Detection of apples in RBG images

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<u>תקציר</u>

<u>מטרות המחקר</u> לפתח לבחון ולאמת מערכת הדמיה להערכה אוטומטית של מספר הפירות לעץ כבסיס להערכת יבול. מטרות פרטניות: לפתח אלגוריתמים לזיהוי תפוחים בתמונות באורכי גל נבחרים; להעריך את הקשר שבין כמות התפוחים הנראית בתמונה לכמות התפוחים על העץ (כולל המוסתרים); לפתח פרוטוקול בחירת עצים ליצוג נכון של המטע בהתאם לוריאביליות המרחבית של רמות היבול בין עצים במטע.

<u>תכנית המחקר</u> הפעילות בשנה הראשונה התמקדה בשלושה תחומים (1) גיבוש טכניקת צילום, (2) פיתוח כלי חישובי שיאפשר עיבוד יעיל של התמונות, (3) ניתוח ראשוני של מספר תמונות.

<u>תוצאות ודיון</u> צולמו מספר רב של תמונות במצבי תאורה שונים וממרחקים שונים במהלך כל עונת הגידול. התמונות צולמו עם מצלמה צבעונית רגילה (RGB) ועם שתי מצלמות היפר-ספקטראליות, האחת מהטכניון (דר' רפי לינקר) והשנייה מהמינהל המחקר החקלאי (דר' וקטור אלחנתי). הוגדרו התמונות הרצויות כך שסיכויי ההצלחה של העיבוד המתמטי יהיו מרבים. גובשו הנחיות עבור הצילומים שיבוצעו בהמשך הפרויקט.

פותחה תוכנה ייעודית המאפשרת עיבוד יעיל של התמונות. בשל מורכבות העיבודים המתמטיים הדרושים, פיתוח כלי חישובי יעיל הינו הכרחי כדי לאפשר חקירה של מספר גישות ואלגוריתמים בזמני חישוב סבירים. הגישה לזיהוי התפוחים הינה דו שלבית כאשר השלב הראשון מתמקד בזיהוי אזורים "מבטיחים" (בעלי סיכוי גבוה לכלול תפוח). בשלב השני, יופעלו באותם אזורים שזוהו כמבטיחים אלגוריתמים יותר כבדיםמבחינת זמני חישוב כדי לוודא אם אכן נמצא באזור תפוח או תפוחים.

לגבי תמונות ה RGB, השלב הראשון של הניתוח, קרי זיהוי אזורים בעלי סיכוי גבוה לכלול תפוח, עומד לקרת סיום והתוצאות משבעיות רצון. הניתוח בוצע גם על מספר תמונות היפר-ספקטראליות, כאשר המטרה הינה לזהות מספר קטן של אורכי גל בעזרתם ניתן לזהות את התפוחים. גם כאן האלגוריתם זיהה את רוב האזורים הכוללים תפוחים. הניתוח יורחב בשנה שנייה ושלישית כדי לזהות אורכי הגל האופטימלים.

Introduction

The objective of this project is to estimate yield by detecting apples in images acquired under natural conditions. However, it is hard to define how many apples appear in a given image, and which of those should be counted. Figure 1 below shows a typical situation: The apples that grow on the closest side of the tree appear clearly, except in area A, where some of the apples are hidden in the cluster. In area B we see many apples that grow on the other side of the tree; if we detect them, we might count them twice, as the other side of the tree might be processed separately. If we look carefully, we see more and more apples hidden in the picture. A human observer will need a very long time to come with an estimate to the right number of apples in this picture. A machine should not be expected to surpass a human observer but will have the advantage of performing the operation automatically. Based on these simple observations, the objective of the present work can be stated as:

To detect the apples that grow on the side of the tree close to the camera in a consistent way that is strongly correlated to the actual yield.

Figure 1: Typical image

Several photographing parameters have a strong influence on the images and the ability of detecting objects:

Lighting

Light conditions are crucial. Direct sunlight creates many shades that completely alter the image, as shown in Figure 2. The best lighting is diffusive light. Natural diffusive light exists around sunrise and sunset, and on cloudy days. Atmospheric conditions can change the spectrum of the natural light; this can be avoided by artificial diffusive lighting at night.

Figure 2: Influence of lighting and shading conditions

Camera position and orientation

Shooting position influences the image content (Figure 3). The position should be frontal to the tree side and the inspected tree should fill the image as much as possible. If possible, the ground should not appear in it, as it influences the color distribution in the image. Any position other than frontal is likely to be unusable for this project.

Figure 3: Typical images taken at diffent angles and camera positions

Partial hidden objects

Apples usually grow in clusters. Some of them are partially hidden by other apples or by leaves (Figure 4). The detection process will have to handle partially covered objects and deal with clusters of apples and not only single apple objects.

Figure 4: Typical apple cluster with partially hidden objects

Data collection

Over one hundred pictures were taken at regular intervals from flowering to harvest. These pictures were taken from different distances at various times of the day, under different lighting conditions and using several cameras. The pictures were inspected visually in order to determine the conditions that appeared optimal for analysis. This visual inspection led to the selection of 37 images for the development and preliminary testing of the algorithms (see below) and the establishment of guidelines for taking pictures in the coming season.

Data analysis

A computational platform that is both user-friendly and computationally efficient is being developed. The platform enables for user to define manually various types of objects in the pictures and calibrate and test various algorithms.

The first stage of the data analysis is to create mathematical models for the objects present in the images. Defining the geometry of the objects is essential for two reasons:

1. The final results of the detection will be expressed by the number, location and size of those objects;
2. The calibration process is based on marking such objects manually on the pictures and studying their properties.

The objects are represented as follows:

- Apple body is represented as ellipsoid: X,Y of center point, two radius, and a rotation angle.
- Area of petals is represented the same way.
- Stems are represented as rectangles: X,Y of center point, width, height, and a rotation angle.
- Apple is represented as a combination of apple body and optional stem and petal area.
- Apple cluster is represented as a set of apples.

All objects have a “Z-order” (depth) property, indicating which one is the closest to the camera, which one is the next etc, which is used to detect partial occlusion (Figure 5).

Figure 5: left: Original image. Middle: Image with objects marked by the user. Right: Image as seen by the algorithm (notice the objects relative depth and partial masking)

Figure 6 shows an example of the user interface used to define the objects. The objects marked by the user are used to calibrate (train) algorithms that can be used to analyze other images. The analysis itself is a two-stage process: First, regions that have a high probability of containing apples are identified using computationally efficient algorithms. Next, algorithms that are computation-wise more demanding are applied to these "promising" regions.

Figure 6: Image with marked objects: The rectangles indicate regions that the user chose to exclude from the analysis

Current results

The preliminary results presented in this section correspond to the first stage of the two-stage analysis outlined above. At the moment detection of apple surface is based on color and smoothness using a statistical classifier built for this purpose. The fact that the images were taken with different cameras and under different light conditions makes it difficult to find a strong color-smoothness feature, but the first results are nonetheless encouraging. For instance, a classifier calibrated using Figure 6 was used to analyze the image shown in Figure 7 (top frame) and the results are presented in Figure 7 (bottom frame). In this Figure, the brighter pixels indicate that the classifier identified them as having a higher probability of belonging to "apple" objects. Similar typical results are shown in Figure 8.

Figure 7: Top: original image. Bottom: result of the analysis. Pixel brightness indicates probability of pixel to belong to apple object.

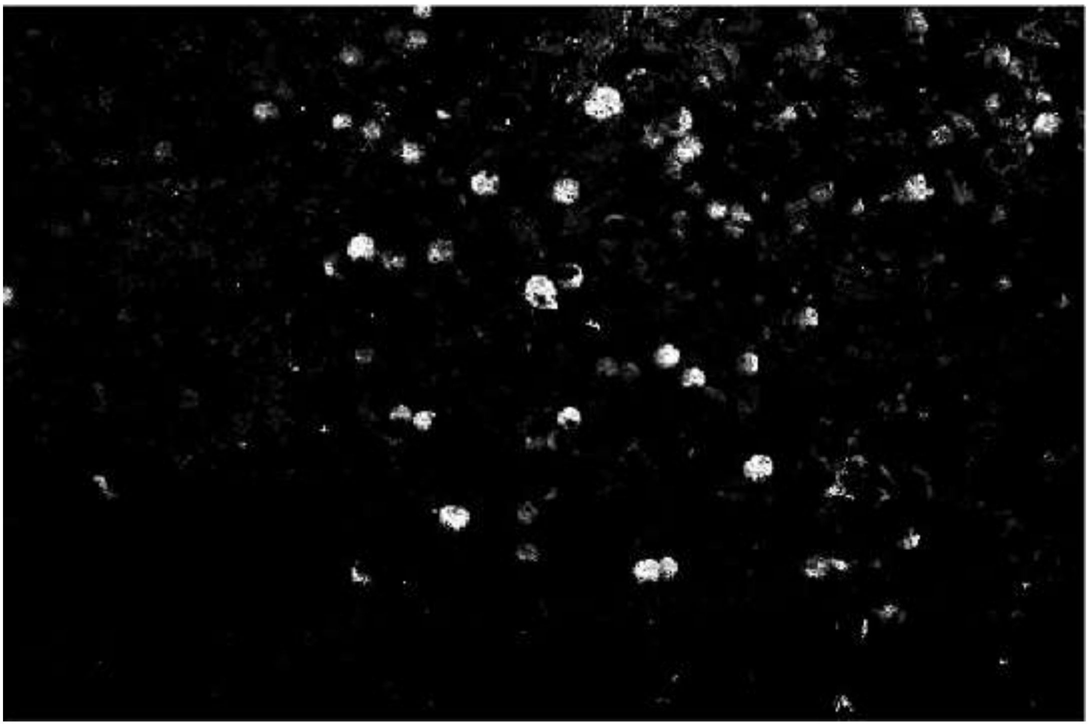

Figure 8: Top: image used to calibrate the classifier. Middle: image tested. Bottom: result of the analysis

Conclusions and future work

Accomplishments

- Photographing parameters for future pictures have been defined
- The main objects present in the images (apples, leaves, stems) have been defined mathematically
- A framework for marking such objects on the images and a building a study set have been developed
- Promising preliminary results have been obtained

Next steps

- Take large number of pictures in 2008 following the guidelines developed so far
- Enlarge the study set by marking manually more objects
- Investigate additional features for object detection
- Develop an efficient algorithm for extracting and counting the objects (apples) in the "promising regions" identified