based on enhance digital surface models acquired by correlation or LIDAR systems. The result of the segmentation is an image of identifiers or labels that associate each pixel to a region number. The detection of occulted areas is base don the tests of labels values.

### 3.5. Method that generates orthophotos from a sequence of oriented images

In this method all the images covering the area of interest are used in one step to generate the orthophoto (fig. 1.4). The concept governing the method is that for a point the grey value is taken on the image whose perspective centre is the closest to this point. To prevent double mapping of pixels, once a pixel is rectified it is prevented from being used again from other images. For this purpose, a flag image is created to store the pixels used and avoid their use another time (Boccardo et al, 2000).

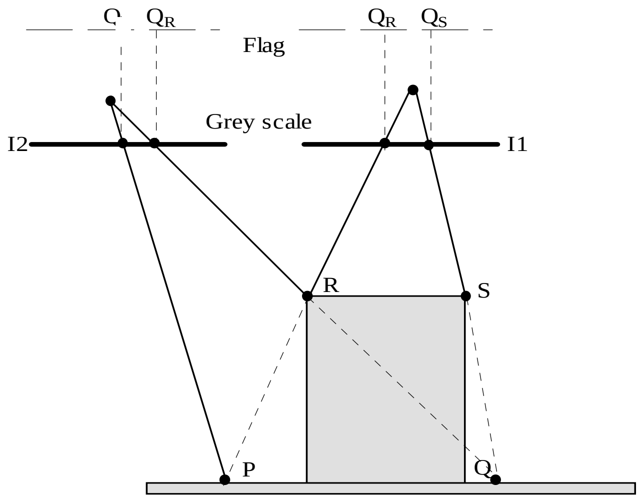


**Figure 1.4:** Concept used to generate true orthophoto from a sequence of photos

## 4. IMPLEMENTATION OF VOP SOFTWARE

### 4.1. Software characteristics

VOP is software developed to generate true orthophotos. Its computing modules were developed in C++ language and the graphic interface with Visual Basic language.
The methodology adopted software is based on the steps explained above and presented by the following flowchart (fig. 3.5).

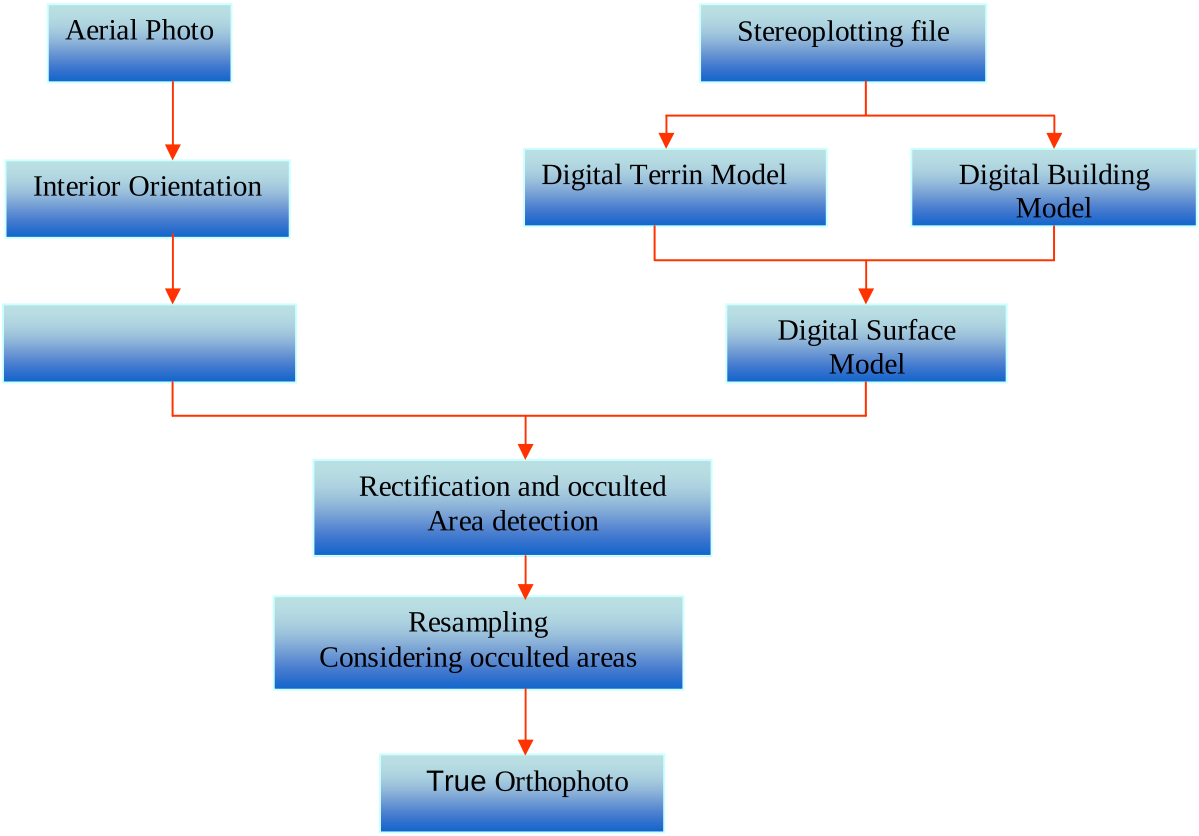


**Figure 1.5:** Flowchart of the main steps for the true orthophoto production

The different steps to generate true orthophotos are accessible through the main menu of the developed software presented in fig. (1.6).


**Figure 1.6:** Main menu of VOP software

### 4.2. Validation of the software

The validation of the software developed was done using photos flown at 1/7500 scale with 152.0 mm. camera focal length. These photos were scanned at 1270 dpi resolution. The test area presents buildings with heights varying between 4 m. and 8 m.

The digital surface model (DSM) used to generate the true orthophoto was derived by combination of a digital terrain model (DTM) acquired by conventional photogrammetric sampling and a digital building model (DBM) taken from a 3D the stereo plotting of the area. The true orthophoto generated has an RMS of 0.15 m computed from coordinate differences of check points.

A visual evaluation shows that when superimposing vector stereo plotting with the digital true orthophoto all features (including buildings) are in their correct position (fig. 4.22); whereas in the conventional orthophoto, only features with insignificant height differences superimpose with their homologous on the orthophoto, buildings particularly are largely displaced (fig. 1.7)

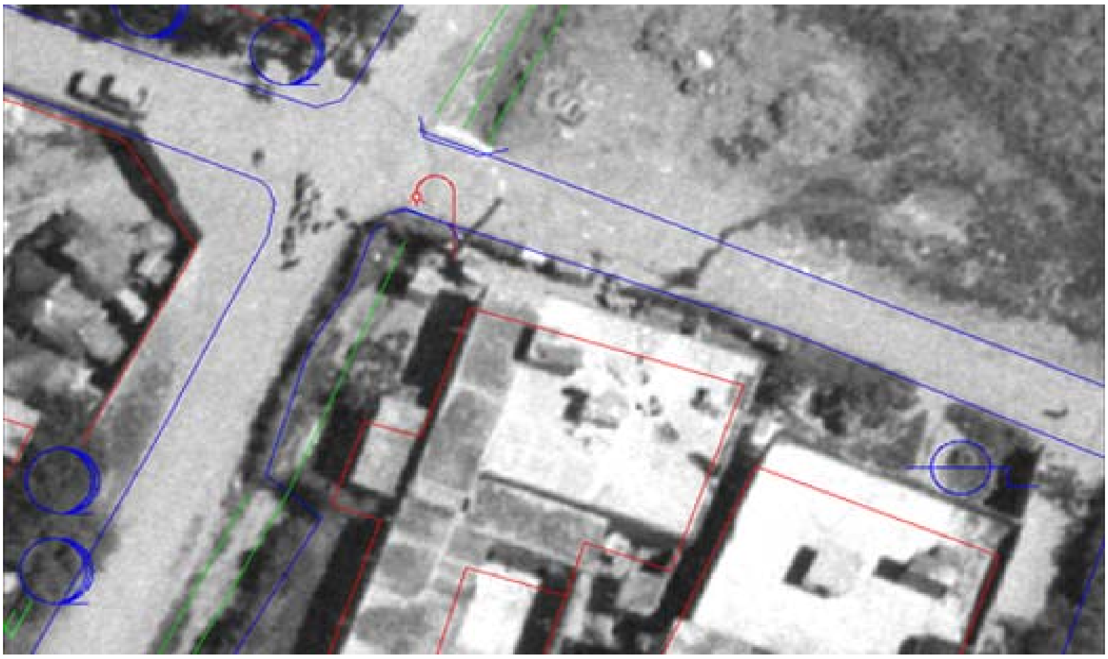

**Figure 1.7:** Displacement of buildings on conventional orthophoto

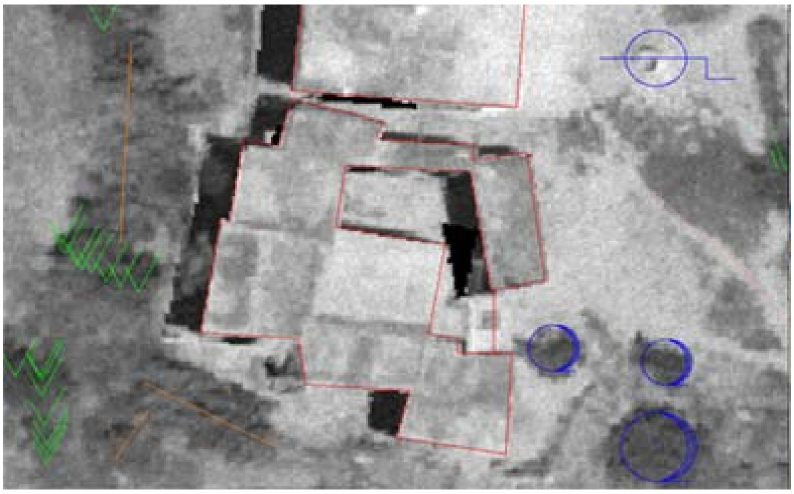

**Figure 1.8:** Superimposition of vector data on true orthophoto

## 5. CONCLUSION

The software developed was the Z-buffer algorithm which proved to be efficient in detecting occulted areas. In order to detect all occlusions and to fill in all the gaps it is necessary to have higher longitudinal and lateral overlaps. The cost related to the production of true orthophotos is mainly determined by the effort to produce the digital surface model and also by extension of the overlaps. Because of the higher cost induced by this, generation of true orthophotos can be limited to urban highly populated areas with man made structures presenting significant height differences.

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## BIOGRAPHICAL NOTES

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