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# Multi-target tracking for flower counting using adaptive motion models

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ARTICLE INFO

*Article history:*
Received 27 December 2007
Received in revised form
16 July 2008
Accepted 16 July 2008

*Keywords:*
Multi-target tracking
Flower counting
Adaptive motion model
Particle cloud

ABSTRACT

Counting the number of flowers in a plant is an example of agricultural quality inspection issues in which a simple 2D image of the product does not suffice. It is essential to see the object under inspection from multiple viewpoints to get a clear estimation of the quality of the product. In order to use multiple viewpoints to obtain a proper quality assessment, a multi-target tracking algorithm that accurately identifies relevant features of the product under inspection is proposed in this paper. The approach is illustrated with an experiment in which the flowers in a number of plants are counted. For the presented method, the plant rotates in front of a camera and a number of consecutive images is taken. The tracking algorithm detects, predicts, and matches the (partially occluded) flowers in the image. The experiments provide a proof of principle of the proposed method. The conclusion of this paper is that the presented multi-target tracking algorithm can be used to solve many similar quality assessment issues for agricultural objects.



## 1. Introduction

### 1.1. *Problem setting*

In the horticultural sector, many potplants are sold. For those cultivars that may have approximately 15 flowers in full bloom, the number of flowers in the plant at the selling moment determines the price. Typically, a plant with 5–8 flowers has a higher commercial value than a plant with less than 5 or more than 8 flowers. Accurate flower counting in such plants is relevant for determining their price. Manual counting of the number of flowers in a plant, though, is a costly and errorprone task. Based on this information, the possibility to automatically count the number of flowers in a plant has been studied. In this paper, the results of this study are presented.

Automatically counting flowers in a plant is not trivial: in general, not all flowers of a plant will be visible from one viewpoint. Moreover, flowers may be partly occluded or may overlap each other in an image. Therefore, information from more than one viewpoint is needed and has to be combined to estimate the location of the flowers.

The purpose of this research is to present a multi-target tracking algorithm that is well suited to solve the problem of flower counting in a rotating plant. Instead of using a complex method that is relatively context-free and that can be used for many types of tracking problems, this paper describes a less formal method that is well adapted to the difficulty of the problem. The designed method is different from existing tracking methods in the sense that (i) the background – i.e. the plant itself – is not moving with respect to the sequence of images, but merely rotating in the center of the images, (ii) the motion model of the targets is elliptical, but its parameters are unknown and (iii) because of the flexible nature of plants the plant parts are shaking due to the rotation and therefore noisy measurements need to be taken into account. The presented tracking algorithm gives information about the

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0168-1699/$ – see front matter 
doi:10.1016/j.compag.2008.07.004

targets' positions and provides information about the number of targets. The algorithm has the capability to perform an accurate counting of flowers in plants in an automated way.

### 1.2. Related work

Various methods for target tracking have been described in the literature. Some methods are based on blob tracking or kernel tracking (Collins, 2003; Comaniciu et al., 2003; Yang et al., 2004). These algorithms are usually of low computational complexity, but require many subsequent images to ensure that changes between targets from image to image are small enough. Another type of approach explicitly uses information on the movement of the targets to predict the position of the targets in the next image. Two examples of such methods are Kalman filters and particle filters (see e.g. Anderson and Moore, 1979; Doucet et al., 2001; Gelb, 1974; Gordon et al., 1993; Grewal and Andrews, 1993; Maybeck, 1979, 1982). They are used for all kinds of tracking and estimation problems (Casarin and Trecroci, 2006; Gustafsson et al., 2002; Hobbs and Bohn, 2006; Li et al., 2003; Negenborn, 2003; Peng et al., 2005; Rekleitis, 2004). Both the Kalman filter (Koller et al., 1994) and particle filters (Hue et al., 2002; Isard and MacCormick, 2001; Koller-Meier and Ade, 2001; Maskell et al., 2003; Tao et al., 1999) have been used for multi-target tracking problems. Kalman filters and particle filters use a model of a target's behaviour in time to predict a target's state on a subsequent image. The predicted target state is then matched with detected target states in that image. As the prediction is based on a model, it needs to deal with noise. The detected target states incorporate noise as well. To estimate a target's state and calculate the estimation error, the Kalman and particle filter use a Bayesian inference process. The predicted and detected target state and the expected noise of the prediction and detection are the input of the process. The estimated target's state and estimation error are the output of the process.

A third type of tracking algorithms is JPDAF (Cox, 1993). This method uses a Bayesian inference process to calculate the correspondence between target states and detected targets. JPDAF is an often-used algorithm for tracking multiple objects. Combinations of different methods are also used, like particle filters to track the target states and JPDAFs to assign measurements to the individual targets (Schulz et al., 2003). However, the Kalman filter, particle filter and JPDAFs have been developed for situations in which the motion model of the targets is unknown. These methods are unnecessarily involved for the problem of flower counting as presented in this paper, since in this problem the *type* of motion model of the targets is known, but the *parameters* of the motion model have to be estimated for each target.

The approach to flower counting presented in this paper only uses a particle filter in the resampling process. Particle filters use a set of particles that are hypotheses for the target state and represent the target state's probability distribution. Particles have weights assigned to them to indicate their likelihood as a hypothesis for the true target state. The particles are predicted using a motion model and their weights are updated according to the likelihood of their position given a detection. In time, particles with insignificant likelihoods are discarded and the particle cloud is resampled to prevent depletion of the cloud.

### 1.3. Research questions

In this paper, the following research questions are addressed:

- How can an unknown number of similar targets in a set of pictures be tracked?
- How can information about the movement of the 'master object' (the plant in this study) be used to estimate the parameters of the motion model for each individual target (the flowers)?
- How can noise in the measurements be taken into account?

The article is organized as follows: in Section 2 the multi-target tracking algorithm is explained. In Section 3, the experiments are discussed that have been used to verify the presented tracking algorithm. In Section 4, these results are discussed and conclusions are drawn in Section 5.

## 2. Theory

In this paragraph, the scope of the problem for which the proposed tracking algorithm is suitable is set and the general setup of the tracking algorithm is described.

### 2.1. Scope

The basic assumption of this paper involves a plant that is rotated in front of a camera. The camera takes a limited number of images of the plant and from this set of images, the number of flowers in the plant has to be determined. Typically, plants for which the number of flowers is of commercial interest have less than 10 flowers.

The problem setting implies a rotating plant. In the subsequent images of the plant, the targets' movements are elliptical. The parameters of this ellipse have to be calculated in the tracking process.

The tracking algorithm consists of four basic steps, as depicted in Fig. 1. First, the master object is recorded using a number of 2D images. Next, these images are segmented to identify the position and shape of the targets. Then an iterative process is started in which the position of a target in image $t+1$ is predicted based on its position in images $t, t-1, \ldots$ and on the information obtained from the motion model. The predicted position of a target is matched with the measured positions of the targets in image $t+1$. With the matches made, a new cycle of prediction and matching is started. When all detected targets are matched, the number of targets can be counted. Note, that the algorithm cycles through the set of images repeatedly.

### 2.2. Segmentation

As a first step, the images are segmented such that only flowers are recognized as targets, and other plant parts are labeled as background by applying an RGB threshold. In previous projects, recordings of the three types of plants used in the