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Research Paper

Method for assessing the quality of data used in evaluating the performance of recognition algorithms for fruits and vegetables

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In studies on agricultural robot vision systems, data used to evaluate algorithm performance, such as successful recognition rates, vary because of various factors. If the variation is too large, representation of the actual performance of algorithms by the data is bound to be poor. Here we present a method for analysing the quality of data used to evaluate the performance of a recognition algorithm for occluded tomatoes based on measurement system analysis. The measurement system included a soft measurement tool (a counting method for the number of successful recognitions), appraisers, measured objects (recognition results of 300 occluded tomato images), the usage method for the soft measurement tool and measurement environments. The measurement system was analysed on the basis of its repeatability and reproducibility. Repeatability and reproducibility were both evaluated based on Fleiss's Kappa values, free-marginal multirater Kappa values and Kendall coefficients. Test results showed that repeatability was excellent or fair to good based on Fleiss's Kappa values and excellent based on free-marginal multirater Kappa values and Kendall coefficients for the three appraisers. Further improvement in the soft type of measurement tool is necessary. Reproducibility was fair to good with Fleiss's Kappa values and free-marginal multirater Kappa values, and good with Kendall coefficients. Large values of measured feature resulted in inferior repeatability and reproducibility.

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1. Introduction

Researchers have focused on agricultural robots to address the problem of labour shortage and high labour cost in the production of crops (Belforte, Deboli, Gay, Piccarolo, & Ricauda Aimonino, 2006; Hiremath, van der Heijden, van Evert, Stein, & ter Braak, 2014; Jeon & Tian, 2009; Ota et al., 2007; Tong, Li, & Jiang, 2013). The main tasks of the vision systems of agricultural robots are to acquire the information of quality, size, 3D position information, number of crops and to realise the visual navigation. To do that, many algorithms are used, including segmentation algorithms, recognition algorithms and localisation algorithms. Some data are measured or counted to evaluate the performance of these algorithms. The success rate of segmentation is typically used to evaluate the performance

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Nomenclature

Symbols

a	Number of measurement feature values
g_j	Number of ties among n samples for the jth appraiser
K	Kappa value
k_i	Measurement results of the ith object measured by three appraisers
K_f	Free-marginal multirater Kappa
k^F	Fleiss Kappa
k_k^F	Fleiss Kappa of measurement feature value k
k_{ij}	Measurement results of the ith object measured by the jth appraiser
m	Total measurement times of every measured object
n	Number of measured objects
P_c	Probability of agreement of measurement results produced by chance
P_o	Probability of agreement of measurement results produced by real measurement
R	Average of the range of measurement results through two measurements of n measured objects measured by three appraisers
R_{ij}	Order of X_{ij} among (X_{1j}, X_{2j}, ……, X_{nj})
R_j	Average of the range of measurement results through two measurements of n measured objects measured by the jth appraiser
W	Kendall coefficient
x_{ik}	Measurement times of the ith measured object of which the measured feature value is k
x_k	Total measurement times of the measured objects of which the measured feature values are k
t_h	Length of the hth tie
Z	Degree of agreement
$\sigma(k^F)$	Standard deviation of k^F
$\sigma(k_k^F)$	Standard deviation of k_k^F

Abbreviations

MSA	Measurement System Analysis
RAOT	Recognition Algorithm for Occluded Tomatoes

of segmentation algorithms (Bac, Hemming, & van Henten, 2013; Bai et al., 2014; Bulanona, Kataoka, Ota, & Hiroma, 2002). The metric for recognition algorithms is usually recognition precision, which is the ratio of successful recognition number to the total number of recognitions (Fu et al., 2015; Si, Liu, & Feng, 2015), while localisation error is employed to analyse localisation algorithms (Bac, Hemming, & van Henten, 2014; Nissimov, Goldberger, & Alchanatis, 2015; Si et al., 2015). In current research, these data are used directly to evaluate the performance of algorithms. However, these data always vary because of factors such as personnel, tools, objects, methods, environments associated with counting and other random factors. If the variance is too large, these data cannot objectively reflect the actual performance of the algorithms. Consequently, the conclusions drawn from the data are unreliable. Thus, the quality of these data should be evaluated before the data are used. Data quality pertains to the effectiveness of the data, i.e. the degree to which the actual performance of the algorithms is reflected objectively by the data. An issue that needs to be addressed is how the quality of the data applied in assessing algorithm performance can be evaluated. This paper presents a method for evaluating the data quality of the number of successfully recognised tomatoes applied in assessing the performance of a recognition algorithm for occluded tomatoes (RAOT) (Xiang, Ying, & Jiang, 2013).

RAOT is applied in the vision system of tomato harvesting robots. Harvesting robots are used to automatically harvest fruits and vegetables (Dong, Heinemann, & Kasper, 2011; Hayashi et al., 2010; van Henten, Hemming, van Tuijl, Kornet, Meuleman, & Bontsema, 2002; Tanigaki, Fujiura, Akase, & Imagawa, 2008; Zhao, Lv, Ji, Zhang, & Chen, 2011). The vision systems of harvesting robots aim to recognise fruits and vegetables correctly (Kondo & Ting, 1998). Extensive research has been conducted on recognition algorithms for fruits and vegetables (Jiménez, Ceres, & Pons, 2000; Xu, Imou, Kaizu, & Saga, 2013). Recognition precision is commonly used to evaluate the performance of such recognition algorithms. To acquire recognition precision, correctly counting the number of successful recognitions is a top priority. For large samples, the number of successful recognitions is usually counted manually by determining the correctness of the recognition results using visual inspection (Cai, Zhou, Li, & Fan, 2008; Fu et al., 2015; Li, Li, Gao, Yi, & Li, 2013; Lu & Sang, 2015; Plebe & Grasso, 2001; Si et al., 2015; Xiang, Jiang, & Ying, 2014; Xun, Chen, Li, Liu, & Xu, 2007). In current research, the number of successful recognitions counted manually was directly used to evaluate the performance of recognition algorithms without assessing data quality. Meanwhile, the data quality of the number of successful recognitions counted manually depends significantly on the experiences of appraisers. Having different appraisers can result in inconsistent number of successful recognitions. Even with the same appraiser, multiple appraisals can result in inconsistent data. Thus, the data quality of the number of successful recognitions counted manually cannot always be guaranteed. Hence, data quality should be evaluated before using the data to assess the quality of recognition algorithms, thereby ensuring that these data can reflect the actual recognition results. The reliability of evaluations of recognition algorithm performance can be guaranteed by utilising successful recognitions with high data quality.

This study aims to identify a method for assessing the quality of data used to evaluate the performance of recognition algorithms for fruits and vegetables applied in the vision system of agricultural robots. Moreover, this study aims to guarantee that such data can reflect the actual performance of recognition algorithms in order to facilitate reliable and meaningful conclusions. To that end, we present a new method for analysing the quality of data used to evaluate recognition algorithm performance. This method is based on the analysis of data quality of the number of successful recognitions employed to assess the performance of RAOT. This work is the first to present a method to evaluate the quality of data used to evaluate the performance of recognition algorithms used in vision systems of agricultural robots.

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