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Automatic extraction of tents during Hajj from airborne images to support land use optimization

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Abstract

With the huge number of pilgrims performing Hajj (Islamic Pilgrimage), the use of urban space is a major concern for engineers, urban designers, and urban planners. Pilgrims must stay in the Holy Area (Arafat) for one day as part of Hajj rituals. For this reason, pilgrims are housed in lightweight temporary structures: tents. In Arafat, these tents are constructed before each Hajj season. The arrangement of these tents differs from one year to another and from location to location. For the spatial and temporal constraints of ritual happening in Arafat, space optimization is an important issue. The extensive demand for a rapid, automatic, and high quality algorithm for feature extraction has been the subject of much recent research. In this paper, we present an approach for detecting and extracting tents using airborne images. The approach is used to calculate the areas covered by tents. It utilizes the intensity in digital images in two stages. First, it classifies tents from other features in Arafat's environment. Second, it calculates the number of tents based on image matching subroutines. This can evaluate the design and planning of tents' layout and space optimization. Using this automatic approach, the number of pilgrims in a tested area can also be estimated according to the average capacity of one-meter squares covered by tents. Moreover, services, utilities, and transportation needs can be determined more precisely. An actual sample area in Arafat during the Hajj season is used to test the approach developed in this research.

Keywords: Feature extraction; Image understanding; Hajj; Land use optimization; Image matching

1. Introduction

Hajj is one of the five pillars (central duties) of Islam. It is a set of acts of worship to be performed in and around Makkah at least once in a lifetime by every Muslim who satisfies certain conditions. The nature of today's Hajj (Islamic pilgrimage) requires substantial planning and effort to provide support and infrastructure [3]. Hajj is one of the world's largest annual events. Over two million pilgrims gather every year at the same time to perform their religious duty within a circumscribed urban space.

An important challenge facing Makkah's local authorities during this time is providing adequate temporary housing for pilgrims in the Holy Environs near Makkah, including Arafat and Mina. Pilgrims have to spend two or three days in Mina, and one day in Arafat. According to Islamic literature, staying in Arafat is one of the pillars of Hajj. Pilgrims must stay in Arafat part during the ninth day of the twelfth month of the lunar calendar named Thul Hijjah. These spatial and temporal constraints require pilgrims to stay in lightweight structures (tents) (Fig. 1). However with the increasing number of pilgrims and the limited space of Arafat, space utilization is a serious concern. Several years ago, the Saudi government constructed fixed tent structures in Mina; in Arafat the tents are erected and taken down annually. The design and planning for a tent camp vary from year to year. In some cases spaces are not utilized efficiently or the design causes overcrowding without providing adequate space for circulation and services.

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Fig. 1. An aerial image of Arafat area showing its spatial limits (Courtesy: Space Imaging Middle East).

Urban designers, planners, and decision makers are increasingly dependent on software applications to support their decisions. However the use of these applications is limited by the availability of updated and reliable field data. They need tools to calculate the space covered by tents in order to evaluate the way that constructed camps are utilizing space. Such a tool is necessary to evaluate the situation of previous years and also to help in the design, planning, and construction of tent camps in the future. Meanwhile tent space calculation facilitates the estimation of the services and utilities needed for these camps. Counting tents is a faster way of calculating the spaces covered by tents, because the area of a single tent is known in advance. Doing this manually is a time-consuming and labor-intensive process. This paper presents a means of counting tents automatically from airborne images.

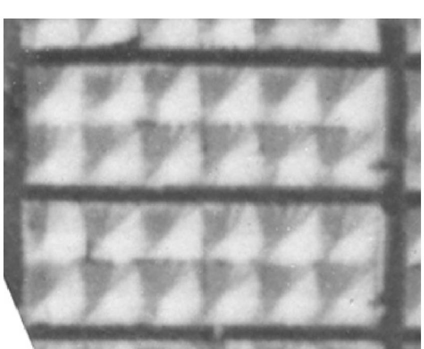

Fig. 2. Sample airborne image of a tent camp.

2. Methodology

In this research, a matching algorithm is utilized using digital aerial images in order to estimate the number of tents in a sample area in Arafat. Three sample aerial photographs of different locations in Arafat are selected, then scanned and transformed into a digital form. From each sample aerial image (Fig. 2) a tent template (Fig. 3) is extracted to simulate the reality and minimize any radiometric affects. This template will be passed over the tested image and for each pixel the matching function will be computed.

Cross-correlation matching is an algorithm to locate corresponding image patches based on the similarity of gray levels [4,6]. The cross-correlation approach computes the matching function between the template and the corresponding

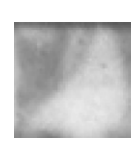

Fig. 3. A sample tent template.

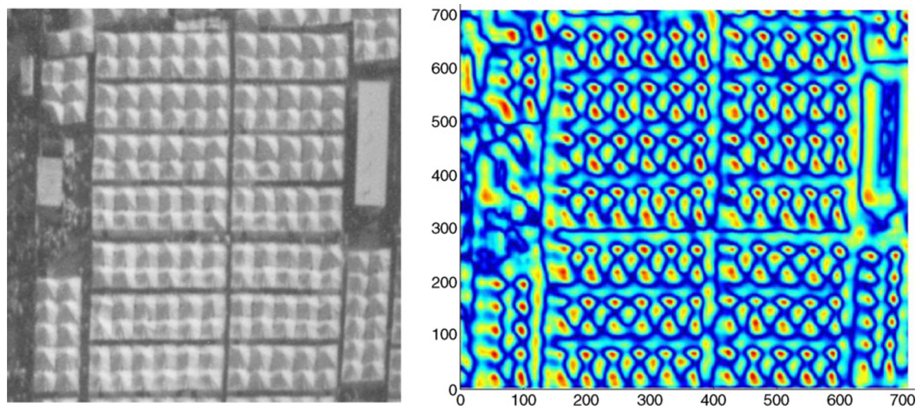

Fig. 4. 2D colored map of the match function of Sample 4.

window. The cross-correlation matching function over two windows of N pixels each can be written as:

$$C_{uv} = \frac{\sum_{i=1}^{N} (u_i - \bar{u})(v_i - \bar{v})}{\left[\sum_{i=1}^{N} (u_i - \bar{u}) \sum_{i=1}^{N} (v_i - \bar{v})\right]^{1/2}}$$

Where : C_{uv} : Match function between the template window (u) and the image window (v).

u_i, v_i : Intensity value at position i.

$\bar{u}, \bar{v}$: Mean intensity value of the window $\frac{\sum_{i=1}^{N} u_i}{xN}, \frac{\sum_{i=1}^{N} v_i}{N}$ respectively.

The ideal template is passed through the image and the matching function will be computed and recorded at the center pixel of the patch. The match function ranges from + 1 to − 1. The max value equals + 1, which means there is a full match between the two windows; in other words, they are identical [8,2,9]. During this research we neglected the values below zero since they are useless for this application. The matching function results of two processed samples are shown in Figs. 4 and 5. Fig. 4 shows the 2D colored map of the matching function results while Fig. 5 shows the 3D representation. A threshold is used to distinguish matches from non-matches. Then the pixels with a cross-correlation above the threshold are considered candidates for the match. To get the number of tents, another processing step has been performed. A maximum filter is passed over the matching function results with a window size that is similar to the template size [1,7,5].

3. Results

The approach utilized to calculate the number of tents in this research showed acceptable results (Figs. 6 and 7). A black dot is drawn automatically at the center of a matched tent, indicating that a tent match has been found. Fig. 6 shows the matches of Sample Area 1. In this sample area all tents are identified.

Fig. 7 shows the matches of Sample Area 4. In this sample area 94% of the tents are identified. The actual number of tents in the sample is 193 tents. The number of matches using the approach is 189 tents. The successful number of matches is 185 tents. The number of false matches is 4. The number of missing tents is 8.

Table 1 summarizes the results of implementing the approach on the tested areas. For the sample tested area, the table shows

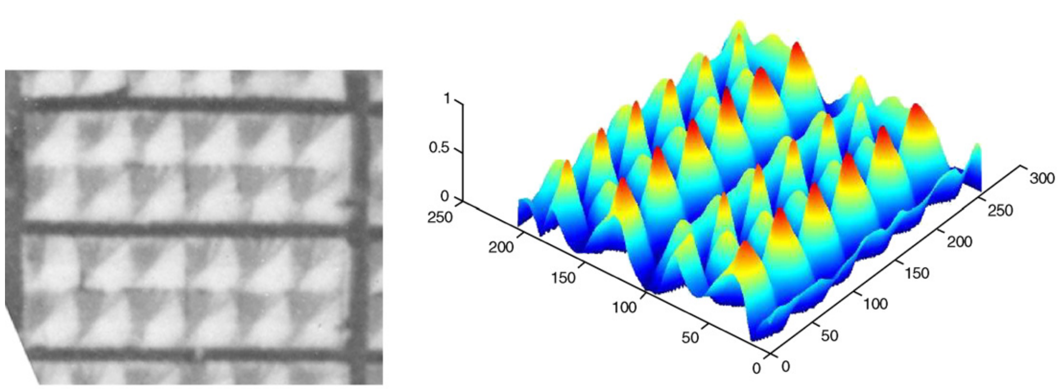

Fig. 5. 3D colored map of the match function of Sample 1.

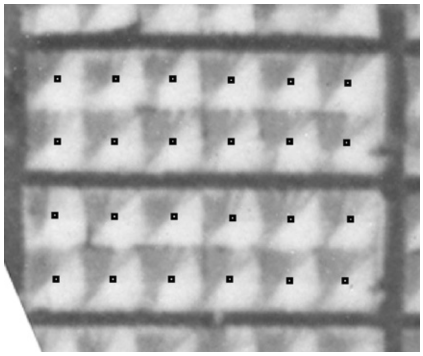

Fig. 6. Matches of Sample 1.

the actual number of tents, the number of matches using the approach, the number of successful matches, the number of false matches, the number of missing tents, and the detection rate (efficiency). It shows that Samples 1 and 3 have a 100% detection rate. Sample 2 has an 88% and Sample 4 has a 94% detection rate. In general, the results of the four samples demonstrate the validity of utilizing the approach for automatic extraction of tents from airborne images.

4. Discussion

This research shows the validity of using airborne images to calculate the number of tents. This is done by employing the matching algorithm described above. This approach can be used to support applications in urban design and planning. For instance it can be used to automatically calculate the number of constructed tents within a specified area in Arafat. This automatic calculation saves time and resources and provides an instant number of tents for a given airborne image. This approach can support the decisions of urban designers and planners. The following paragraph explains some of the possible uses of the approach by urban designers and planners.

Space optimization is an important use of the approach described in this research. The approach can be used to compare the space utilization of a specific area in Arafat in different years.

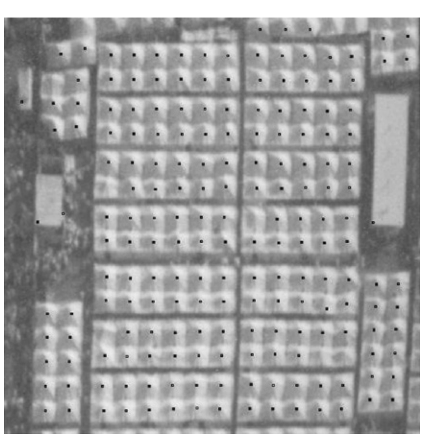

Fig. 7. Matches of Sample 4.

Table 1
Summary of the results

	Sample1	Sample2	Sample3	Sample4
Actual number of tents	24	24	44	193
Number of matches using the approach	24	23	44	189
Successful matches	24	22	44	185
False matches	0	1	0	4
Missing tents	0	2	0	8
Efficiency (detection rate)	100%	88%	100%	94%

An aerial photograph can be taken for the same area during different Hajj seasons. Then a comparison can be automatically made by utilizing the same approach on the images taken at different times. In previous years there were two main problems related to urban space utilization in Arafat during Hajj. The first one is the overcrowding of tents in a space. Some of these problems might impede the movement of pilgrims between the tents. Another problem is the inadequacy of services to be provided for pilgrims in a particular tent camp. In this case the space is not carefully designed and optimized. Since the space in Arafat is limited, this causes a waste of space that should be used to accommodate more pilgrims.

The distribution of tents across Arafat is another important issue that can make use of the matching approach. An urban designer or planner can use the matching approach to evaluate the distribution of tents across the whole Arafat area. This is helpful in knowing how the distribution of tents can be optimized in the whole Arafat area. This is essential to avoid inappropriate distribution that interferes with the services and the traffic. The relationship between housing distribution and transportation is very important, especially in Arafat area where two million people have to stay for one day then move quickly to another place.

Providing adequate services for pilgrims is another concern for urban designers and planners. This approach can use the matching approach to quantify the number of tents and then calculate the amount of services that pilgrims need,. Through this an urban designer or planner could utilize this tool to determine which and how many utilities are needed. Other related uses are to understand and evaluate the distribution of services in Arafat.

In short, the matching approach can facilitate the process of counting tents and save time and resources. Counting tents could help in counting people in some since. This can support the research of urban planners and designers in analyzing previous tents' layout designs and proposing new designs that optimize space. The use of housing space and the distribution of services based on spatial distribution of tents are major benefits of this approach.

For future work, this research could go further in many directions. One of these directions is to automatically build quick virtual 3D Computer Aided Design (CAD) models or 3D Geographic Information System (GIS) of tent camps. This can be done by passing the results of the output of the matching approach to a CAD or GIS software to build the 3D representation of tents.

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