Automated Pollinator Monitoring for Crop Farming

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Abstract: Pollinating bee species face an increased risk of extinction worldwide. The annual value of this pollination service in the U.S. is calculated at US $ 15 billion and the estimate worldwide is US $ 65 – 70 billion. But, endeavors on pollinator monitoring and management must build on reliable surveillance and monitoring of pollinator species. This contribution presents the ABIS toolset for species identification pollinating bees as a mobile location-based service that can operate in scientific collections as well as in the field.

1 Problem statement

One-third of the world's crops demand for pollination to set seed and fruits. The great majority of them are pollinated by many of the estimated 25 000 species of bees. The annual value of this service in the U.S. is calculated at US $ 15 billion and the estimate worldwide is US $ 65 – 70 billion for the year 2009 [MC00], [ARS14], [FWS14]. But, all the bee species face an increased risk of extinction worldwide due to loss of habitat and forage, rapid transfer of parasites and diseases, air and soil pollution, pesticides etc.

In the meantime, there is a worldwide increasing public awareness of pollinator, esp. of bees fostered by international initiatives (e.g. the International Pollinator Initiative (IPI)). In Germany, for example, the SPIEGEL news magazine published three articles on national and international pollinator and especially bee decline in January, April, and June 2014. BBC news launched at least two contributions on pollinator protection in June and November 2014. CNN news launched at least two contributions on pollinator distinction and protection in May and June 2014. The contribution of June 2014 reported that president Obama announced a plan to save honey bees. Thereby, a fact sheet of the *White House* on "The Economic Challenge Posed by Declining Pollinator Populations" updated the role of pollinators stating that "pollinators contribute more than $24 billion to the United States economy, of which honey bees account for more than $15 billion through their vital role in keeping fruits, nuts, and vegetables in our diets." The fact sheet also states that "since 2006, commercial beekeepers in the United States have seen honey bee colony loss rates increase to an average of 30% each winter" [TWH14].

In the US, some institutions think that other pollinating bee genera like the bumble bees or mason bees might replace the endangered honey bees [ARS14]. However, all bee species face the general pollinator decline and pollinators cannot be exchanged on a one-for-one basis, as various bee species settle, nest, feed, and pollinate in different ways.

Therefore, a serious approach to any kind of national and even international endeavors on pollinator monitoring and management must build on *reliable surveillance and monitoring of pollinator species*.

2 Automated Bee Identification System

At Bonn University, we developed an automated fingerprinting approach to identify bee species, the Automated Bee Identification System (ABIS) [St06], [St07]. ABIS is based on a structural analysis of images of the forewings of the bees. ABIS can used on a conventional notebook and needs a digital camera mounted on microscope. Therefore, ABIS goes as a mobile location-based service that can operate in situ and in vivo. ABIS comes today along as a Java-implemented stand-alone program J·ABIS that can be supported for data management by a MySQL database management system with a Java-based front-end called AbisCommander (cf. fig. 1). ABIS performs a fully automated analysis of images taken from the forewings of bees. The images of the forewings show opaque veins (that appear dark) and transparent cells (that appear bright). ABIS shows the following processing pipeline: first, the contours of the veins are extracted via edge extraction; second, the vein contours are grouped such that a network of veins result where loops of veins enclose the wing cells; third, morphometrical features like angles between veins and surface area ratios between neighbored cells are used to form a feature vector; forth, the species identification is performed via a supervised classification based on the extracted feature vectors of the forewings. The complete processing chain is explicitly described in [St07].

This fully automated analysis is the outstanding quality of ABIS compared with all other approaches, which demand for intensive interactive processing of each specimen, especially that of [GOG00] or [Ro04] which are the most competitive approaches. The approach of [GOG00] demands to cut off the forewings of the bees and to position the forewing for image taking interactively to create a normalized image of the forewings with respect to orientation. The approach of [Ro04] demands to mark interactively the junction points of the veins. Both interactions are not necessary in ABIS since ABIS employs in its processing pipeline an explicit generative model of the structure and geometrical variations of the forewings of bees. This generative model guides the extraction of the veins from the forewing image as well as the derivation of the feature vectors. The generative model of the venation network of the bee forewings as well as the classification model (forth step of the processing pipeline) is learned within a training step of ABIS. This training step is done once and in an automated way. After training, ABIS can be used for identification of all species that it was trained for. In the training step ABIS needs about 20 – 30 forewing images of specimen per species to learn the generative model of the structure and geometrical variations of the forewings of bees and the classification model.

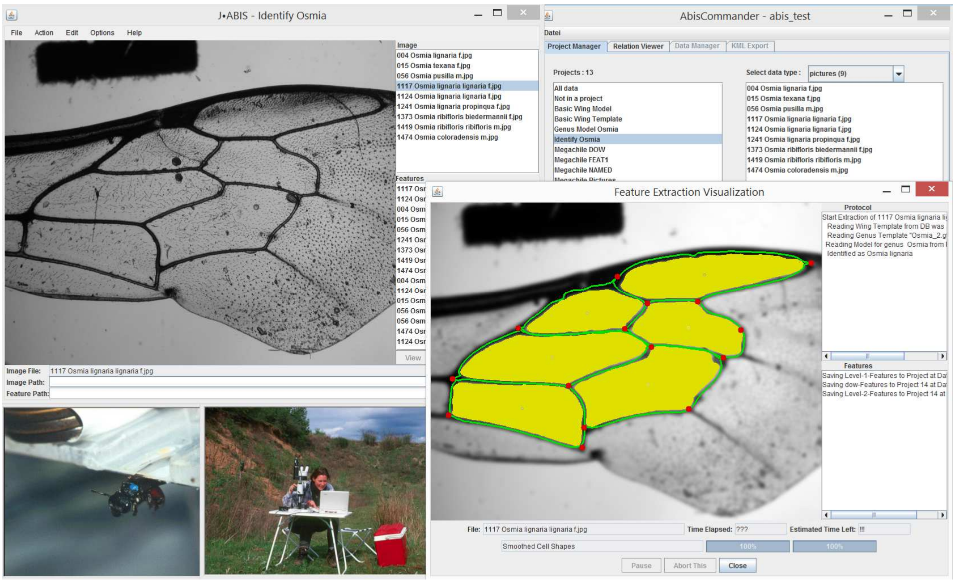

Figure 1: A densely packed computer screenshot showing the GUI of J·ABIS (TL), the GUI of AbisCommander (TR), a GUI showing results of processing a wing image and the result of species identification (BR), and two pictures showing the application in the field (BL).

3 Applications and outlook

ABIS has been implemented and successfully applied to species identification in Germany, Brazil and the U.S. Even the very difficult to distinguish species *Bombus sylvarum* und *Bombus veteranus could be identified* with a correct classification rate of 99 % using a leave-one-out cross validation procedure.

In Brazil, ABIS was also employed within a research project to identify even subspecies! And even in this challenging application, ABIS revealed a recognition rate of about 94% (leave-one-out cross validation), which was on the one hand “only” 94% due to the very close relationship of all subspecies groups, but on the other hand sufficient and clearly better than results of other morphometric approaches and in line with results obtained on genetic markers [Fra09].

Up to now, all these results were achieved in projects on biodiversity and systematics. But, the impressive results suggest employing the ABIS toolset also in projects to support monitoring and management of pollinators in agriculture.

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References

[ARS14] U. S. Department of Agriculture, Agricultural Research Service.: Colony Collapse Disorder. http://www.ars.usda.gov/Services/docs.htm?docid=15908 (Sept. 12, 2014).

[Fra09] Francoy, T.M., Wittmann, D., Steinhage, V., Drauschke, M., Müller, S., Cunha, D.R., Nascimento, A.M., Figueiredo, V.L.C., Simoes, Z.L.P., De Jong, D., Arias, M.C., Goncalves, L.S.: Morphometric and genetic changes in a population of Apis mellifera after 34 years of Africanization, Journal Genetics and Molecular Research, Vol. 8, No. 2, 709-717, 2009.

[FWS14] U.S. Fish & Wildlife Service. Pollinators. http://www.fws.gov/pollinators/Index.html (Sept. 12, 2014).

[GOG00] Gauld, I.D., O'Neill M.A., Gaston, K.J.: Driving Miss Daisy: the performance of an automated insect identification system. In: Austin, A.D., Dowton M. (eds.): Hymenoptera: Evolution, Biodiversity and Biological Control. CSIRO, Canberra (2000) 303–312.

[MC00] Morese, R.; Calderone, N.: The Value of Honey Bees as Pollinators of U.S. Crops in 2000, Cornell University.

[Ro04] Rohlf, F.J.: tpsDig, digitize landmarks and outlines, version 2.0. Department of Ecology and Evolution, State University of New York at Stony Brook (2004)

[St06] Steinhage, V.; Schröder S.; Roth, V.; Cremers, A. B.; Drescher, W.; Wittmann, D.: The Science of "Fingerprinting" Bees. Magazine of the Deutsche Forschungsgesellschaft german research, Vol. 1/2006, 19-21, 2006.

[St07] Steinhage, V.; Schröder S.; Lampe, K.-H..; Cremers, A. B.: Automated Extraction and Analysis of Morphological Features for Species Identification. In N. MacLeod (Ed.): Automated Taxon Identification in Systematics: Theory, Approaches and Applications. The Systematics Association Special Volume Series 74. Chapter 8, 115-129, CRC Press, Taylor & Francis Group, 2007.

[TWH14] The White House - Office of the Press Secretary: Fact Sheet: The Economic Challenge Posed by Declining Pollinator Populations. http://www.whitehouse.gov/the-press-office/2014/06/20/fact-sheet-economic-challenge-posed-declining-pollinator-populations. (Sept. 12, 2014).