Machine Vision Inspection of Insect Infested Pistachio Nuts from X-ray Images *

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Abstract

An X-ray based system for the inspection of pistachio nuts for internal insect infestation is presented. The novelty of this system is two-fold. First, we construct an invariant representation of infested pistachios from X-ray images that is rich, robust, and compact. This is accomplished by linking the troughs on the image and constructing a joint curvature-proximity distribution table for each nut. Second, we partition the joint distribution table into several regions, where each region is used independently to train a backpropagation (BP) network. The outputs of these subnets are then collectively trained with another BP network. We show that the resulting hierarchical network has the advantage of reduced dimensionality while maintaining a performance similar to the standard BP network.

1 Introduction

We present a system that is being evaluated for the inspection of pistachio nuts viewed with an X-ray sensor. The X-ray device reveals internal defects that cannot be otherwise detected by external evidences in the visible domain. In particular, we are interested in identifying insect infested nuts since they contribute to aflatoxin contamination[1] [18]. Presently, only manual inspection based on color, size and density of pistachio nuts is used to remove the externally damaged nuts. A complete automated system should test for internal damages as well, since not all infestations are externally manifested.

In this paper, we outline an inspection system for detecting internal defects which has the following novel features: First, we derive an *invariant* representation that captures pertinent information on infested as well as non-infested nuts; second, we show that by partitioning this invariant representation, a classifier with reduced dimensionality can be constructed. From a geometric perspective, infestation can be characterized by a dark tunneling appearance in the X-ray image. The tunnel corresponds to the reduced density of the natural content of the nut and to the replacement of that content by a cocoon, insect debris, and air, which have lower X-ray absorption properties. The construction of an invariant representation is complicated by the fact that the tunnel can occur at any spatial location and direction. Some air gaps are due to natural separations between the two halves (cotyledons) of the nut meat. These natural features may be more or less apparent during imaging depending on the resting position of the nut. However, the natural separations are generally accentuated by higher contrast than those that are caused by infestation. In this context, our invariant representation first encodes the tunnels and their magnitude, and then parametrizes this representation with respect to location and orientation. Tunnels can be represented in terms of local positive curvature maxima; these local maxima are then linked to form long curve segments. The invariant and compact representation of these curve segments, with respect to rotation and translation, is then encoded by constructing the distribution of local curvature maxima as a function of distance to the outer boundary of the nut. This distribution is a two dimensional joint histogram with the necessary invariant properties.

The second aspect of our work is in the design of the classifier, which is based on a backpropagation network. We show that partitioning the histogram into several regions, training a network for each region independently, and combining these subnets in a hierarchical fashion can lead to an effective classifier with reduced dimensionality (number of weights) than a standard backpropagation network.

In the next section, a brief summary of the image acquisition system is given. Then in sections 3 and 4, we outline the details of the invariant representation and classification. In each section, we present the intermediate result of our system followed by examples. The paper concludes in section 5 with a summary and a description of future efforts.

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[1] Aflatoxin is a natural carcinogenic compound, and its concentration is limited by the U.S. and European regulatory agencies.