Computer Vision Technology on Food Science

Abstract

Computer vision is a science that extracts useful information about an object from an observed image or image sequence automatically by analyzing in theoretical and algorithmic bases. Computer vision systems are increasingly used for detection of the surface defects, contamination, and quality inspection of the foods in the food industry. Essentially, such systems take the place of human inspectors to assess the various quality characteristics of raw and ready-to-eat foods. Computer vision technology plays a key role by giving rapid, precise, and consistent results as well as having relatively low cost. Today, computer vision systems are considered as an indispensable part of food processing units for real-time quality assessment and control. Effective techniques will be developed to process image stream data in real time to meet increased production amounts and comply with quality requirements. Robot-controlled and fully automated production will be key technology about quality assurance for competitive food producers in near future. Also, consumers will be able to check the quality of their products by themselves in the near future thanks to developing mobile hardware and software technologies.

Keywords: Computer vision, Food quality assessment, Image analysis

Öz


Anahtar Kelimelere: Bilgisayarla görüntü, Gıda kalite değerlendirme, Görüntü analizi

1. Introduction

Control of the safety and quality of food and food products in modern food production facilities is an important and critical issue because the producers have to comply strictly with the rules and they have to fulfill the demands of the customers (Sun 2007).
determined or the last consumable date can be determined. These quality attributes are related to features that can be measured with non-destructive techniques. The quality of food can be evaluated by investigating the changes in their visual properties, such as size, color, shape, and texture (Wu et al. 2013, Valous et al. 2010).

These analyses were done by humans before computer vision systems were developed, and this method was costly and subjective. In addition, computer vision techniques can perform better than human operators and human perception in the spectral range of uncertain conditions for human operators.

2. Computer Vision Technologies

Great deals of inspection tasks are repetitive, boring, and extremely tedious so the effectiveness of the efficiency depends on the human inspectors. This inspection tasks can be automated using computer vision. Computer vision is a promising technology for food safety and quality assurance applications, because of having advantages such as much higher operating speed, consistency, reliability, objectivity and applicability to industrial environments (Park 2016).

Although computer vision systems are very easy to use, they have the ability to do quite complex tasks. The main tasks can be classified as image acquisition, processing or analysis, and recognition processes. The various properties of the objects are obtained from the acquired images during the analysis phase, and the final decisions are made in recognition process by using various image processing techniques and algorithms (Mery et al. 2013).

These images can be acquired in the visible spectrum or ultraviolet and infrared spectrum. Various image acquisition systems (multispectral, hyperspectral, ultrasound) may have to be used because of the response of products distinctly at different wavelengths (Daugaard et al. 2010, Kiani et al. 2016).

The first task in image processing is to capture the image. The image can be seen as a 2D matrix with integer values. Each element is called a pixel in this matrix. The information obtained from the image is the location of the pixels and intensity values of each pixel. Image preprocessing can be done to enrich the details before the image analysis phase. Image segmentation and feature extraction are the other important steps in image processing. Image segmentation can be defined as recognition of the object and separating it from the background of the image. Measurement of the characteristics (size, color, shape, appearance, texture) of the object takes part in feature extraction phase. The last step is object classification that is automation of human visual inspection and decision making process. Object can be identified and classified into one of the finite set of classes by simulating human thinking process artificially with algorithms such as artificial neural network (ANN), fuzzy logic, decision tree, statistical methods or support vector machine (SVM) (Jackman et al. 2013, Mery et al. 2010).

Image capture systems are not error-free and perfect, so this results in distortions and loss in the images. Image preprocessing techniques aim to remove noises, artifacts, and useless signals to correct these faults without cost (Dowlati et al. 2012).

2.1. Challenges

Lighting is one of the most important factors that most seriously affect the final result of any computer vision system. Improper lighting can cause unexpected or erroneous results in the system (Vithu and Moses 2016). However, providing sufficient image resolution is another challenge. High-resolution requirements are necessary to provide better performance in computer vision applications to improve accuracy (Zhang et al. 2014). Another challenge is to examine rounded objects by considering all their surfaces. Regular cameras capture images that represent only a portion of the surface, which is a projection of the object (Misimi et al. 2016).

3. Applications on Food Science

There are numerous and various computer vision based applications for food safety and control. In this study, applications are classified as Meat, Poultry, Seafood, Fruit, Vegetables, Grain, and Bakery products. Other studies that do not fall into this classification have been ignored (Sun 2007).

3.1. Meat

Meat quality can be evaluated by considering chemical, microbiological, and sensory attributes. The most important parameters are flavor of the meat, juiciness, and tenderness. Table 1 shows applications in the area of meat.

3.2. Poultry

Appearance and texture are two main attributes for prediction of quality. Skin color, appearance defects, and cooked meat pinkness parameters affect the final decision. Table 2 shows applications in the area of poultry.
3.3. Seafood
Fish and seafood are most vulnerable food products. Physical properties, microbial contamination, and appearance play an important role in assessing the quality of seafood. Table 3 shows applications in the area of seafood.

3.4. Fruit
The quality of fruits can be evaluated by considering physical and chemical attributes. Shape and texture also give information about the quality. Table 4 shows applications in the area of fruits.

3.5. Vegetables
The appearance of vegetables is one of the first quality determinants includes color, size, shape, and gloss. Table 5 shows applications in the area of vegetables.

3.6. Grain
Bulk density, moisture content, shape, diameter are important factors while classifying grain. Table 6 shows applications in the area of grain.

### Table 1. Applications for Meat

<table>
<thead>
<tr>
<th>Product</th>
<th>Application</th>
<th>Technique</th>
<th>Accuracy (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porcine meats</td>
<td>Prediction of color and pH</td>
<td>NIR hyperspectral</td>
<td>72,6 and 86</td>
<td>Liu et al. (2014)</td>
</tr>
<tr>
<td>Pork muscles</td>
<td>Classification</td>
<td>IR hyperspectral</td>
<td>93.14</td>
<td>Pu (2015)</td>
</tr>
<tr>
<td>Pork</td>
<td>Detection of PSE (pale, soft, exudative)</td>
<td>Image analysis</td>
<td>-</td>
<td>Chmiel et al. (2016)</td>
</tr>
<tr>
<td>Pork</td>
<td>Classification</td>
<td>Image analysis</td>
<td>89 – 100</td>
<td>Zapotoczny et al. (2016)</td>
</tr>
<tr>
<td>Beef</td>
<td>Measuring meat color</td>
<td>Image analysis</td>
<td>-</td>
<td>Girolami et al. (2013)</td>
</tr>
<tr>
<td>Meat and turkey</td>
<td>Assess quality parameters</td>
<td>Multi-spectral</td>
<td>95</td>
<td>Daugaard et al. (2010)</td>
</tr>
<tr>
<td>Lamb</td>
<td>Prediction of tenderness</td>
<td>Hyperspectral</td>
<td>84</td>
<td>Kamruzzaman et al. (2013)</td>
</tr>
<tr>
<td>Beef, lamb, and pork</td>
<td>Prediction of color</td>
<td>Hyperspectral</td>
<td>97, 84, and 82</td>
<td>Kamruzzaman et al. (2016)</td>
</tr>
<tr>
<td>Lamb</td>
<td>Predicting chemical constituents</td>
<td>Hyperspectral</td>
<td>95, 80, and 91</td>
<td>Pu et al. (2014)</td>
</tr>
</tbody>
</table>

### Table 2. Applications for Poultry

<table>
<thead>
<tr>
<th>Product</th>
<th>Application</th>
<th>Technique</th>
<th>Accuracy (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broiler chickens</td>
<td>Weight prediction</td>
<td>3D camera</td>
<td>92,2</td>
<td>Mortensen et al. (2016)</td>
</tr>
<tr>
<td>Poultry</td>
<td>Classification</td>
<td>Image analysis</td>
<td>89 – 100</td>
<td>Zapotoczny et al. (2016)</td>
</tr>
<tr>
<td>Chicken</td>
<td>Measuring color</td>
<td>Image analysis</td>
<td>-</td>
<td>Girolami et al. (2013)</td>
</tr>
<tr>
<td>Chicken</td>
<td>Prediction of color</td>
<td>Image analysis</td>
<td>99, 74, and 88</td>
<td>Barbin et al. (2016)</td>
</tr>
</tbody>
</table>

### Table 3. Applications for Seafood

<table>
<thead>
<tr>
<th>Product</th>
<th>Application</th>
<th>Technique</th>
<th>Accuracy (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salmon</td>
<td>Classification</td>
<td>Hyperspectral</td>
<td>98.2</td>
<td>Xu et al. (2017)</td>
</tr>
<tr>
<td>Grass Carp Fish</td>
<td>Microbial contamination</td>
<td>Hyperspectral</td>
<td>-</td>
<td>Cheng and Sun (2015)</td>
</tr>
<tr>
<td>Shrimp</td>
<td>Evaluating freshness</td>
<td>Image analysis</td>
<td>90</td>
<td>Ghasemi-Varnamkhasti et al. (2016)</td>
</tr>
<tr>
<td>Sea bream</td>
<td>Evaluating freshness</td>
<td>Image analysis</td>
<td>99</td>
<td>Dowlati et al. (2013)</td>
</tr>
<tr>
<td>Salmon fillets</td>
<td>Assessing tenderness</td>
<td>Hyperspectral and chemometric</td>
<td>90.5</td>
<td>He et al. (2014)</td>
</tr>
<tr>
<td>Shrimp</td>
<td>Assess quality</td>
<td>Multispectral</td>
<td>76, 100</td>
<td>Xiong et al. (2016)</td>
</tr>
</tbody>
</table>
3.7. Bakery Products
Most bakery products, such as cake, bread, crackers, and muffins have certain shape and size attributes that represent their quality. Standard deviation of change in thickness, diameter, and weight are important parameters to be considered. Table 7 shows applications in the area of bakery products.

4. Future Research Directions
Most challenging issues are developing effective image segmentation algorithms, system robustness, real-time

Table 4. Applications for Fruit

<table>
<thead>
<tr>
<th>Product</th>
<th>Application</th>
<th>Technique</th>
<th>Accuracy (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blueberries</td>
<td>Microbial contamination and assess quality parameters</td>
<td>Image analysis</td>
<td>-</td>
<td>Matiacevich et al. (2011)</td>
</tr>
<tr>
<td>Date fruits</td>
<td>Determining viscoelastic characteristics</td>
<td>Image analysis</td>
<td>-</td>
<td>Alirezaei et al. (2013)</td>
</tr>
<tr>
<td>Apple</td>
<td>Grading</td>
<td>Image analysis</td>
<td>92.5</td>
<td>Moallem et al. (2016)</td>
</tr>
<tr>
<td>Apple</td>
<td>Detection of bruise</td>
<td>Hyperspectral</td>
<td>98</td>
<td>Keresztes et al. (2016)</td>
</tr>
<tr>
<td>Grape</td>
<td>Prediction of quality</td>
<td>3D imaging</td>
<td>82, 83, and 71</td>
<td>Ivorra et al. (2015)</td>
</tr>
<tr>
<td>Mango</td>
<td>Prediction of maturity</td>
<td>NIR spectroscopy</td>
<td>74, 68</td>
<td>Jha et al. (2014)</td>
</tr>
<tr>
<td>Papaya</td>
<td>Prediction of shrinkage</td>
<td>Image analysis</td>
<td>85.2, 89.1</td>
<td>Udomkun et al. (2016)</td>
</tr>
<tr>
<td>Strawberry</td>
<td>Evaluation of ripeness</td>
<td>Hyperspectral</td>
<td>95, 83.3</td>
<td>Zhang et al. (2016)</td>
</tr>
<tr>
<td>Cherries</td>
<td>Classification</td>
<td>Image analysis</td>
<td>85</td>
<td>Wang et al. (2012)</td>
</tr>
</tbody>
</table>

Table 5. Applications for Vegetables

<table>
<thead>
<tr>
<th>Product</th>
<th>Application</th>
<th>Technique</th>
<th>Accuracy (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato</td>
<td>Classification</td>
<td>Image analysis</td>
<td>94</td>
<td>Dutta et al. (2015)</td>
</tr>
<tr>
<td>Onion</td>
<td>Classification</td>
<td>Hyperspectral, 3D, and X-ray imaging</td>
<td>88.9</td>
<td>Wang et al. (2015)</td>
</tr>
<tr>
<td>Tomato</td>
<td>Evaluating the quality</td>
<td>Image analysis</td>
<td>96.47</td>
<td>Arakeri et al. (2016)</td>
</tr>
<tr>
<td>Potato</td>
<td>Detection of blackspot</td>
<td>Hyperspectral</td>
<td>94</td>
<td>López-Maestresalas et al. (2016)</td>
</tr>
<tr>
<td>Soybean</td>
<td>Prediction of color and moisture</td>
<td>Hyperspectral</td>
<td>86.2, 97.1</td>
<td>Huang et al. (2014)</td>
</tr>
<tr>
<td>Green peas</td>
<td>Evaluating the quality</td>
<td>Image analysis</td>
<td>-</td>
<td>Barzegar et al. (2015)</td>
</tr>
<tr>
<td>Carrot</td>
<td>Classification</td>
<td>Computed Tomography</td>
<td>87.9</td>
<td>Donis-González et al. (2016)</td>
</tr>
</tbody>
</table>

Table 6. Applications for Grain

<table>
<thead>
<tr>
<th>Product</th>
<th>Application</th>
<th>Technique</th>
<th>Accuracy (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>Classification texture, shape, and texture&amp;shape</td>
<td>Image analysis</td>
<td>82.61, 88.00, and 87.27</td>
<td>Chaugule and Mali (2014)</td>
</tr>
<tr>
<td>Rice</td>
<td>Classification</td>
<td>Image analysis</td>
<td>98</td>
<td>Pazoki et al. (2014)</td>
</tr>
<tr>
<td>Rice kernels</td>
<td>Evaluation of implicit properties</td>
<td>Image analysis</td>
<td>92</td>
<td>Jinorose et al. (2014)</td>
</tr>
<tr>
<td>Wheat, cassava and corn flour</td>
<td>Analysis of flour adulteration</td>
<td>Hyperspectral</td>
<td>97</td>
<td>Su et al. (2017)</td>
</tr>
<tr>
<td>Wheat</td>
<td>Classification</td>
<td>Image analysis</td>
<td>85.72</td>
<td>Khoshroo et al. (2014)</td>
</tr>
</tbody>
</table>
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Over the last two decades, computer vision techniques such as color, multispectral, hyperspectral, thermal, x-ray and MR imaging have been extensively researched and developed for fast, objective, consistent, reliable and non-destructive assessment and evaluation of food quality. It mostly uses reflectance mode to perceive and detect surface quality attributes such as shape, size, color, and texture.

Computer vision is an important technology that enables machines to localize raw materials and better characterize them before handling and processing. In recent years, it has shown great potential to perform such tasks by evaluating physical changes and their image properties. Computer vision will remain as a key research area for the food industry.

Impressive work has already been done on food characterization and quality control and safety, but more research can provide us to obtain more information from contactless methods. It has been proven that the non-destructive systems investigated in the quality evaluation and assessment have been successfully applied, so that objective measurements are provided. Digital imaging and spectroscopic technologies continue to advance rapidly, and developed techniques can be sophisticated in industrial applications.

5. Conclusion

Combined with effective digital image processing techniques, computer vision is a proven technology that can provide proper and convenient information on food quality and safety. Over the last two decades, computer vision techniques such as color, multispectral, hyperspectral, thermal, x-ray and MR imaging have been extensively researched and developed for fast, objective, consistent, reliable and non-destructive assessment and evaluation of food quality. It mostly uses reflectance mode to perceive and detect surface quality attributes such as shape, size, color, and texture.

Computer vision is an important technology that enables machines to localize raw materials and better characterize them before handling and processing. In recent years, it has shown great potential to perform such tasks by evaluating physical changes and their image properties. Computer vision will remain as a key research area for the food industry. Fast and reliable control systems are an important issue to ensure that food is safely produced during processing as the public demands better and safer food quality.

Impressive work has already been done on food characterization and quality control and safety, but more research can provide us to obtain more information from contactless methods. It has been proven that the non-destructive systems investigated in the quality evaluation and assessment has been successfully applied, so that objective measurements are provided. Digital imaging and spectroscopic technologies continue to advance rapidly, and developed techniques can be sophisticated in industrial applications.

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