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Cover Picture: AI image generated by James Gilbert (see pages 193–198).

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Meetings

Electronics & Computing and Data Special Interest Groups Meeting Artificial Intelligence (AI) in Entomology

3rd July 2024, Syngenta Jealott's Hill and Online

Convenors: Mark O'Neill, James Gilbert, Rob Lind

Report by Richard Harrington

It is clear that AI will have a profound impact on many aspects of our lives, and it is timely to consider how it is already being used in entomology and what the future might hold. Syngenta, as one of the world's leading life sciences companies, was an appropriate host for the meeting. The Jealott's Hill International Research Centre is home to 1,000 employees, many of whom are entomologists. Jim Reay, Head of CPD Capability Development, welcomed delegates and outlined Syngenta's portfolio, highlighting areas where AI can help, such as designing safe and effective new chemistry technologies and modelling pest outbreaks. Jim said that the company is very keen on collaborations and stressed that good people are more vital than technology.

Let me start by defining 'deep learning', a term that came up repeatedly. It is a method in AI that teaches computers to process data in a way that is inspired by the human brain. Deep learning models can recognise complex patterns in pictures, text, sounds and other data to produce accurate insights and predictions.

Rob Lind (Syngenta) and Mark O'Neill (Tumbling Dice) set the scene, speaking about the rise of AI in insect science. Rob pointed out that artificial neural networks (ANNs), which are the basis of much AI, could be bioinspired in that insect brain networks are similarly highly structured in layers, using 'skip connections' to feed the output of one layer as the input to the next layers. 'Data is king' is Rob's mantra – 'good data in, good model out'. Data on which models are trained can be real or synthetic, and Rob warned of potential risks from models training on AI-generated data, as this could lead to echo chambers (going round in meaningless circles). Biotic neural networks have the advantages of insight, reasoning, theory of mind, sentience and subjectivity. Abiotic neural networks have the advantages of data retention, data analysis, imitation and objectivity. Partnerships between the two are synergistic. Rob outlined the evolution of AI from

Fig. 1. System for attracting and photographing moths (credit Grace Skinner).

Fig. 2. DIY Camera trap (credit Maximilian Sittinger).

rule-based algorithms through predictive AI to generative AI, potentially leading to multimodal artificial general intelligence.

Mark discussed these points in relation to optimising biodiversity identification in the field, key issues being power efficiency, computational efficiency, data bandwidth and the extraction of relevant patterns from an ocean of irrelevant ones. The solution, he said, is computationally efficient, low power machine learning. He showed an example of drone footage used to count and identify four species of dragonfly using a novel approach that is both fast and efficient but does not involve mainstream machine learning. Intelligent motion detectors extract relevant patterns using heuristics. The extracted patterns are then broken down into a set of sub-images (shards), which are correlated with a pre-labelled training dataset using a hybrid pixel-pattern/network-connectivity correlator to identify them. Around 95% of the classifiable material was correctly identified to species, outclass rejection (of patterns which are not in the training set) was excellent and errors of omission were acceptable given the noise in the data. Overall, it compares very favourably with deep learning approaches needing more computational resources and hence power.

The theme of monitoring movement was continued by Joris Mattheijssens (Ghent University, Belgium) and Bo Li (Syngenta). Joris is studying insect pollination of the Kiwiberry ("like a small but tastier Kiwifruit"). Timelapse cameras monitored one male and one female plant, and insects were detected on the images using a chain of deep learning and computer vision techniques. He found that Western Honeybees (*Apis mellifera*) only visit female flowers whereas bumblebees (not separated to species) visit both sexes and are more active than *A. mellifera*, so are much more useful. Pre-anthesis pollination was detected, which can be problematic in female flowers because it causes scars to form on the fruits, although it is useful in male flowers as it prolongs the overlap of flowering periods. Bo is studying the activity of fruit flies (*Drosophila* spp.) using a video-based multi-object tracking system (DELIA) as a model system to assess the potency of insecticides in terms of symptoms and mortality. The hope is that this can improve on manual assessment, which is time-consuming, subjective and cannot follow the activity of individual flies. The evaluation metrics showed promising results for all the tracking methods used, although further development is necessary to recognise if an individual insect is moribund.

There is a great demand for monitoring data. Toke Thomas Høye (Aarhus University, Denmark) described how deep learning models can help in the development of a globally-standardised monitoring system using insect camera traps. He outlined some of the challenges, such as the need to understand how resources change in time in order to choose a suitable camera position. The EU MAMBO project (https://www.mambo-project.eu/) uses standardised flower-bed communities for pollinator monitoring. An open access dataset shows visitation rates for individual insects to individual flowers. Visits to earlier-opening flowers tend to be shorter. The project also involves automated image-based monitoring of moths and other insects attracted to globally standardised UV light sources. These data can be used for understanding seasonal dynamics and day-to-day variation without killing insects or going into the field, and have huge potential in studies of phenology, functional ecology, species interactions and ecological monitoring. Important steps are being taken towards global standards for image-based autonomous monitoring of insects (AMI). Currently, 70 AMI traps are running in EU countries. Building on the Aarhus design, UKCEH and partners have engineered a resilient, reliable and scalable system which uses UV lighting and a high-resolution camera to attract and photograph moths. The images are put into a machine learning

Fig. 3. Site tour (credit James Gilbert).

Fig. 4. Oscar Healey, Imperial College.

pipeline to detect, track and classify individuals to provide information on species presence, relative abundance and trends over time. Grace Skinner (UKCEH) described this system (Fig. 1) and pointed out that the traps can be left out for months at a time and can be used for monitoring the effects of extreme weather events, tracking within-night activity patterns and assessing the impact of agri-environment schemes on moth diversity and abundance.

How can collaboration between humans and machines, or augmented intelligence (AuI) improve insect identification? This was the question raised by Song-Quan Ong (Aarhus University, Denmark and Universiti Malaysia Sabah, Malaysia). Currently, we are at a semi-autonomous stage which requires human taxonomists. To identify insects caught on sticky traps, Song-Quan demonstrated an AuI pipeline consisting of two annotation stages, a deep learning model to locate all insects on the trap, followed by a hierarchical file system that allows taxonomists to classify the insect image files and organise their taxonomy into folders with the help of a pre-trained deep learning model that pre-annotates the insects prior to review. An augmented one-step model could perform similarly to (or better than) humans given a larger amount of high-quality training data.

Maximilian Sittinger (German Centre for Integrative Biodiversity Research, Halle-Jena-Leipzig) described a DIY camera trap (Fig. 2) for pollinator monitoring based on low-cost, off-the-shelf hardware components and open-source Python software. It can be operated by a solar panel. It is being used in the SEPPI (Standardised European Monitoring of Plant–Pollinator Interactions) project (https://seppi-pollinate.weebly.com/) to record potential pollinators and study their interactions. Currently there are 58 camera traps in eight countries, and it is hoped that the automated method will capture spatial trends in pollinator diversity, composition, visitation rate and network structure.

During an extended lunch break, there was the opportunity to view posters and go on a site tour (Fig. 3). Grab your sandwiches. The tour was guided by Gary Needham and Iain McGonigal and demonstrated how Syngenta is using imaging systems and AI, together with automation, to screen for new ways to control insects.

Nine posters were presented. Caitlin O'Farrell (University of Portsmouth) is using AI to map and predict taphonomic change and insect activity during decomposition, in order to predict the post-mortem interval, and is exploring whether these methods can replace the need for human studies. Oscar Healy (Imperial College London) (Fig. 4) is developing an open-source, low-cost photogrammetry platform to create coloured 3D models of insects for application in research, education, outreach, conservation and animation. Maria Anastasiada (Cranfield University) is combining computer vision and deep learning methods for automated detection and tracking of insect pollinators in Thailand. Vasileios Vasileiadis (Syngenta) is using a low-cost, solar-powered sensor that draws on AI and machine learning algorithms to quantify and identify bees at genus level autonomously. Zsófia Varga-Szilay (ELTE Eötvös University, Hungary) is detecting Buff-tailed Bumblebees (*Bombus terrestris*) on three plant species in the Azores using computer vision-based deep learning methods as part of an effort to unravel differences in their foraging behaviour. Tim Lukins (Forest Research) is developing a lab-based machine-learning classification system based on a convolution neural network (CNN) to identify and classify soil fauna, whilst filtering out spurious detection. CNN is a deep learning architecture used in image processing. Gregoire Noel (University of Liège, Belgium) is using CNN to identify and count insects from high-resolution pictures of collections, initially from 80 lepidopteran and coleopteran families from Africa. Gytis Bernotas (University of West England) is using CNNs to distinguish the sexes of the Yellow Mealworm beetle (*Tenebrio molitor*), which is only possible from differences in gap sizes between the visible abdominal tergites and is important in breeding programmes for farming the insects as animal feed. Mukilan Deivarajan Suresh (Newcastle University) is exploring the potential of deep learning and image-based recognition in advancing biomonitoring, especially of pest and beneficial insects in an agricultural context.

Okay, lunch boxes away please. Presentations so far have


Fig. 5. Azores native forest (credit Sébastien Lhoumeau).

discussed how AI can help the study of insects. With Barbara Webb (University of Edinburgh), the boot was on the other foot as she spoke about how insects can inspire AI. Her group's aim is to understand the mechanisms underlying insect behaviour and to test that understanding by building the mechanisms embodying their hypotheses as mathematical models, computer code or actual machines, and show the relevance of insect capabilities to AI. Ant navigation was used as an example. Desert ants navigate in complex, cluttered terrain over distances of up to 1 km by path navigation (dead reckoning) and visual memory. Ants were tracked with GPS and hand-held downward cameras and LiDAR used to reconstruct what they were seeing. Naïve ants on their first exit from the nest make a foraging excursion then follow a direct route home. After that they take a direct route out and back. Ants which are then experimentally displaced back to the food can, after a short search, find their way back to the nest along the route they have only twice seen, thus demonstrating accurate visual memory. Visual memory must involve pattern recognition, and the ants must associate the views they experience with their progress towards food or their nest. There is much to learn about how memory is organised in the insect brain and such understanding may lead to low-cost, low-computation solutions for navigation and other tasks relevant to AI such as intelligent robotics.

Although from the University of Southern Queensland, Australia, Derek Long was present in person to speak about an AI-powered, smart phone-based app for monitoring Silverleaf Whitefly (*Bemisia tabaci*) (SLW), a major pest of cotton, in an attempt to replace labour-intensive methods of assessing the need for control. 1,600 annotated images were used in algorithm development, and nymph identification using lens-magnified images in the field was 89% accurate. This method allows assessment of parasitism and hence the scoring of the nymphs as viable or unviable. For non-magnified images, identification is in two stages, a one-shot object detection followed by zooming in for classification, which was 75% accurate. This method is quicker but cannot detect parasitism. The biggest challenge is building trust in the system with the industry. The first version has been released and the next step is commercialisation for widespread deployment, hopefully resulting in reduced chemical control.

Detection of insects in the soil cannot be done with cameras. Karthik Ashok (Baker Consultants Ltd) is developing a neural

Fig. 6. *Pseudophloeophagus tenax borgesi*, which is endemic to the Azores archipelago (credit Sébastien Lhoumeau).

Fig. 7. SLAM (Sea Land Air Malaise) trap (credit Sébastien Lhoumeau).

network-based system to detect the acoustic stridulation signals of wireworms (larvae of click beetles) using off-the-shelf microphones, recorders and TensorFlow-based models. Mesocosms (colonies in pots) involving two genera of wireworms (*Agriotes* and *Athous*), which are pests of potato, were used in development of the prototype. The plan is to use the technology in early-warning detection and species assessment across the UK.

Understanding mosquito behaviour is crucial to developing monitoring tools. Khaled Mostafa Hussein and Mohamed Hany Abdelfatah (October University for Modern Sciences and Arts, Egypt) tracked the movement of three mosquito species using computer vision. Six videos each tracked six mosquitoes in a laboratory setting. The trajectory of each mosquito was extracted, and deep learning successfully classified the different directional movement patterns. Heatmaps were used to quantify activity levels, and this made it possible to distinguish the sexes accurately.

Mosquitoes such as *Culex quinquefasciatus* can fly in complete darkness without crashing into anything. Richard Bomphrey (Royal Veterinary College) wants to know how they do this, and whether such understanding can be applied to aircraft. Using an eight-camera system operating at 10,000 frames per second, he has built up a high-resolution picture of mosquito wing deformation and identified the forces generated. The mosquitoes are equipped with pressure mechanoreceptors. As they approach a barrier, pressure waves activate the sensors and lead to an avoidance reaction. The acoustic profile of the pressure waves tells them their orientation. Richard has applied this technology via a CNN to quadcopters and shown that it works in preventing them from colliding with objects. Richard has been studying dragonflies in a similar way and has mapped in detail the sensilla on the wings which detect strain and airflow. By filming in a wind tunnel and simultaneously looking at which neurons are spiking, he is building a picture of the flight control mechanism which, again, has potential for application in aircraft systems.

A very different application of AI and computer vision led Jack Hollister (University of Southampton and Natural History Museum London) to the astonishing conclusion that 20% of the Museum's British and Irish Lepidoptera are potentially wrongly labelled for one reason or another, not necessarily the fault of the original labeller as the nomenclature may have changed or there are issues with their online portal. He pointed out that

Fig. 8. The panel (credit James Gilbert).

it is important not to let the AI see the labels. Another unusual use of AI is in the reporting of extreme aversion to insects (entomophobia). Moshe Gish (University of Haifa, Israel) was surprised at the skewing of the aversion frequency curve to the most extreme categorisation when Japanese citizens were asked to rate their level of fear and disgust in response to various images of insects, and the finding that there was no correlation between the aversion score and the use of insecticides in homes. He recognised that the questioning needed to be more nuanced and developed a Computerised Adaptive Test using ChatGPT to do this, which resulted in the most extreme category being broken down into smaller units. If a subject gave an extreme score in response to a picture or question, the next picture or question was milder, and *vice versa*. This resulted in a more objective scoring system than one involving self-recording. Interestingly, only women were tested as it has been shown that men tend not to admit fear!

To manage biodiversity conservation, it is important to be able to predict likely outcomes in response to the many agents of change. Sébastien Lhoumeau (University of the Azores, Portugal) is developing a recurrent neural network (RNN) to forecast arthropod community composition within the native forest (Figs 5, 6, 7) of Terceira in the Azores. RNNs are suited to analysing temporal and sequential data. The dataset used to train the RNN model consisted of arthropod species abundance records from a long-term environmental monitoring project. The RNN was able to capture complex dynamics and generate accurate forecasts for the next sampling period, thus demonstrating its potential in early detection of potential shifts in community structure and the identification of critical conservation areas.

Following the presentations, Rob Lind, Mark O'Neill, Barbara Webb and Richard Bomphrey led a lively panel (Fig. 8) discussion which highlighted the incredible speed of progression in the use of AI in entomology. It was agreed that we are at the dawn of something big, and that another meeting in two or three years would probably involve very different conversations. For example, quantum computing may take possibilities to a new level. AI will be an essential player in solving major issues such as climate change and biodiversity loss. The importance of sharing code and data to make it possible for people to build on each other's systems was highlighted. The continued importance of human taxonomic expertise was emphasised, and it was suggested that it would be useful if AI systems could question taxonomists so as to close the feedback loop. However, with 20% of the Natural History Museum's British butterflies being wrongly identified, the concept of human experts was called into question by some and defended vigorously by others. AI and humans make different sorts of mistakes and hence synergy is essential. There was concern over how we can be sure that AI is being correctly used and not hallucinating, and how we can referee AI-generated papers.

Thus ended a truly fascinating and consequential day. James Gilbert summed up and greatly pleased your pedantic *Antenna* editor by re-emphasising that that data ARE king! Well said, that man. Many thanks to the convenors, presenters, coauthors and RES staff. A future meeting on this theme beckons.