A Race Against Time:
Biodiversity Research using Digital Image Analysis

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University of Bonn

- Edward O. Wilson, Dep. of Organismic and Evolutionary Biology, Harvard University:

~ 27,000 species extinct per year

- National Research Council:

about 50% of all current species

may already be extinct by 2100

Bees

highly diverse, widely unknown, fascinating, ecologically and economically important



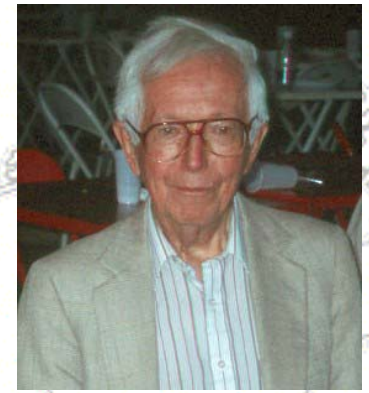
- 20.000 known species, 30.000 estimated
- i.e. in Germany 50% of the 550 species are endangered



- studies on one of them, A. mellifera, led to Nobel prize to K.v. Frisch

Bees

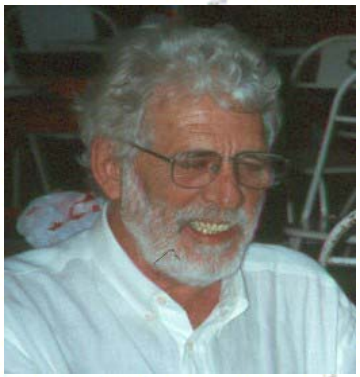
- **main pollinators of food crops i.e. 73% of the world's crops → a critical ecological and economical resource**
- **annual value of the service of pollination has been reported to be between 65 and 70 billion US dollars**



Professor Emeritus
Charles D. Mitchener
(* 1919)

Professor Emérito
Doutor Padre Jesus
Santiago Moure
(* 1912)

- **bee taxonomy is a difficult task.**
- **current lack of taxonomical experts**
- **most experts are 60 ++**



Professor Julio
Cammargo
(* 1939)

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ABIS - Automatic Bee Identification System

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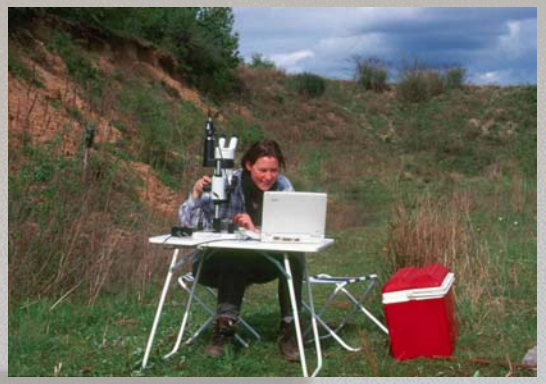
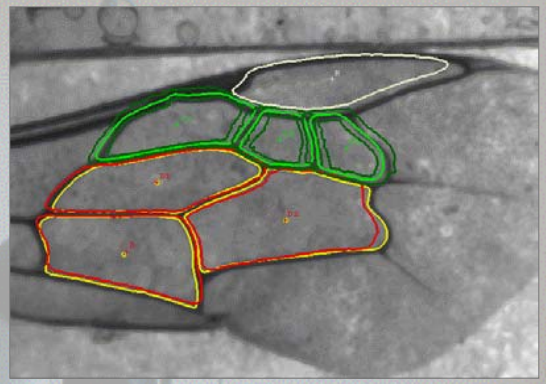
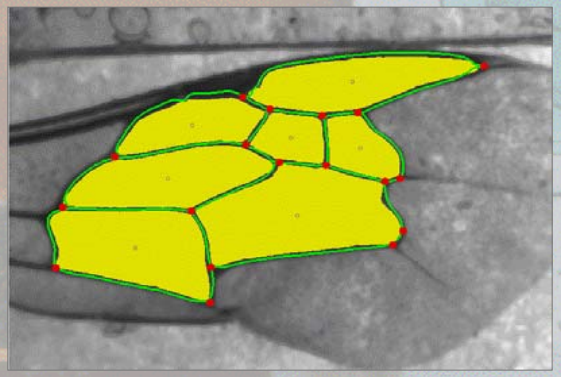
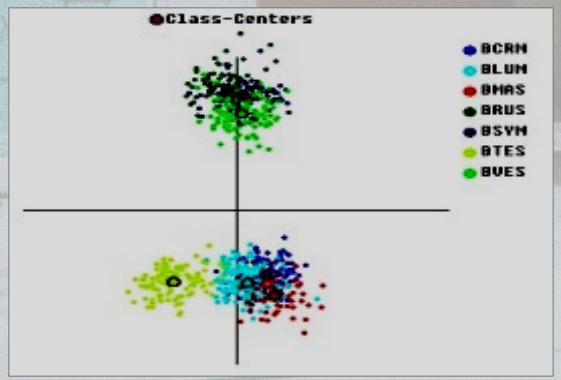


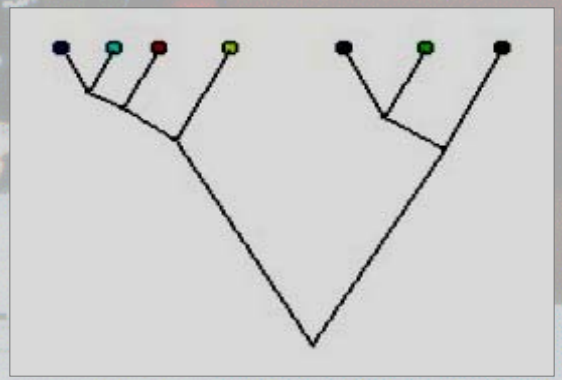


ABIS = Automated identification of bees' species

- **knowledge-based image analysis of the bee forewings**
- **nonlinear discriminant analysis for identification**







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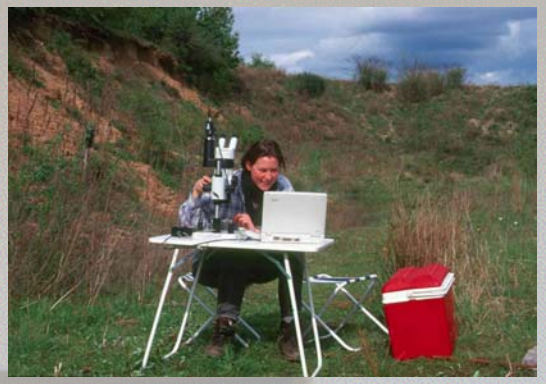
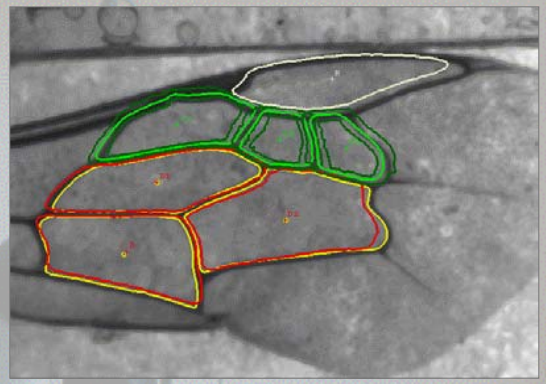
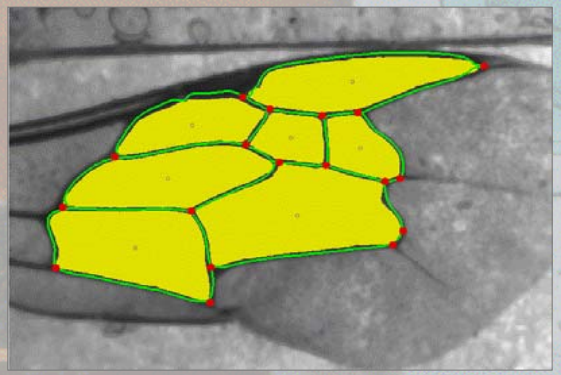


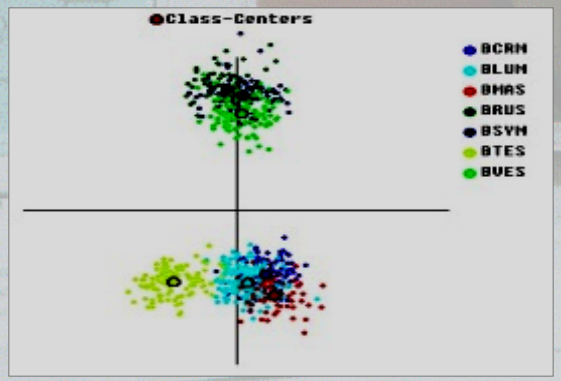


Neural Information Processing Systems

V. Roth, V. Steinhage: ***Nonlinear Discriminant Analysis Using Kernel Functions***

=> ***Feedback from Application to Computer Science Technology***





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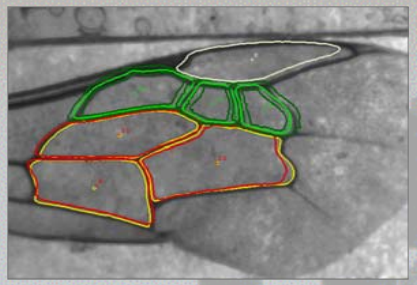
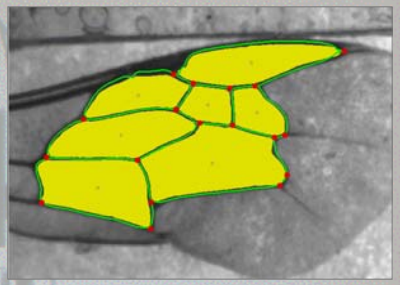
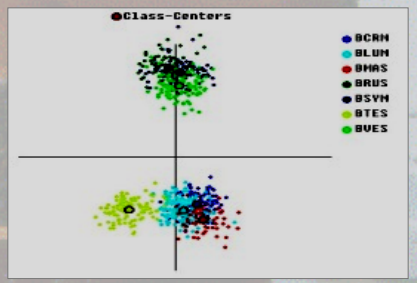
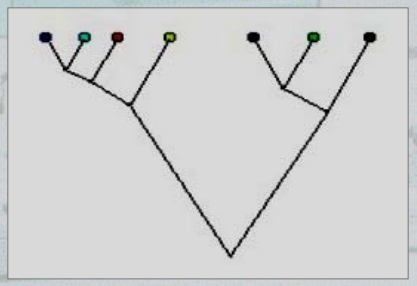
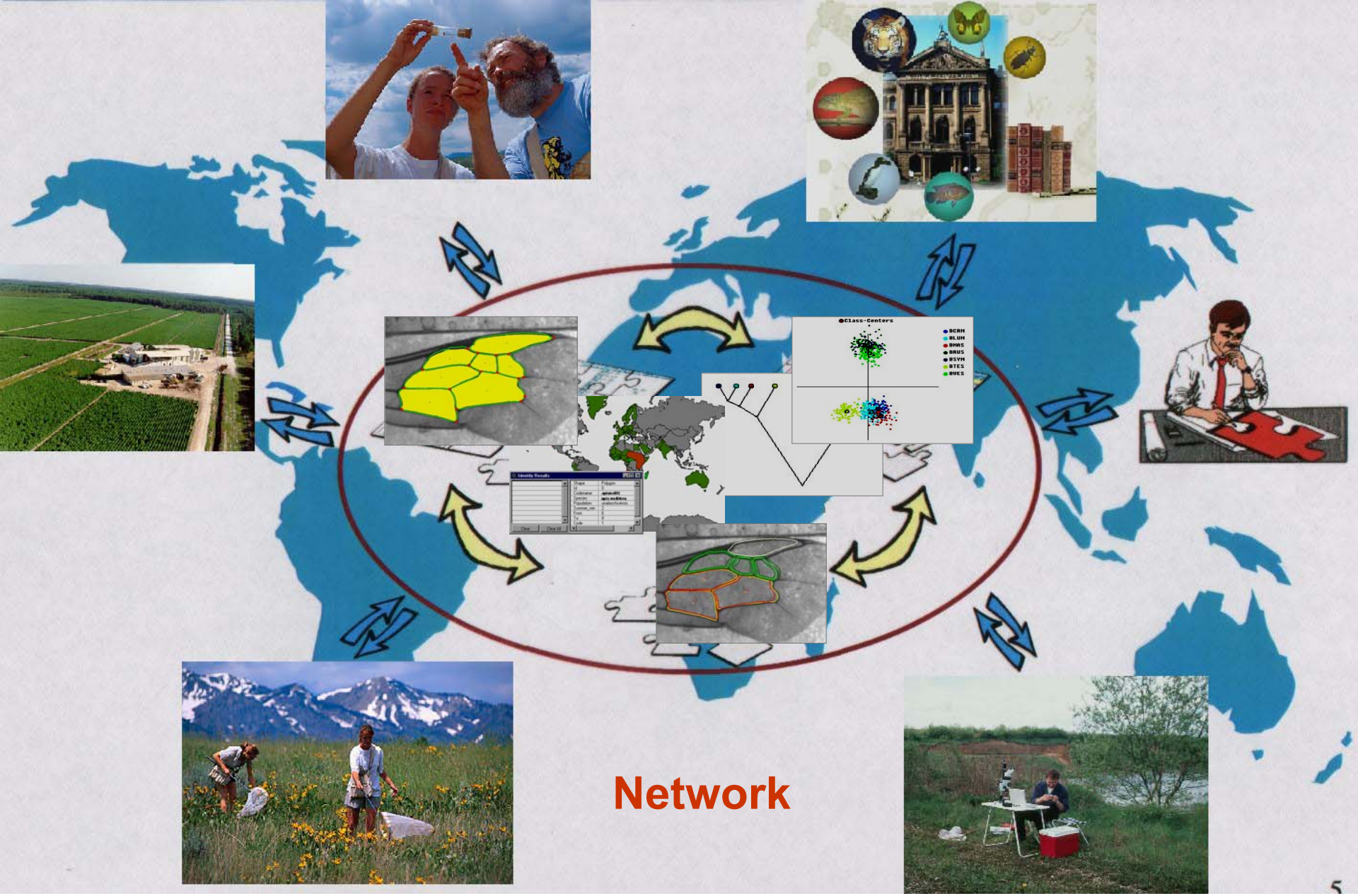



From: James Cane <jcane@biology.usu.edu>
To: James Thomson <jthomson@zoo.utoronto.ca>; Dieter Wittmann <wittmann@uni-bonn.de>
Sent: Thursday, November 30, 2000 7:30 PM
Subject: Re: CE; other bee stuff

James - did I reply? The German with the software for bee ID based on wing venation is Dieter Wittman and several colleagues. ... I was skeptical, but when it even correctly assigned the sex as well as the species to one of three sibling Andrena that Terry provided, we were all amazed. They are apparently even able to assign geographic races of Bombus with it in central Europe. I'd very much like it used here to enable me to confidently ID the western species of Osmia that we are turning to repeatedly for alternative crop pollinators. . . .







Network

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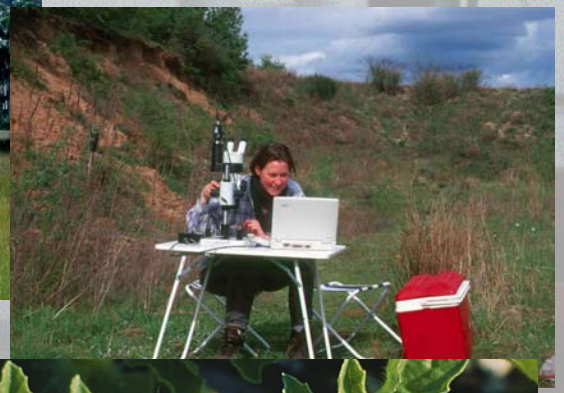
Dimensions of Application

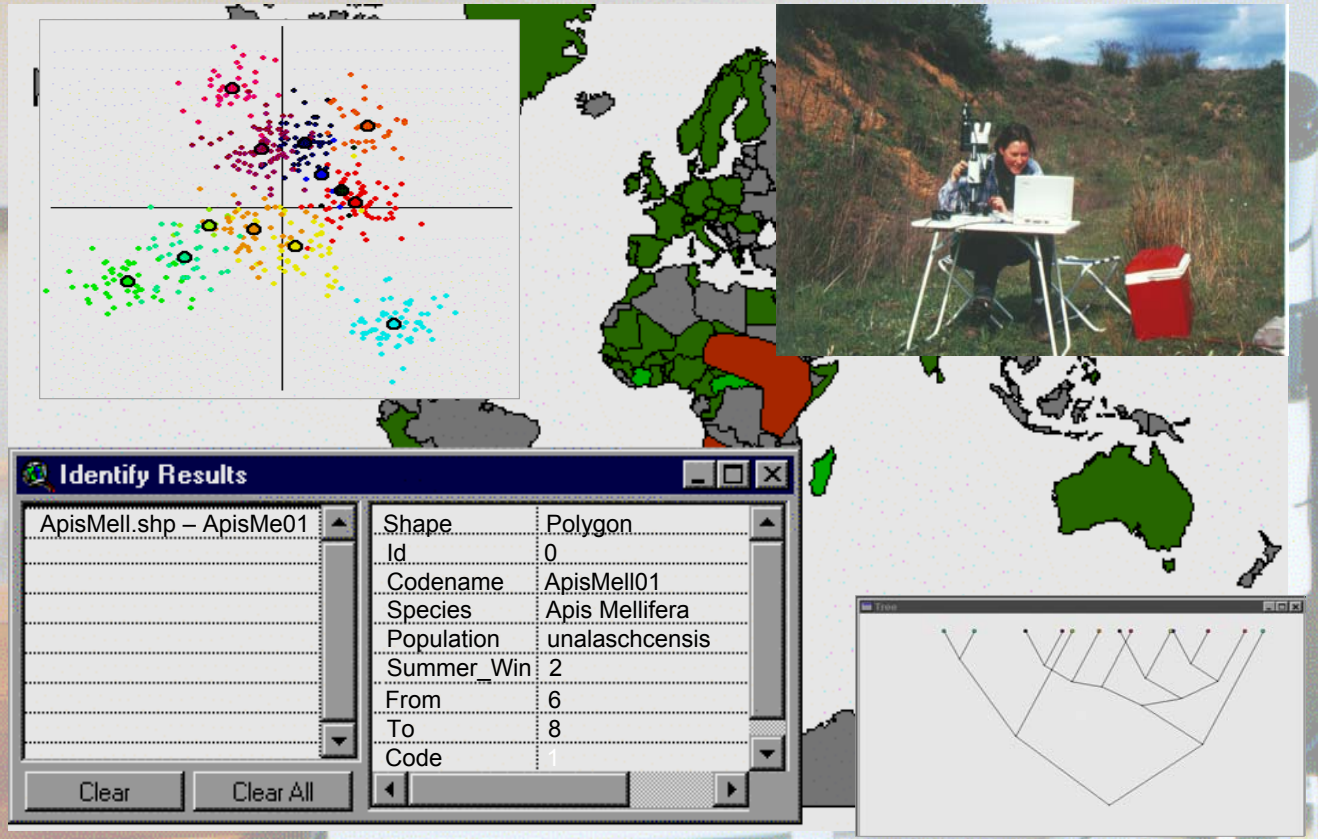
Survey and Monitoring

Investigations of Bee Biology



Support of Bee Systematics

Pollination



- Research
- Conservation
- Planning
- Monitoring
- Communication
- Cooperation
- Interdisciplinarity
- Ecology
- Economy
- ...

ABIS & GIS

ABIS: Automated Identification of Bee Species

V. Steinhage[2], S. Schröder[1], T. Arbuckle[2], D. Wittmann[1], A. B. Cremers[2]

Introduction

Insect taxonomy - in particular bee taxonomy - is a difficult task. The lack of experts greatly hampers studies on bee conservation and ecology. Bees are the main pollinators of wild plants and crops, and therefore are a critical ecological and economical resource. The annual value of the service of crop pollination has been reported to be between 65 and 70 billion US$. However, throughout the world bee populations are in decline. Therefore, the International Pollinator Initiative (IPI) was implemented as a cross-cutting initiative within the Convention on Biodiversity (CBD). The IPI co-ordinates world-wide action to monitor pollinator decline, to assess their economic value and to promote their restoration and sustainable use.

As an important tool for the IPI we have developed a system for the automated identification of bee species that employs knowledge-based image analysis of the bees' fore wing. Here, we present the current status of the Automatic Bee Identification System ABIS - in a suite of software tools for the identification and monitoring of bee species. We also work on coupling the artificial intelligence recognition tools with a geographical information system (GIS) and with the joint EDIS project (Entomological Data Information System).

Fig. 1: Female bee of the genus *Anthophora*

Fig. 2: Female bee of the genus *Dasypoda*

Results

Image Acquisition in museums and in the field

The first step in the recognition of a bee is to acquire an image of its fore wing. The ABIS-equipment consists of a stereo microscope with a CCD- or Digital Camera and a notebook. Alive bees or collection specimens are mounted with their fore wing on the illuminated table under the microscope (Fig. 3). The equipment can also be used in the field (fig. 4). The images are stored as high-resolution, high-quality JPEG files for subsequent processing by the image processing system. Instead of posting bee specimens, images of their wings can be sent via e-mail to expert centres for identification.

Fig. 3: Experimental Apparatus

Fig. 4: Identification of alive bees in the field

Automatic Image processing

Actually, we develop a fully automatic extraction algorithm for the image processing of the identification system. The system automatically detects edges in the pattern of wing venation and, with the help of genera-specific wing templates, it formulates hypotheses on the location of key cells within this pattern. Once these cells have been detected, numerical features can be generated which describe the cells and their topological relationships. These features are the input to a sophisticated statistical recognition engine.

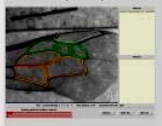


Fig. 5: After several seconds (red bars) the system has detected edges, veins and centres of gravity (dots) in the wing pattern.

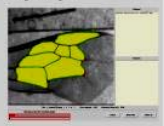


Fig. 6: The area of the cells, their outlines and the position of the vein junctions have been detected.

Identification of species

For the identification we have developed a non-linear generalisation of classical Linear Discriminant Analysis which we called Kernel Discriminant Analysis.
This classifier constructs non-linear decision functions which efficiently can be done by using kernel functions.
The system can only identify species with which it has been trained. In our experiments the minimum training set for closely related species was 30 well identified specimens per species. The system works with a fully automatic image analysis and obtains a confidence of identification beyond 95%.
As a very helpful tool for the user, the results of the classification are visualised (cluster plots and dendrogram in fig. 7 and 8. The dendrogram represents the similarities between species and may help to formulate first hypotheses on their phylogeny.

Experimental Results

In order to corroborate the high identification performance of the system we carried out several tests with species which can hardly be identified by specialists. Among others we sought to separate the bees from a species complex comprised of *Bombus lucorum*, *Bombus terrestris*, *Bombus cryptarum*, and *Bombus magnus*. We trained the system with images of the wings of 70 individuals per species, and successfully achieved an identification rate of over 95%. This is notable because it is likely to be higher than the rate achievable by a human expert when dealing with this extremely difficult task. In further experiments with the German *Colletes* and *Andrena* as well as with American *Osmia* species we again achieved such high identification rates of over 95%.

Fig. 7: Screenmap representing the clusters of 11 species of Colletes after the training phase. Centres of the clusters are marked by a circle. Coloured dots and abbreviations give species names. The dendrogram indicates similarities between species.

Fig. 8: Screenmap after the identification of one specimen (yellow dot with arrow). Circled coloured dots indicate centres of clusters of the 11 species. Upper left: Lcru = one individual identified as *Colletes cruzella*

Conclusion

The ABIS project is a innovative part of the joint EDIS project which aims to build and establish a national Entomological Data Information System in Germany. The important and crucial first step for such information system is the capture and classification of input data. ABIS offers an efficient solution for this task within the field of mapping and monitoring of insect species. This system can be applied by museum taxonomists as well as by field workers with no special training in bee taxonomy. Wing images or readymade data can be sent on disc or via internet to institutions which offer this automatic identification service.
The developed methods may be also useful in the identification of several other insect groups then bees like other Hymenoptera or Diptera.

ABIS Publications

Arbuckle, T., Schröder, S., Steinhage, V., Wittmann, D. (2001): *Biodiversity Informatics in Action: Identification and Monitoring of Bee Species using ABIS.* To appear in Proceedings of *Sustainability in the Information Society*, Conf. on Environmental Informatics, Oct. 10 - 12, 2001, ETH Zürich, Switzerland, 2001.

Schröder, S. (2001): *Automatisierte Identifikation von Bienenarten (Apoidea, Hymenoptera) anhand ihrer Flügelgeäder durch Methoden der digitalen Bildverarbeitung und der numerischen Klassifikation.* Dissertation, Verlag ULE Glauca, Stuttgart, 112 S.

Roth, V., Pogoda, A., Steinhage, V., Schröder S. (2000): *Automatisierte Artidentifizierung von Insekten durch Bildanalyse: Künstliche Intelligenz* (1), S. 48-49.

Roth, V., Pogoda, A., Schröder, S., Steinhage, V., (1999): *Pattern Recognition Combining Feature- and Pixel-based Classification Within a Real World Application.* In: *Mustererkennung 1999*, 21. DAGM-Symposium, Bonn, 129-136. Informatik aktuell, Springer.

Roth, V., Steinhage, V. (1999): *Nonlinear Discriminant Analysis Using Kernel Functions.* In: *13th Internat. Conf. on Neural Information Processing Systems*, NIPS '99, Nov. 30 – Dec. 2, 1999, Denver (Colorado).

Articles about the project

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