



# VistaMilk

A World Leading SFI Research Centre



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# Foreword

The vision of the VistaMilk Centre is to be a world leader in the agri-food technology sector through innovation and enhanced sustainability across the entire dairy supply chain from soil to society, positively impacting the environment, animal well-being and the health of consumers. This vision will be achieved by greatly improving the soil-to-society supply chain connectivity, thereby improving resource efficiency, better meeting consumers' expectations and improving profitability and resilience. In delivering on this vision, VistaMilk pools domain expertise across a range of areas and technologies to create a truly unique collaboration to benefit the Agri-Tech and Agri-Food industries.



The €40m VistaMilk SFI Research Centre consists of >200 scientists from 7 research institutes and has more than fifty committed industry partners. The industry partners span the whole food chain as well as representing several different domain areas of expertise. VistaMilk has distributed the problem domain into three main themes of consideration 1) pasture, 2) animal and 3) food. VistaMilk is focused on delivering on the three strategic goals of *Sustainability*, *Food Security*, and *Prosperity and Societal Enrichment*

Given VistaMilk's mission of *being an agent of responsible and sustainable growth for the Irish dairy and Ag-Tech industries by being a world leader in fundamental and translational research for digital pasture-based dairying*, the importance of translating science to practice is critical to realising impact. VistaMilk is committed to delivering impact on sustainable food systems, namely those associated with economic, social and environmental sustainability. One strategy to expedite the process of delivering impact is to summarise and showcase a selection of VistaMilk's scientific publications into easily accessible summaries with a particular emphasis on outcomes and impact. The selection of impact pieces in this booklet provide a snapshot of the ground-breaking fundamental and applied research portfolio being undertaken in the VistaMilk SFI research center across the soil-to-society supply chain.

Donagh Berry  
VistaMilk Director





# 2022

1. A Novel RCS based CRFID Tag Design - Nadeem Rather, John Buckley, Brendan O'Flynn, Melusine Pigeon

2. Nearest Neighbour-Based Data Augmentation for Time Series Forecasting - Duncan Wallace, Derek Greene, Eoin Delaney and Mark Keane

3. Towards On-Device AI and Blockchain for 6G enabled Agricultural Supply-chain Management - Muhammad Zawish, Nouman Ashraf, Rafay Iqbal Ansari, Steven Davy, Hassan Khaliq Qureshi, Nauman Aslam and Syed Ali Hassan

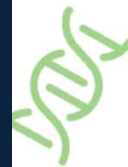
4. Using deep learning to classify grassland management intensity in ground-level photographs for more automated production of satellite land use maps - Mohamed Saadeldin, Rob O'Hara, Jesko Zimmermann, Brian Mac Namee, Stuart Green

5. Predicting livestock behaviour using accelerometers: A systematic review of processing techniques for ruminant behaviour prediction from raw accelerometer data - Lucile Riaboff, Laurence Shalloo, Alan Smeaton, Sébastien Couvreur, Aurélien Madouasse and Mark Keane

6. A novel minimal set decode-amplify-forward (MS-DAF) relaying scheme for MIMO-NOMA - Muhammad Zeeshan, Mahnoor Ajmal, Muhammad Umar Farooq and Tabinda Ashraf

7. The role of compute nodes in privacy-aware decentralised AI - Joana Tirana, Christodoulos Pappas, Dimitris Chatzopoulos, Spyros Lalis and Manolis Vavalis

8. Preliminary Classification of Selected Farmland Habitats in Ireland Using Deep Neural Networks - Lizy Abraham, Steven Davy, Muhammad Zawish, Rahul Mhapsekar, John Finn and Patrick Moran



# 2022

9. Forecasting for Sustainable Dairy Produce: Enhanced Long-Term, Milk-Supply Forecasting Using k-NN for Data Augmentation, with Prefactual Explanations for XAI - Eoin Delaney, Derek Greene, Laurence Shalloo, Mike Lynch and Mark Keane

10. Addressing out-of-distribution label noise in webly-labelled data- Paul Albert, Diego Ortego, Eric Arazo, Noel O'Connor and Kevin McGuinness

11. 5G/SDR-Assisted Cognitive Communication in UAV Swarms: Architecture and Applications - Muhammad Zeeshan, Muhammad Umar Farooq, Kashif Shahzad and Adnan Akhuzada

12. Fast Channel Selection for Scalable Multivariate Time Series Classification - Bhaskar Dhariyal, Thach Le Nguyen and Georgiana Ifrim

13. The Repeatability of Grazing Efficiency as a Perennial Ryegrass Variety Trait - Tomás Tubritt, Luc Delaby and Michael O'Donovan

14. Global Regulatory Frameworks for Fermented Foods: A Review - Arghya Mukherjee, Beatriz Gómez-Sala, Eibhlís O'Connor, John Kenny and Paul Cotter

15. Breeding for improved protein fractions and free amino acids concentration in bovine milk - Giulio Visentin, Donagh Berry, Angela Costa, Audrey McDermott, Massimo De Marchi and Sinead McParland

16. The Association Between Genomic Heterozygosity and Carcass Merit in Cattle - David Kenny, Tara Carthy, Craig Murphy, Roy Sleator, Ross Evans and Donagh Berry



# 2022

17. Assessing nitrous oxide emissions in time and space with minimal uncertainty using static chambers and eddy covariance from a temperate grassland - Rachael Murphy, Karl Richards, Dominika Krol, Amanuel Gebremichael, Luis Lopez-Sangil, James Rambaud, Nicholas Cowan, Gary Lanigan and Matthew Saunders

18. Nitrous oxide emission factors from an intensively grazed temperate grassland: A comparison of cumulative emissions determined by eddy covariance and static chamber methods - Rachael Murphy, Matthew Saunders, Karl Richards, Dominika Krol, Amanuel Gebremichael, James Rambaud, Nicholas Cowan and Gary Lanigan

19. Are subjectively scored linear type traits suitable predictors of the genetic merit for feed intake in grazing Holstein-Friesian dairy cows? - Maeve Williams, Craig Murphy, Roy Sleator, Siobhán Ring and Donagh Berry

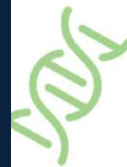
20. Exploiting genetic variability in the trajectory of lactation yield and somatic cell score with each progressing parity - Maeve Williams, Craig Murphy, Roy Sleator, John McCarthy and Donagh Berry

21. Re-assessing the importance of linear type traits in predicting genetic merit for survival in an aging Holstein-Friesian dairy cow population - Maeve Williams, Roy Sleator, Craig Murphy, John McCarthy and Donagh Berry

22. Is your noise correction noisy? PLS: Robustness to label noise with two stage detection - Paul Albert, Eric Arazo, Tarun Krishna, Noel O'Connor and Kevin McGuinness

23. VistaMilk's 'Coding with Cows' - Megan O'Brien, Richard Burke and Lucile Riaboff

24. Unsupervised domain adaptation and super resolution on drone images for autonomous dry herbage biomass estimation - Paul Albert, Mohamed Saadeldin, Badri Narayanan, Brian Mac Namee, Deirdre Hennessy, Noel O'Connor and Kevin McGuinness





# 2022

25. Embedding contrastive unsupervised features to cluster in-and out-of-distribution noise in corrupted image datasets - Paul Albert, Eric Arazo, Noel O'Connor and Kevin McGuinness

26. Utilizing unsupervised learning to improve sward content prediction and herbage mass estimation - Paul Albert, Mohamed Saadeldin, Badri Narayanan, Brian Mac Namee, Deirdre Hennessy, Aisling O'Connor, Noel O'Connor and Kevin McGuinness

27. Using deep learning to detect digitally encoded DNA trigger for Trojan malware in Bio-Cyber attack - Mohid Siblee Islam, Stepan Ivanov, Hamdan Awan, Jennifer Drohan, Sasi Balasubramaniam, Lee Coffey, Srivatsan Kidambi and Witawas Sri-Saan

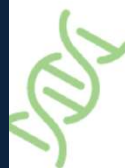
28. Optimal Power Allocation and Cooperative Relaying under Fuzzy Inference System (FIS) Based Downlink PD-NOMA - Asif Mahmood, Mohamed Marey, Moustafa Nasralla, Maged Esmail and Muhammad Zeeshan

29. A simulation and experimental study of electrochemical pH control at gold interdigitated electrode arrays - Benjamin O'Sullivan, Bernardo Patella, Robert Daly, Ian Seymour, Caoimhe Robinson, Pierre Lovera, James Rohan, Rosalinda Inguanta and Alan O'Riordan

30. SERS based detection of herbicide MCPA using electrochemically synthesised 2D-silver nanodendrites functionalised with cyclodextrin - Robert Daly, Tarun Narayan, Fernando Diaz, Julio Gutierrez Moreno, Michael Nolan, Alan O'Riordan and Pierre Lovera

31. Contribution of genetic variability to phenotypic differences in on-farm efficiency metrics of dairy cows based on body weight and milk solids yield - Donagh Berry and John McCarthy

32. Linear type trait genetic trends in Irish Holstein-Friesian dairy animals- Donagh Berry, Siobhán Ring and Margaret Kelleher



# 2022

33. Quantifying genetic differences between exported dairy bull calves and those sold for domestic beef production - Donagh Berry, Siobhán Ring and Alan Twomey

34. Characterisation of eight cattle with Swyer syndrome by whole-genome sequencing - Donagh Berry, Ermias Herman, Tara Carthy, Rebecca Jennings, Nadri Bandi-Kenari, Rebecca O'Connor, John Mee, Jim O'Donovan, Darragh Mathews and Paul Stothard





Nadeem Rather

## CONTEXT

Health monitoring of animals is an essential part of ensuring their well-being and the quality of dairy products. To facilitate health monitoring it is important to develop easy to access systems that provide relevant information to farmers.

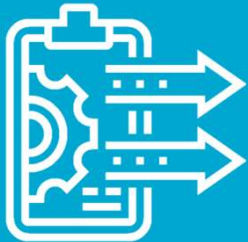


## PROBLEM STATEMENT

Can we use a chip-less, battery-less antenna to store health data derived from chemical changes in cow tear fluids?

## ACTIVITIES

Design a chip-less antenna to store data and have sensing capability



## OUTPUTS

We designed a circular shape antenna based on electric radio waves to work on the contact lens size of a cow  
The antenna can differentiate between 255 cows with sensing capability

## OUTCOMES

A chip-less sensing antenna can now be attached to a contact lens for testing



## IMPACTS



A low-cost and non-invasive health monitoring system would help farmers and other stakeholders ensure the well-being of the herd  
Additionally, such a smart sensor system would provide ease of access and facilitate data-based decision making

### Further Information:

A Novel RCS based CRFID Tag Design  
Nadeem Rather, John Buckley, Brendan O'Flynn, Melusine Pigeon. 2022  
2022 16th European Conference on Antennas and Propagation (EuCAP)  
<http://dx.doi.org/10.23919/EuCAP53622.2022.9769588>

## IMPROVING FORECASTING ACCURACY BY USING SIMILAR DATA SOURCES

Duncan Wallace

### CONTEXT

Forecasting involves the estimation of figures based on historical data. In particular, our research is focusing on the model provided by Facebook Prophet and seeks to determine whether forecasts made using this model can be improved upon using data augmentation techniques.

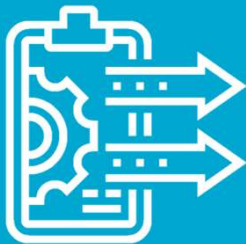


### PROBLEM STATEMENT

Is it possible to improve the accuracy of forecasting?

### ACTIVITIES

In our analysis of whether data augmentation improved our forecasting accuracy, tests were conducted to see if performance was effected by the type of forecasting performed (e.g. weather versus dairy output) and whether any patterns could be identified that would allow filtering of unsuitable time series for augmentation.



### OUTPUTS

Forecasting accuracy was improved using the methodology we developed.

### OUTCOMES

Significant differences in performance were identified when using different datasets, with filtering identified as a necessary step in overall approach.



### IMPACTS



Novel research in the context of nearest neighbour use in time series forecasting.

#### Further Information:

Nearest Neighbour-Based Data Augmentation for Time Series Forecasting  
Duncan Wallace, Derek Greene, Eoin Delaney and Mark Keane. 2022  
<https://ceur-ws.org/Vol-3105/paper10.pdf>

## EDGE INTELLIGENCE FOR SMART FARMING APPLICATIONS

Muhammad Zawish

### CONTEXT

Artificial Intelligence on network Edge shifts computations from the cloud to the data source (mobile device) ensuring secure and quick decisions. However, deployment of Artificial intelligence (AI) models, particularly deep neural networks (DNNs) on edge is hindered by their huge parameters.

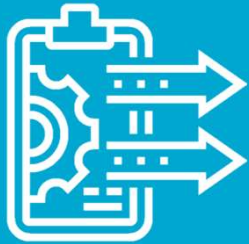


### PROBLEM STATEMENT

How can we compress an AI model for a particular application, such as Biomass estimation, so that it could be used on resource-limited mobile edge devices?

### ACTIVITIES

We propose an iterative pruning technique which compress the AI model iteratively and creates a roadmap of descendant models with various complexity-accuracy trade-offs. Since each device is different from other, using the proposed approach, a suitable model can be generated based on a certain execution requirements.



### OUTPUTS

The research output produced from this activity lead to a publication in IEEE Internet of Things Magazine

### OUTCOMES

Mobile edge intelligence proved to be reliable when security and response time are the concern. AI models are not suitable for direct execution on resource-constrained mobile edge. Thus, iterative compression is a viable solution in generating multiple task specific AI models with resource complexity trade-offs.



### IMPACTS

Moving intelligence from the cloud to mobile edge devices can reduce the amount of useless and wasteful data transmission to and from the cloud thereby reducing the energy requirements

#### Further Information:

Towards On-Device AI and Blockchain for 6G enabled Agricultural Supply-chain Management  
Muhammad Zawish, Nouman Ashraf, Rafay Iqbal Ansari, Steven Davy, Hassan Khaliq Qureshi, Nauman Aslam and Syed Ali Hassan. 2022  
IEEE Internet of Things Magazine  
<https://doi.org/10.48550/arXiv.2203.06465>



## GRASSLAND MAPPING USING SATELLITE AND GROUND-LEVEL IMAGERY

Mohamed Saadeldin

### CONTEXT

Collecting accurate reference data for training and validating remotely sensed grassland mapping is important. Satellite imagery is commonly used for this task, but can be affected by weather conditions and limited resolution.

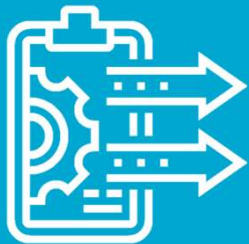


### PROBLEM STATEMENT

To map grassland into three management classes (intensive, extensive, abandoned) using both satellite and ground-level imagery.

### ACTIVITIES

Ground-level photographs were taken during the 2018 EUROSTAT Land Use/Coverage Area Frame Survey (LUCAS) in addition to Sentinel 1 and Sentinel 2 satellite imagery  
Ground-level photos were manually labelled into the three management intensity classes which were used to train and validate a Convolutional Neural Network model (CNN). The predicted labels were used to train random forest classification model on satellite imagery



### OUTPUTS

The developed CNN model trained on ground level photos achieved classification of three management intensity classes with an accuracy of >90%  
Random forest (RF) model trained on satellite imagery and using labels predicted by the CNN model achieved classification accuracy of >84%

### OUTCOMES

Ground-level photographs can be used to provide estimates of level of management intensity of grasslands utilising trained CNN models without the need for human experts  
Models trained on ground-level photograph can be utilised to generate less accurate labels that are good enough to train satellite imagery models



### IMPACTS

Machine learning models trained on larger satellite imagery datasets (automatically labelled using the developed CNN models) can provide more accurate grassland mapping/classification on a large scale. Moreover, landowners can self-assess/classify their grassland using ground-level images collected by their smartphones, while regulatory bodies can verify that using satellite imagery

#### Further Information:

Using deep learning to classify grassland management intensity in ground-level photographs for more automated production of satellite land use maps

Mohamed Saadeldin, Rob O'Hara, Jesko Zimmermann, Brian Mac Namee and Stuart Green. 2022

Remote Sensing Applications: Society and Environment Volume 26, April 2022, 100741. <https://doi.org/10.1016/j.rsase.2022.100741>

Lucile Riaboff

## CONTEXT

Farmers are used to observing their cows in the field to make sure they are healthy and not stressed; this is time consuming and subjective  
Digital tools and artificial intelligence are developing in many fields  
New technologies could thus help farmers to monitor their animals

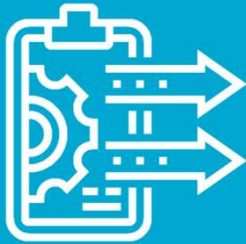


## PROBLEM STATEMENT

What is the most appropriate AI algorithm to develop new tools for animal monitoring?

## ACTIVITIES

A review and summary of the processes that are used in studies to monitor livestock behaviour collected with activity data was carried out to make recommendations on the most promising techniques



The review recommends collecting data on many animals and using artificial intelligence so that the behavioural monitoring from activity data is reliable and can be carried out regardless of farm, breed and other factors

## OUTPUTS

## OUTCOMES

The guidelines from this review will be used in further studies to develop a farmer-friendly livestock behaviour monitoring tool



Tools to monitor automatic livestock behaviours are really promising to address several challenges in farming, such as ensuring that animals are healthy, calm, and have sufficient grass to eat, amongst other behaviours

## IMPACTS

### Further Information:

Predicting livestock behaviour using accelerometers: A systematic review of processing techniques for ruminant behaviour prediction from raw accelerometer data

Lucile Riaboff, Laurence Shalloo, Alan Smeaton, Sébastien Couvreur, Aurélien Madouasse and Mark Keane. 2022  
Computers and Electronics in Agriculture. <https://doi.org/10.1016/j.compag.2021.106610>

## RELIABLE COMMUNICATION IN FUTURE RADIO ACCESS TECHNOLOGY

Muhammad Zeeshan

### CONTEXT

Cooperative communication is used to extend the connectivity range through relaying  
It results in huge network overhead if the number of relays are not selected properly

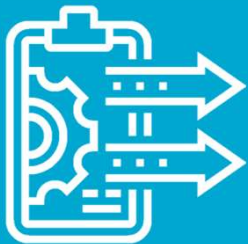


### PROBLEM STATEMENT

Need to find the minimum relay set without compromising the overall performance

### ACTIVITIES

An algorithm was developed by using minimal set selection procedure  
The scheme was simulated and verified through MATLAB simulations



### OUTPUTS

A generic framework was developed that is integral with various communication protocols  
The findings have been published in Telecommunication Systems Journal

### OUTCOMES

The research activity has produced minimal network overhead with approximately the same performance compared to the case with no relay selection



### IMPACTS

This research can enhance the connectivity in future wireless networks  
This research is expected to benefit wireless industrial networks, security applications and smart city solutions

#### Further Information:

A novel minimal set decode-amplify-forward (MS-DAF) relaying scheme for MIMO-NOMA  
Muhammad Zeeshan, Mahnoor Ajmal, Muhammad Umar Farooq and Tabinda Ashraf. 2022  
Telecommunications Systems  
<https://doi.org/10.1007/s11235-022-00894-2>



**ALLOW SMALL DEVICES LIKE MOBILE PHONES TO COLLABORATIVELY WORK ON ARTIFICIAL INTELLIGENT PROGRAMS, WHILE PRESERVING THEIR PRIVACY**

**Joana Tirana**

**CONTEXT**

Machine learning is a type of artificial intelligence that allows software applications to become more accurate at predicting outcomes. Federated learning is a machine learning protocol that allows many individuals to train in a collaborative way, whilst knowing their data is being protected.



**PROBLEM STATEMENT**

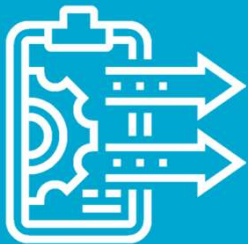
Mobile phones do not provide the resources to run machine learning programs, thus they need to use more powerful devices and offload parts of the machine learning tasks to them

**ACTIVITIES**

We have proposed that individuals use other powerful machines, such as the cloud, to perform computationally heavy machine learning tasks. The user will send the helper machines such tasks and will receive the results. Running numerous experiments will find the optimal number of helper machines that individuals can use to accelerate their training.



**OUTPUTS**



We created a program that mobile phones can use in order to run machine learning tasks in collaboration with other machines that are located in a cloud server

**OUTCOMES**

Training time is reduced when we use more powerful machines such as the cloud, which means the results can be obtained quicker  
Additionally, the program will offer more privacy to the users



**IMPACTS**



The method developed can offer privacy to users, which is greatly reassuring to those involved  
Using helper nodes to assist small devices means they can complete the tasks on bigger and more powerful machines, while also preserving the user's privacy

**Further Information:**

The role of compute nodes in privacy-aware decentralised AI  
Joana Tirana, Christodoulos Pappas, Dimitris Chatzopoulos, Spyros Lalis and Manolis Vavalis. 2022  
EMDL '22: Proceedings of the 6th International Workshop on Embedded and Mobile Deep Learning  
<https://dl.acm.org/doi/10.1145/3539491.3539594>

## AUTOMATIC LABELLING OF FARMLAND HABITATS IN IRELAND

Lizy Abraham

### CONTEXT

Ireland has a wide variety of farmlands that includes arable fields, grassland, hedgerows, streams, lakes, rivers, and native woodlands  
Habitat mapping can be utilised in a variety of applications in nature conservation

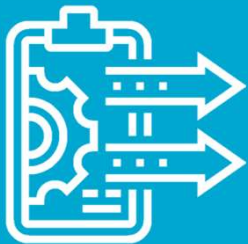


### PROBLEM STATEMENT

Traditional methods of habitat identification rely on field surveys, which are resource intensive; therefore there is a strong need for digital methods to improve the speed and efficiency of identification and differentiation of farmland habitats

### ACTIVITIES

Collect and label habitat images of representative Irish farmlands collected using unmanned aerial vehicles  
Develop a deep learning method for the automatic labelling of farmland habitat types



### OUTPUTS

High-resolution drone images were collected over 18 different habitat types that were grouped into six broad categories and labelled them most accurately

### OUTCOMES

An approach for the automatic labelling of selected farmland habitats in Ireland was developed  
The approach has been validated on a high-resolution dataset collected using drones



### IMPACTS

Alabelling and classification of farmland habitats in Ireland will be an important contribution to the improved monitoring and preservation of ecosystems.

#### Further Information:

Preliminary Classification of Selected Farmland Habitats in Ireland Using Deep Neural Networks  
Lizy Abraham, Steven Davy, Muhammad Zawish, Rahul Mhapsekar, John Finn and Patrick Moran. 2022  
Sensors  
<https://doi.org/10.3390/s22062190>

## IMPROVING MILK SUPPLY FORECASTING ACCURACY AND INFORMING FARMERS ON ACTIONS THAT CAN BE TAKEN TO BOOST FUTURE YIELD

Eoin Delaney

### CONTEXT

Current forecasting models often underperform in long term forecasting  
 A goal is often to forecast next year's herd's milk yield using granular historic data  
 Accurate forecasting and explanation can aid budgeting and promote sustainable practices on farms

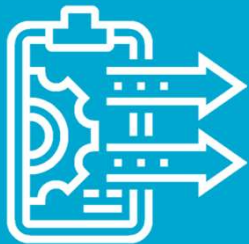


### PROBLEM STATEMENT

Can we provide accurate long term milk supply forecasts for commercial dairy farms?  
 Can we inform farmers about how that can improve their practices (to boost profitability and sustainability)?

### ACTIVITIES

Dataset from industry partner with historical herd milk yield  
 Generated accurate long term milk supply forecasts  
 Compared with other forecasting methods  
 Generated novel explanations for prediction that can help farmers understand actions that can boost future milk yield



Novel technique on how to generate explanations for forecasting tasks that can help users realise actions to improve performance  
 A novel forecasting method

### OUTPUTS

### OUTCOMES

Forecasting accuracy improved using proposed methodology. More accurate than the next best model by 3.6M litres over the forecasting period  
 Explanations indicating that reducing the calving window and extending the drying off period could improve performance on farm



Improved milk supply forecasts that could aid with resource allocation, planning and budgeting for farmers and for processors  
 This is the first work that considers pre-factual explanations for time series forecasting. It also suggests good practices for farmers to follow

### IMPACTS

#### Further Information:

Forecasting for Sustainable Dairy Produce: Enhanced Long-Term, Milk-Supply Forecasting Using k-NN for Data Augmentation, with Prefactual Explanations for XAI Eoin Delaney, Derek Greene, Laurence Shalloo, Mike Lynch and Mark Keane. 2022  
 To appear in Proc. 30th International Conference on Case-Based Reasoning (ICCBR-2022).  
[https://doi.org/10.1007/978-3-031-14923-8\\_24](https://doi.org/10.1007/978-3-031-14923-8_24)



# HOW TO REDUCE DATASET CREATION COSTS BY USING IMAGES GATHERED FROM SEARCH ENGINES ON THE WEB

Paul Albert

## CONTEXT

Great datasets are the secret behind successful artificial intelligence systems  
 Creating such datasets requires extensive amounts of human labour to ensure data is relevant

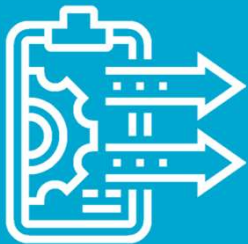


## PROBLEM STATEMENT

What type of problems could we expect when creating an image dataset from web searches, and how can we train an algorithm to deal with this imperfect data?

## ACTIVITIES

The identification and assessment of two types of imperfections in image datasets were gathered from the web  
 A robust algorithm was designed to correct these imperfections



The robust algorithm was shown to automatically identify both types of imperfections and to correct them  
 This allows us to improve the dataset quality without the need for human labour

## OUTPUTS

## OUTCOMES

Informed decisions can now be made when using search engines to gather large datasets from the web  
 We now know what types of biases to look out for



## IMPACTS



This work enables smaller companies to use advanced artificial intelligence systems to solve concrete problems, even if they cannot afford to gather huge curated datasets

### Further Information:

Addressing out-of-distribution label noise in weblly-labelled data  
 Paul Albert, Diego Ortego, Eric Arazo, Noel O'Connor and Kevin McGuinness. 2022  
 IEEE/CVF Winter Conference on Applications of Computer Vision (WACV) 2022  
<https://doi.org/10.1109/wacv51458.2022.00245>

## DRONE SWARM COMMUNICATION FOR MONITORING APPLICATIONS

Muhammad Zeeshan

### CONTEXT

Like humans, coordinated effort is essential to bring efficiency in multi-agent communication systems  
Developing a reliable communication solution for drone swarms is a major challenge

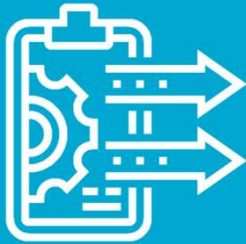


### PROBLEM STATEMENT

A challenge of drone swarm communications exists

### ACTIVITIES

The methodology and verification was based on MATLAB simulations  
The proof-of-concept implementation was based on software defined radios (SDR)



### OUTPUTS

The open-interface communication solution integral with any application

### OUTCOMES

Validated the proof of concept for the realisation of hybrid connectivity framework for drone swarms intended for monitoring applications  
The work is a stepping stone towards the development of indigenous communication solutions for drone swarms.



### IMPACTS

It is expected that the research will create an indigenous ecosystem for drone swarms and software defined radio development, while impacting positively on various surveillance and monitoring applications

#### Further Information:

5G/SDR-Assisted Cognitive Communication in UAV Swarms: Architecture and Applications  
Muhammad Zeeshan, Muhammad Umar Farooq, Kashif Shahzad and Adnan Akhunzada. 2022  
IEEE IT Professional  
<https://ieeexplore.ieee.org/document/9811512>

## OBTAINING IMPORTANT FEATURES IN CLASSIFICATION BASED ON RECURRING PATTERNS

Bhaskar Dhariyal

### CONTEXT

Ubiquitous access to sensors has made data collection from multiple sources extremely convenient. However, with the increase of data sources, the chances of some sources collecting inaccurate data are also high  
The inaccurate data increases the time required to get feedback and erodes the accuracy of the result

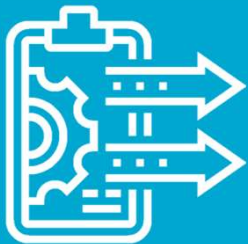


### PROBLEM STATEMENT

Identify and remove the sources which record inaccurate data

### ACTIVITIES

For every individual data source, you represent a complete data with a single data point  
Identify useful data sources by calculating distance between every class pair, for each data source. The useful data sources helps perform classification quickly  
The method was tested on 26 benchmark datasets from different domains and a real-world dataset



A faster and more accurate approach that does not require human involvement

### OUTPUTS

### OUTCOMES

Our method showed a significant reduction in time and memory required for analysis  
It enables users to get feedback quickly



Reduced computation time leads to faster analytics. Reduced memory leads to more space for useful data, reducing storage costs  
This mean faster analytics, and quicker action. Once the users get results quickly, they have more time to act on the presented analysis

### IMPACTS

#### Further Information:

Fast Channel Selection for Scalable Multivariate Time Series Classification  
Bhaskar Dhariyal, Thach Le Nguyen and Georgiana Ifrim. 2022  
International Workshop on Advanced Analytics and Learning on Temporal Data  
[https://link.springer.com/chapter/10.1007/978-3-030-91445-5\\_3](https://link.springer.com/chapter/10.1007/978-3-030-91445-5_3)



VARIETY GRAZING EFFICIENCY RANKING MAINTAINED YEAR AFTER YEAR.

Tomás Tubritt

**CONTEXT**

The Pasture Profit Index is a perennial ryegrass variety selection tool used by the grass seed industry. Measuring differences in grazing efficiency between varieties is a new development in perennial ryegrass evaluations. Can the grass seed industry be confident in the accuracy of these evaluations

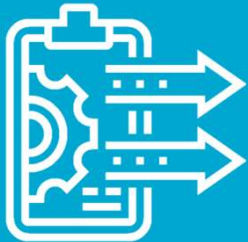


**PROBLEM STATEMENT**

Are perennial ryegrass grazing evaluations accurate and repeatable in their assessment of grazing efficiency?

**ACTIVITIES**

Variety plots were grazed concurrently by dairy cows in a rotational grazing system with 8 to 10 grazing events annually. Data from these trials was used to develop grazing efficiency estimates for each variety. The grazing efficiency of a variety in a particular trial was compared to the grazing efficiency of that same variety in another, separately managed trial to examine whether similar grazing estimations exist.



Moderate to strong correlations were found between trials for grazing efficiency evaluation indicating that our trials are robust in their assessment of grazing efficiency

**OUTPUTS**

**OUTCOMES**

Grazing efficiency estimates are now published within the Pasture Profit Index, allowing commercial farmers to select high grazing efficiency varieties with confidence



**IMPACTS**



Users of the Pasture Profit Index can be assured that selecting a variety that ranks highly for grazing efficiency, will deliver benefits in their grazing management  
Farmers using high grazing efficiency varieties can expect to increase their grass utilisation and increase profitability

Further Information:

The Repeatability of Grazing Efficiency as a Perennial Ryegrass Variety Trait  
Tomás Tubritt, Luc Delaby and Michael O'Donovan. 2022  
Agronomy MDPI  
<https://doi.org/10.3390/agronomy12030577>

## FRAGMENTED GLOBAL FRAMEWORK FOR FERMENTED FOODS: TIME FOR CHANGE?

Arghya Mukherjee

### CONTEXT

Fermented foods are being consumed in ever greater amounts in globally. However, the current global regulatory frameworks remain fragmented and are not well understood and has never been reviewed

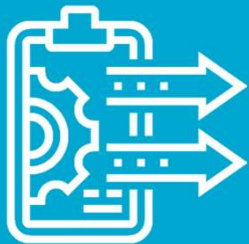


### PROBLEM STATEMENT

There is limited understanding of the regulations for these foodstuffs, the approaches of different nations and organisations in designing such legislative frameworks, and the strengths and limitations of such regulations

### ACTIVITIES

Regulations pertaining to fermented foods for various nations and organisations including the EU, FAO, USA, UK, China, India, Russian Federation, Canada and others were reviewed and discussed



### OUTPUTS

Results suggest that there is a lack of harmonisation among most regulations with international legislations remaining highly fragmented for same

### OUTCOMES

This is the first time the global regulatory frameworks for fermented foods have been reviewed  
Along with a peer-reviewed review article, findings of the research were also posted on public forums



### IMPACTS

Better understanding of the global regulation of fermented foods were gained  
This is particularly important when considering design and manufacture of novel functional foods

#### Further Information:

Global Regulatory Frameworks for Fermented Foods: A Review  
Arghya Mukherjee, Beatriz Gómez-Sala, Eibhlís O'Connor, John Kenny and Paul D. Cotter  
Frontiers in Nutrition  
<https://doi.org/10.3389/fnut.2022.902642>

## BREEDING FOR IMPROVED PROTEIN FRACTIONS AND FREE AMINO ACIDS IN BOVINE MILK

Giulio Visentin

### CONTEXT

Detailed milk composition affects the quality of a variety of dairy products that can be manufactured  
Milk rich in free amino acids tends to have unfavourable cheese-making characteristics

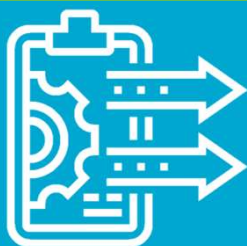


### PROBLEM STATEMENT

What is the potential to breed for different milk protein fractions and free amino acids in dairy cow milk?

### ACTIVITIES

Equations to predict granular milk quality features from routinely available infrared analyses of milk were developed  
Variability in milk protein and free amino acid concentration were partitioned into genetic and non-genetic components



Inter-animal difference in genetic merit accounted for 19% to 55% of the variability in milk protein fractions and 8% to 29% of the variability in milk free amino acid concentration

### OUTPUTS

### OUTCOMES

Milk infrared spectral analyses can be used to routinely predict milk protein fraction and free amino acid concentration with reasonable accuracy  
It is possible to generate national genetic evaluations for the granular milk quality features of protein fraction and free amino acids



Breeding programs can be used to improve both the protein fraction and free amino acid content of milk

### IMPACTS

#### Further Information:

Breeding for improved protein fractions and free amino acids concentration in bovine milk  
Giulio Visentin, Donagh P. Berry, Angela Costa, Audrey McDermott, Massimo De Marchi and Sinead McParland. 2022  
2022 J Anim Breed Genet. 1-13 10.1111/jbg.12681  
<https://doi.org/10.1111/jbg.12681>

## HOW HETEROGENEITY IN THE GENOME ASSOCIATES WITH CARCASS MERIT IN CATTLE

David Kenny

### CONTEXT

Crossbreeding which contributes to heterogeneous genomes is known to provide an additional benefit in performance for some traits  
Access to large genomic datasets in cattle enables deeper interrogation of this phenomenon

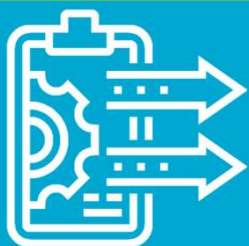


### PROBLEM STATEMENT

What DNA variants, if any, demonstrate non-additive genetic effects in that an individual carrying different variants at a particular region of the genome outperform the average of individuals carrying two copies of the same variants

### ACTIVITIES

Genotypes at >600,000 locations on the genome on almost 30,000 Irish cattle used  
Carcass traits investigated included carcass weight, conformation and fat score  
Measures of global and local genomic heterozygosity used



### OUTPUTS

The associations between the different measures of genomic heterozygosity and the carcass traits were all of small biological significance  
Few genomic variants demonstrated significant non-additive associations with carcass merit

### OUTCOMES

Genomic heterozygosity both at a global level and at the level of individual regions of the genome contribute little to the observed variability in carcass merit



### IMPACTS

Accounting for genomic heterozygosity levels of individual animals will do little to improve the accuracy of prediction and therefore do not need to be considered in national genetic evaluations

#### Further Information:

The Association Between Genomic Heterozygosity and Carcass Merit in Cattle  
David Kenny, Tara Carthy, Craig Murphy, Roy Sleator, Ross Evans and Donagh Berry. 2022  
Frontiers in Genetics  
<https://doi.org/10.3389/fgene.2022.789270>



## MEASURING NITROUS OXIDE EMISSIONS FROM A FERTILISED GRASSLAND IN TIME AND SPACE

Rachael Murphy

### CONTEXT

There are few long term data sets of nitrous oxide emissions from agricultural soils at the field scale  
 Optimising the ways in which we measure and handle nitrous oxide data is important in order to reduce overall uncertainty associated with quantifying nitrous oxide

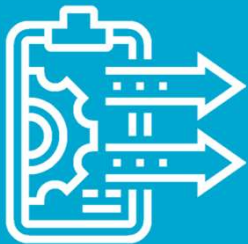


### PROBLEM STATEMENT

Nitrous oxide emissions from agricultural soils are difficult to measure with low uncertainty due to their spatial and temporal variability

### ACTIVITIES

Measured field scale emissions of nitrous oxide using the eddy covariance and static chamber technique and compare emissions from both techniques  
 Applied both normal and log normal (i.e. Bayesian) statistics to nitrous oxide emissions measured by static chambers



Annual data set of nitrous oxide emissions from a fertilised and cut grassland  
 Paper publication in a high impact journal that is renowned for eddy covariance datasets

### OUTPUTS

### OUTCOMES

Better methodologies to quantify field scale emissions of nitrous oxide  
 Improved methods for handling log-normal nitrous oxide emissions that yield lower uncertainties



Improved guidelines for methodologies for measuring nitrous oxide emissions  
 Development of a multivariate process based model to gap-filling missing nitrous oxide values measured by eddy covariance

### IMPACTS

#### Further Information:

Assessing nitrous oxide emissions in time and space with minimal uncertainty using static chambers and eddy covariance from a temperate grassland. Rachael Murphy, Karl Richards, Dominika Krol, Amanuel Gebremichael, Luis Lopez-Sangil, James Rambaud, Nicholas Cowan, Gary Lanigan and Matthew Saunders. 2022  
 Agricultural and Forest Meteorology. <https://doi.org/10.1016/j.agrformet.2021.108743>

## MEASURING NITROUS OXIDE EMISSIONS IN TIME AND SPACE FROM A GRAZED GRASSLAND

Rachael Murphy

### CONTEXT

Measuring nitrous oxide emissions from grazed pastures is complicated due to the different nitrogen pools (fertiliser and animal excreta)  
We need to use both static chambers to measure specific nitrogen pools and eddy covariance for low uncertainty field measurements of nitrous oxide

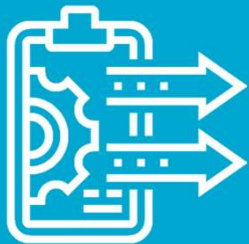


### PROBLEM STATEMENT

Using the eddy covariance technique, can we quantify nitrous oxide emission factors at the field scale?

### ACTIVITIES

Measure field scale emissions of nitrous oxide using the eddy covariance and static chamber technique and compare emissions from both techniques from a grazed grassland  
Upscale local chamber nitrous oxide emissions to the field scale for comparability with eddy covariance measurements



Annual data set of nitrous oxide emissions from a fertilised and cut grassland  
Paper publication in a high impact journal that is renowned for eddy covariance datasets

### OUTPUTS

### OUTCOMES

Improved methodologies for upscaling nitrous oxide emissions to the field scale using management data and literature values  
Highlights improvements for future similar studies - using drone technology to map urine/dung patches to improve upscale estimates of nitrous oxide emissions



Advocates for aggregated nitrous oxide emissions factors because adding individual emission factors from different nitrogen pools leads to over estimations  
Shows that nitrous oxides emissions were lower during grazing suggesting that nitrogen is being lost from the system in a different form or is being accumulated in the soil

### IMPACTS

#### Further Information:

Nitrous oxide emission factors from an intensively grazed temperate grassland: A comparison of cumulative emissions determined by eddy covariance and static chamber methods. Rachael Murphy, Matthew Saunders, Karl Richards, Dominika Krol, Amanuel Gebremichael, James Rambaud, Nicholas Cowan and Gary Lanigan. 2022  
Agriculture, Ecosystems & Environment . <https://doi.org/10.1016/j.agee.2021.107725>

# CAN THE GENETIC MERIT FOR FEED INTAKE OF DAIRY COWS BE PREDICTED BY LINEAR TYPE TRAITS?

Maeve Williams

## CONTEXT

An alternative to directly measuring the feed intake of individual cows would be to identify a set of easier to measure traits that are related to feed intake. Linear type traits are often recorded on dairy cows during their first lactation and have been suggested as suitable predictors of dairy cow feed intake.

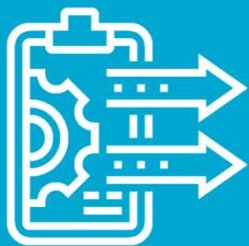


## PROBLEM STATEMENT

Can linear type traits be suitable predictors of the genetic merit for feed intake in grazing Irish dairy cows?

## ACTIVITIES

The genetic relationships between dairy cow feed intake and body-related linear type traits were estimated. Also estimated were the genetic relationships between feed intake and linear type traits after accounting for genetic differences in body weight.



## OUTPUTS

Linear type traits were not suitable predictors of the genetic merit for dairy cow feed intake; when body weight information was also available, linear type traits were even less useful.

## OUTCOMES

It is now known that linear type traits are not useful predictors of the genetic merit for feed intake in grazing dairy cows. Body weight was, however, identified as a potential predictor of genetic merit for dairy cow feed intake.



## IMPACTS

There is no benefit of measuring linear type traits in dairy cattle for use as predictors of genetic merit for feed intake, especially if live-weight data exists.

### Further Information:

Are subjectively scored linear type traits suitable predictors of the genetic merit for feed intake in grazing Holstein-Friesian dairy cows? Maeve Williams, Craig Murphy, Roy Sleator, Siobhán Ring and Donagh Berry. 2022. Journal of Dairy Science. <https://doi.org/10.3168/jds.2021-20922>

## EXPLOITATION OF GENETIC DIFFERENCES IN LACTATION YIELDS AND SOMATIC CELL COUNT WITH EACH PROGRESSING PARITY

Maeve Williams

### CONTEXT

The reproductive performance of Irish dairy cows has improved year-on-year for the past two decades, increasing cow longevity  
Lactation yield is, however, expected to reduce once cows reach a certain age; somatic cell count is also expected to increase with cow age

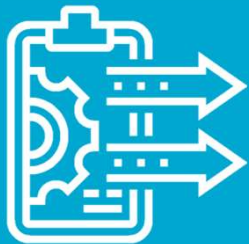


### PROBLEM STATEMENT

Does the profile of total lactation yield or lactation average somatic cell count differ as cows age, especially once maturity is reached?

### ACTIVITIES

Lactation yields and average somatic cell count records from >1m Irish dairy cows were used to determine if differences existed between cows in their trajectories for milk yield or somatic cell count as they aged  
Genetic merit for milk yield traits and somatic cell count in each parity were estimated for all cows



### OUTPUTS

Differences in the trajectory of milk yield traits and somatic cell counts as parity increased were identified between cows  
These differences could be exploited to select for cows that maintain their mature milk yield and low somatic cell counts as they age

### OUTCOMES

The study determined that differences exist between dairy cows for their trajectories for milk production and somatic cell scores  
Strategies for altering the genetic trajectories for milk production and somatic cell count across parities were also proposed



### IMPACTS

Some cows maintain their mature milk yield for longer thereby increasing profitability for producers. Additionally, it was determined that some cows have the genetic merit to maintain a low somatic cell count as they age and thus exploiting these differences could have implications for animal welfare by reducing the incidence of disease.

#### Further Information:

Exploiting genetic variability in the trajectory of lactation yield and somatic cell score with each progressing parity  
Maeve Williams, Craig Murphy, Roy Sleator, John McCarthy and Donagh Berry. 2022  
Journal of Dairy Science.  
<https://doi.org/10.3168/jds.2021-21306>



# UDDER CONFORMATION BECOMES MORE IMPORTANT TO THE GENETIC MERIT FOR SURVIVAL AS DAIRY COWS AGE

Maeve Williams

## CONTEXT

The improvements in reproductive performance of dairy cows likely results in cows living for longer. Given linear type traits are already used by many countries to predict the genetic merit for dairy cow longevity and survival, it may be time to reassess whether they are useful predictors of survival in older cows.

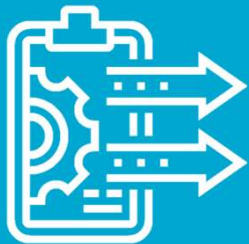


## PROBLEM STATEMENT

Do genetic relationships between linear type traits and dairy cow survival change as cows age?

## ACTIVITIES

The genetic associations between survival in different parities were estimated using the survival records of 52,447 Irish Holstein-Friesian cows. Additionally, using survival data, along with linear type trait records from 52,121 Holstein-Friesian cows, the genetic associations between survival in each lactation and each linear type trait was estimated.



Three udder-related linear type traits (rear udder height, udder depth, and teat length) became more strongly genetically associated with survival as dairy cows aged.

## OUTPUTS

## OUTCOMES

Survival to next lactation is not the same trait genetically as cows age; therefore factors governing survival to the next lactation in young cows may differ from those governing survival in older cows. Type traits most strongly genetically associated with survival in older cows were identified.



The traits identified as most strongly associated with survival in older cows could be used to improve the genetic merit of survival in older cows reducing the need for replacement heifers; this could also reduce the environmental impact of dairy production by diluting the emissions of individual cows over a greater volume of milk.

## IMPACTS

### Further Information:

Re-assessing the importance of linear type traits in predicting genetic merit for survival in an aging Holstein-Friesian dairy cow population  
Maeve Williams, Roy Sleator, Craig Murphy, John McCarthy and Donagh Berry. 2022  
Journal of Dairy Science.  
<https://doi.org/10.3168/jds.2022-22026>

**AN OUT-OF-THE-BOX TOOL TO TACKLE DATASETS CREATED USING IMAGES GATHERED FROM THE WEB TO REDUCE DATASET CREATION COSTS**

**Paul Albert**

**CONTEXT**

An alternative to reduce dataset creation costs is to skip the human labour required to remove anomalies (imperfect datasets)  
 Creating an out-of-the-box image identification tool for imperfect datasets is desirable so users can rapidly develop image identification solutions

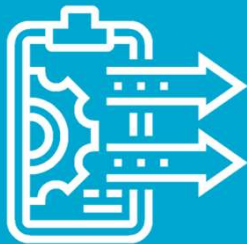


**PROBLEM STATEMENT**

Provide an out-of-the-box tool to perform object identification in images using imperfect datasets from the web

**ACTIVITIES**

Creation of an object identification tool in images that is accurate in identifying imperfect image datasets  
 Testing the accuracy of the tool on 5 different imperfect image datasets



**OUTPUTS**

A peer reviewed paper in a top computer vision conference (WACV 2023)  
 We tested the tool on 5 image datasets which presented different types of imperfections  
 It performed better than other available state-of-the-art tools without the need for expert tuning

**OUTCOMES**

Reduce the need for large amounts of human labour when collecting data



**IMPACTS**

An out-of-the-box tool that enables smaller companies to develop state-of-the-art solutions without the need for expensive data collection

**Further Information:**

Is your noise correction noisy? PLS: Robustness to label noise with two stage detection'  
 Paul Albert, Eric Arazo, Tarun Krishna, Noel O'Connor and Kevin McGuinness. 2022  
 IEEE/CVF Winter Conference on Applications of Computer Vision (WACV 2023)  
<https://doi.org/10.48550/arXiv.2210.04578>

## CODING WITH COWS

Lucile Riaboff

### CONTEXT

As in many fields, the agricultural industry is being revolutionised through the use of computer science using robotic milking machines, grass imaging technology, and cattle activity neck-collars. Coding should be part of the primary school curriculum to educate the new generation to face challenges in many fields, including the agri-food sector.

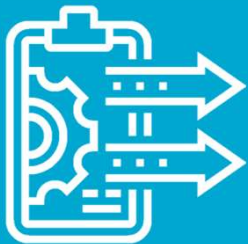


### PROBLEM STATEMENT

Innovative child-friendly learning techniques must be developed to teach the basics of coding from an early age.

### ACTIVITIES

Coding with Cows was developed by using activity data collected from a cattle neck collar, and a coding software designed for a young audience



### OUTPUTS

Coding with Cows is now a free resource available online (<https://codeweek.vistamilk.ie>) to teach coding skills combined with the basics of Irish cattle systems  
It was introduced to teachers during the computer science week

### OUTCOMES

Children as young as nine develop their own coding skills and get output information on cattle  
They become aware of the importance of coding in fields as diverse as agriculture



### IMPACTS

Coding with Cows and its involvement in computer science week aims to educate the younger generation in the coding skills needed to meet the future challenges of agriculture and many other sectors

#### Further Information:

VistaMilk's 'Coding with Cows' to feature in computer science week  
Megan O'Brien, Richard Burke and Lucile Riaboff. 2022

AgriLand

<https://www.agriland.ie/farming-news/vistamilks-coding-with-cows-to-feature-in-computer-science-week/>

# HOW TO ESTIMATE THE BIOMASS COMPOSITION OF GRASS-CLOVER MIXTURE USING ARTIFICIAL INTELLIGENCE ON DRONE IMAGES

Paul Albert

## CONTEXT

Estimating the clover content of grass is important for dairy farmers so they can reduce nitrogen fertilisation costs  
 To evaluate clover content, grass has to be cut and manually separated in a lab which makes the process tedious in practice

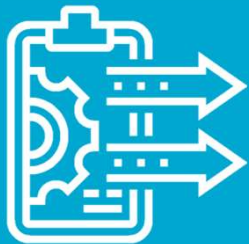


## PROBLEM STATEMENT

Can the manual evaluation of clover content and dry matter be replaced by a tool applying artificial intelligence on drone images of the grass ?

## ACTIVITIES

An image classification tool that does not require large amounts of data collection to function  
 Test of the solution on an Irish grass dataset



A dataset of drone images of Irish grass

## OUTPUTS

## OUTCOMES

The paper demonstrates that estimating clover content and dry matter from drone images is possible  
 Because limited amounts of human labour is required, the solution is scalable to the farm level and can be applied in practice



By utilising the tool, farmers can make informed decisions on nitrogen fertilisation and clover seeding to reduce grass production cost

## IMPACTS

### Further Information:

Unsupervised domain adaptation and super resolution on drone images for autonomous dry herbage biomass estimation  
 Paul Albert, Mohamed Saadeldin, Badri Narayanan, Brian Mac Namee, Deirdre Hennessy, Noel O'Connor and Kevin McGuinness. 2022  
 IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops  
<https://doi.org/10.48550/arXiv.2204.08271>



# HOW TO REDUCE DATASET CREATION COSTS BY USING IMAGES GATHERED FROM SEARCH ENGINES ON THE WEB

Paul Albert

## CONTEXT

Data collection using search engines is a time efficient but imperfect process as some images will be mismatched to the search query  
Human annotators are usually required to clean this up

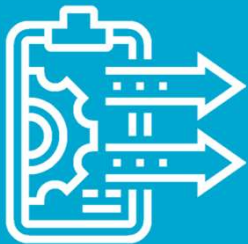


## PROBLEM STATEMENT

How can mismatched images be identified automatically?  
How can we develop an accurate image classification tool using imperfect examples?

## ACTIVITIES

Develop an automatic tool that detect mismatched images  
An accurate image classification tool once the mismatched images have been detected



## OUTPUTS

A peer reviewed paper in a top computer vision conference (ECCV 2022)

## OUTCOMES

Reduce the need for large amounts of human labour when collecting data



## IMPACTS

Enables smaller companies to develop state-of-the-art solutions without the need for expensive data collection

### Further Information:

Embedding contrastive unsupervised features to cluster in-and out-of-distribution noise in corrupted image datasets  
Paul Albert, Eric Arazo, Noel O'Connor and Kevin McGuinness. 2022  
European Conference on Computer Vision (ECCV)  
<https://doi.org/10.48550/arXiv.2207.01573>

**PROPOSING A SOLUTION USING ARTIFICIAL INTELLIGENCE TO EVALUATE THE CLOVER CONTENT OF GRASS USING PHONE IMAGES**

**Paul Albert**

**CONTEXT**

Estimating clover content in grass is important to reduce the amount of fertiliser used and to enhance feed quality for dairy cows  
The only existing process involves manually separating the grass in a lab and is not applicable in practice

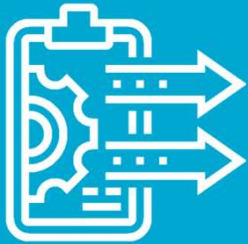


**PROBLEM STATEMENT**

Can computer vision be used to estimate the clover content directly from images?

**ACTIVITIES**

Development of a tool that evaluates the clover content of grass from camera and phone images  
Test the accuracy of the tool on an Irish grass image dataset



**OUTPUTS**

An accurate algorithm to estimate grass/clover/weed content from phone and camera images  
Accurate estimation can be obtained even if the data collection is limited

**OUTCOMES**

A good estimate for clover content can be obtained in real time and in a non-destructive manner using everyday tools (phone)



**IMPACTS**

By utilising the tool, farmers can make informed decisions on nitrogen fertilisation and clover seeding to reduce grass production cost

**Further Information:**

Utilizing unsupervised learning to improve sward content prediction and herbage mass estimation  
Paul Albert, Mohamed Saadeldin, Badri Narayanan, Brian Mac Namee, Deirdre Hennessy, Aisling O'Connor, Noel O'Connor and Kevin McGuinness. 2022  
29th European Grassland Federation (EGF) General Meeting 2022. <https://doi.org/10.48550/arXiv.2204.09343>

# USING DEEP LEARNING TO DETECT DIGITALLY ENCODED DNA TRIGGER FOR TROJAN MALWARE IN BIO-CYBER ATTACKS

Mohid Siblee Islam

## CONTEXT

The use of DNA sequencing and the applications of DNA sequencing is increasing over time. DNA is considered as a future storage medium, showing promise of storing large amount of data. Bacteria are proposed to use as data carrier by encoding into plasmid DNA for nano and micro scale communications.



## PROBLEM STATEMENT

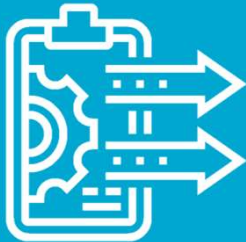
What might be a different attack in DNA sequencing pipeline besides buffer overflow exploit?  
How can we counter the attack?

## ACTIVITIES

We use real plasmid DNA and fragment the trigger message and apply cryptography before encoding the trigger message into DNA to make the detection harder. A well-known algorithm bioinformatics is considered (Needleman-Wunsch) to keep the DNA as natural as possible to make the detection harder. A deep learning-based detection system is proposed to detect the presence of malicious trigger message. A wet lab experiment is conducted to validate whether constructing such DNA sequence is possible in realist or not.



## OUTPUTS



We have managed to fragment, encrypt and encode the trigger message for activating the Trojan and hide it in an existing DNA sequence and try to keep similar to its original form (min number of mutation and inject the fragment where the dissimilarity will be minimum). We detect the Trojan trigger message samples successfully. We successfully constructed DNA sequences with encoded trigger message used for our experimental work in the wet lab.

## OUTCOMES

Using an end-to-end evaluation, we have demonstrated how critical the Trojan attack in the DNA sequence pipeline can be and how difficult it will be to detect. We also show how we can mitigate such attacks using state of the art deep learning techniques.



## IMPACTS



Our work will create social awareness regarding this new way of attacks  
Further research will be conducted to explore other possible attacks in the DNA sequencing pipeline using specially designed DNA  
We will be ready to counter the disaster before it is going to happen

### Further Information:

Using deep learning to detect digitally encoded DNA trigger for Trojan malware in Bio-Cyber attack  
Mohid Siblee Islam, Stepan Ivanov, Hamdan Awan, Jennifer Drohan, Sasi Balasubramaniam, Lee Coffey, Srivatsan Kidambi and Witawas Sri-Saan.  
2022  
Scientific Reports ,Nature. <https://doi.org/10.1038/s41598-022-13700-5>

## RESOURCE MANAGEMENT FOR FUTURE RADIO ACCESS SCHEMES

Muhammad Zeeshan

### CONTEXT

Resource management plays a key role in the development of radio access technologies  
A major challenge is the appropriate power allocation in non-orthogonal multiple access schemes

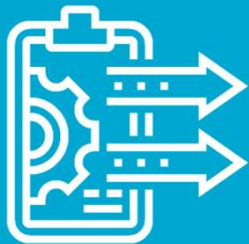


### PROBLEM STATEMENT

Power allocation is one main concerns in power domain non orthogonal multiple access

### ACTIVITIES

The methodology and verification was carried out in MATLAB, by considering close to real environment factors including veretation distance, and channel conditions



### OUTPUTS

A novel algorithm was developed based on heuristic inference, close to human intuition

### OUTCOMES

This research provides guaranteed best possible performance through optimal resource allocation and it has the capability to support multiple users for capacity enhancement



### IMPACTS

Simplify the development of reliable wireless access schemes  
Act as a cornerstone for various outdoor wireless applications

#### Further Information:

Optimal Power Allocation and Cooperative Relaying under Fuzzy Inference System (FIS) Based Downlink PD-NOMA  
Asif Mahmood, Mohamed Marey, Moustafa M. Nasralla, Maged A. Esmail, Muhammad Zeeshan 2022  
Electronics  
<https://doi.org/10.3390/electronics11091338>



## pH CONTROL WITH NO REAGENTS FOR ELECTROCHEMICAL SENSORS

Benjamin O'Sullivan

### CONTEXT

Sensing of many molecules using electrochemical sensors requires the pH of the solution to be adjusted

To do this we need to add dangerous acids or bases which is hazardous for the user and the environment



### PROBLEM STATEMENT

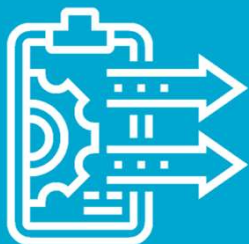
Can we adjust the pH of a solution without the use of dangerous acids or bases, using electrochemical techniques?

### ACTIVITIES

Novel electrochemical circuit designs were developed

These circuits incorporate both the sensor(s) and the system for adjusting the pH of the surrounding solution

The circuits were chemically modified and assessed for both sensing and pH change



### OUTPUTS

We developed an electrochemical system that adjusts the pH of the solution without the use of reagents

This allowed us to alter the pH to whatever level is required to detect a wide variety of molecules

### OUTCOMES

Using this sensor approach, we have able to measure target molecules which could not have been measured previously

For example, nitrates in soil, heavy metals, and even on-chip milk heat stability



### IMPACTS

First, it simplifies the methodology for using electrochemical sensors, allowing anyone, with very little training to use the sensors

Secondly, the system great enlarges the range of chemicals that can be detected electrochemically

#### Further Information:

A simulation and experimental study of electrochemical pH control at gold interdigitated electrode arrays

Benjamin O'Sullivan, Bernardo Patella, Robert Daly, Ian Seymour, Caoimhe Robinson, Pierre Lovera, James Rohan, Rosalinda Inguanta, Alan O'Riordan 2022 Electrochimica Acta

<https://doi.org/10.1016/j.electacta.2021.139113>

## DETECTION OF PESTICIDES IN RIVER SYSTEMS USING NEW MICROCHIP BASED SENSORS FOR CONTINUOUS MONITORING

Robert Daly

### CONTEXT

Presently random grab samples is the method used for detecting pollutants in river systems. A more desirable option would be to be able to continuously monitor the river and flag any pollutants present. The technology presented here is inexpensive and scalable to continuously monitor *in situ* the health of the river in real time.

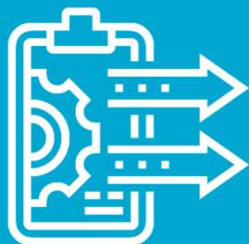


### PROBLEM STATEMENT

Is it possible to develop an electrochemical sensor for real-time monitoring of pollutants in river water?

### ACTIVITIES

The project is aimed at developing novel 2-D nanostructured silver substrates using electrochemistry  
These surfaces are functionalised with an immobilising agent and surface enhanced Raman spectroscopy(SERS) is used to determine the presence of the pollutant of interest



### OUTPUTS

We developed an electrochemical system that adjust the pH of the solution without the use of reagents  
This allowed us to alter the pH to whatever level is required to detect a wide variety of molecules

### OUTCOMES

Novel electrochemical fabrication of SERS substrates was used along with functionalisation to detect MPCA in solution  
A manuscript is currently under review for publication with ACS Materials and Interfaces



### IMPACTS

By monitoring pollution in real time environmental agencies can react quicker and reduce the impact of the pollution on the environment  
Certain pollutants have been found in drinking water in recent years  
If the pollution is detected early maybe this can be prevented

#### Further Information:

SERS based detection of herbicide MCPA using electrochemically synthesised 2D-silver nanodendrites functionalised with cyclodextrin  
Robert Daly, Tarun Narayan, Fernando Diaz, Julio Gutierrez Moreno, Michael Nolan, Alan O'Riordan, Pierre Lovera 2022  
ChemRxiv Analytical Chemistry  
<https://doi.org/10.26434/chemrxiv-2022-48ffg>

## PLENTY OF OPPORTUNITY TO BRED FOR MORE EFFICIENT DAIRY COWS

Donagh Berry

### CONTEXT

Interest is intensifying on milk production efficiency in dairy production  
 Knowledge of the extent of genetic variability for a trait is a prerequisite to genetic selection for that trait

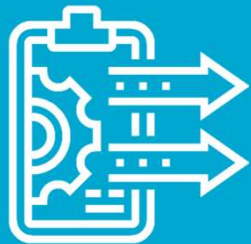


### PROBLEM STATEMENT

How much genetic variability exists in the amount of milk produced per kg of body weight (a measure of efficiency)?

### ACTIVITIES

National data of >10,000 cows from 85 commercial farms with body weight and milk production information  
 Several different measures of efficiency quantified including kgs of milk solids per kg of body weight



Large variability in kgs milk solids per kgs of body weight of which 37% is genetic  
 Genetic selection exclusively for the improved ratio of milk solids per kg of body weight may have unfavourable repercussions for long term efficiency through reduced body condition score

### OUTPUTS

### OUTCOMES

The current national breeding index for Ireland, the (Economic Breeding Index (EBI), already selects for increased milk solid production per kg of body weight  
 The current breeding index also includes fertility thereby negating the impact on selection due on the ratio of reducing body condition score



Genetic evaluation for milk solids per kg of body weight are possible as an ancillary trait to the current breeding index

### IMPACTS

#### Further Information:

Contribution of genetic variability to phenotypic differences in on-farm efficiency metrics of dairy cows based on body weight and milk solids yield

Donagh Berry and John McCarthy. 2022

Journal of Dairy Science

<https://doi.org/10.31694/jds.12331>

## CHANGES IN DAIRY COWS SIZE AND CONFORMATION IN THE PAST TWO DECADES

Donagh Berry

### CONTEXT

A selection of Irish dairy cows are routinely assessed for morphological characteristics  
Knowing past morphological changes can provide future change insights

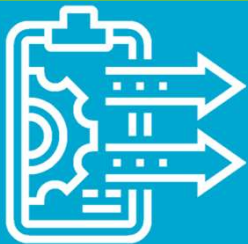


### PROBLEM STATEMENT

How has dairy cow morphology and confirmation of teat, feet and udder changed in the last two decades?

### ACTIVITIES

National data of almost 3 million Irish Holstein Friesian cows was used  
The mean genetic merit of morphological traits for all animals by year of birth was quantified



Dairy cow height has reduced in the last 20 years and in that period cows have also become more narrow and fatter  
Cow locomotion has deteriorated in the last 20 years

### OUTPUTS

### OUTCOMES

Research results have been used to reconsider how linear classification is undertaken and marketed  
National genetic evaluation per linear type classifications is being revisited



While body size is reducing, little change is happening in udder confirmation to warrant any concern

### IMPACTS

#### Further Information:

Linear type trait genetic trends in Irish Holstein-Friesian dairy animals  
Donagh Berry, Siobhán Ring and Margaret Kelleher. 2022  
Journal of Agricultural and Food Research  
<https://www.scienceopen.com/hosted-document?doi=10.15212/ijafnr-2022-0105>



# IS THE GENETIC CHARACTERISTICS OF EXPORTED DAIRY BULL CALVES DIFFERENT TO THOSE RETAINED IN IRELAND

Donagh Berry

## CONTEXT

Ireland export > 100,000 dairy bull calves annually  
It is not clear if the lack of carcass information on these animals bias the national carcass genetic evaluations

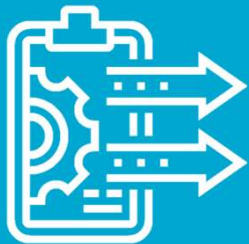


## PROBLEM STATEMENT

Does missing carcass data on exported calves bias national carcass genetic valuations?

## ACTIVITIES

National data on the fate of >40,000 Holstein-Friesian bull calves were available depending on whether or not they were sold for export or not  
The extent of genetic variability on whether a calf was exported or not, as well as, its genetic merit for carcass traits was quantified



4% of the genetic variability on whether or not a calf was exported was due to their genetic merit  
No genetic correlation existed between the export phenotype and either carcass weight, confirmation or fat score

## OUTPUTS

## OUTCOMES

Not considering the exported bull calves in the national genetic valuation does not cause bias  
The export calf phenotype is lowly heritable



Accounting for the export phenotype in carcass genetic valuation is not worth while

## IMPACTS

### Further Information:

Quantifying genetic differences between exported dairy bull calves and those sold for domestic beef production  
Donagh Berry, Siobhán Ring and Alan Twomey. 2022  
JDS Communications  
<https://doi.org/10.3168/jdsc.2021-0105>

## FEMALE CATTLE MASQUERADING AS MALES

Donagh Berry

### CONTEXT

Swyer syndrome is where an individual has the chromosome set of a typical male yet has the appearance of a female  
Identifying such (infertile) animals at birth would be useful for herd management

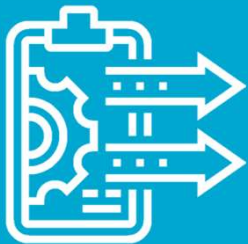


### PROBLEM STATEMENT

Can routinely available DNA signatures be used to detect Swyer individuals early in life?

### ACTIVITIES

Whole genome sequence data of eight suspected Swyer individuals (and controls) were interrogated  
A necropsy of one individual was undertaken



### OUTPUTS

Seven of the eight Swyer syndrome individuals had a deletion on the Y chromosome encompassing the SRY gene  
The eighth individual had no obvious mutation in the SRY gene (SRY+) or indeed in any reported gene associated with sex reversal in mammals

### OUTCOMES

DNA information flanking the SRY gene was provided for inclusion in routinely used genotyping platforms globally – will be included in the updated version of the bespoke Irish bovine genotyping platform



### IMPACTS

A large proportion of Swyer females can be detected early if genotyped thereby reducing costs associated with rearing the animal for breeding purposes

#### Further Information:

Characterisation of eight cattle with Swyer syndrome by whole-genome sequencing  
Donagh Berry, Ermias Herman, Tara Carthy, Rebecca Jennings, Nadri Bandi-Kenari, Rebecca O'Connor, John Mee, Jim O'Donovan, Darragh Mathews and Paul Stothard. 2022  
Animal Genetics

# 2021

35. Characterising soil moisture regimes on poorly drained soils in Ireland using optical satellite derived vegetation indices and the OPTRAM model - Rumia Basu, Colin Brown, Eve Daly and Patrick Tuohy

36. NFC Sensing of Tear Fluid for Animal health Monitoring - Melusine Pigeon, Nadeem Rather, Brendan O'Flynn, John Buckley

37. A Graph-based Molecular Communications Model Analysis of the Human Gut Bacteriome - Samitha Sulakshana Somathilaka, Daniel Martins, Wiley Barton, Orla O' Sullivan, Paul Cotter and Sasi Balasubramaniam

38. A Short Tutorial for Time Series Classification and Explanation with MrSQM - Thach Le Nguyen and Georgiana Ifrim

39. Microfluidic-based Bacterial Molecular Computing on a Chip - Daniel Martins, Michael Taynnan Barros, Benjamin O'Sullivan, Ian Seymour, Alan O'Riordan, Lee Coffey, Joseph Sweeney and Sasi Balasubramaniam

40. Binding Process Analysis of bacterial-based AND Logic Gates - Daniel Martins, Paul Cotter, Orla O'Sullivan and Sasi Balasubramaniam

41. Modulated Molecular Channel Coding Scheme for Multi-Bacterial Transmitters - Daniel Martins, Jennifer Drohan, Sarah Foley, Lee Coffey and Sasi Balasubramaniam

42. Greenhouse gas emissions and nitrogen efficiency of dairy cows of divergent economic breeding index under seasonal pasture-based management - Ben Lahart, Laurence Shalloo, Jonathan Herron, Donal O'Brien, Ricki Fitzgerald, Tommy Boland and Frank Buckley



# 2021

43. Detection of Genomic Imprinting for Carcass Traits in Cattle Using Imputed High-Density Genotype Data - David Kenny, Roy Sleator, Craig Murphy, Ross Evans and Donagh Berry

44. Formulation of a decision support tool incorporating both genetic and non-genetic effects to rank young growing cattle on expected market value - Fiona Dunne, Ross Evans, Mags Kelleher, Siobhan Walsh and Donagh Berry

45. Differences in genetic merit for visually-assessed body condition score materialises as phenotypic differences in tactile-based body condition score in commercial dairy cows - Donagh Berry and Mags Kelleher

46. Contribution of herd characteristics to best linear unbiased estimates of slaughter traits in beef cattle - David Kenny, Craig Murphy, Roy Sleator, Ross Evans and Donagh Berry

47. Identification of genomic regions that exhibit sexual dimorphism for size and muscularity in cattle - Jennifer Doyle, Deirdre Purfield, Tom Moore, Tara Carthy, Siobhan Walsh, Roel Veerkamp, Ross Evans and Donagh Berry

48. Concordance rate in cattle and sheep between genotypes differing in Illumina GenCall quality score - Donagh Berry, Fíona Dunne, Ross Evans, Kevin McDermott and Aine O'Brien

49. Cross-sectional analyses of a national database to determine if superior genetic merit translates to superior dairy cow performance - Siobhan Ring, Ross Evans, Andrew Cromie and Donagh Berry

50. Prediction of genetic merit for live weight and body condition score in dairy cows using routinely available linear type and carcass data - Donagh Berry, Ross Evans and Mags Kelleher





# 2021

51. Dairy Producers Who Market Their Surplus Progeny as Calves Use Germplasm With Slightly Lighter and Less-Conformed Carcasses Than Producers Who Rear Their Surplus Progeny Beyond Weaning - Donagh Berry and Siobhan Ring

52. Choice of artificial insemination beef bulls used to mate with female dairy cattle - Donagh Berry, Siobhan Ring, Alan Twomey and Ross Evans

53. Observed progeny performance validates the benefit of mating genetically elite beef sires to dairy females - Donagh Berry and Siobhan Ring

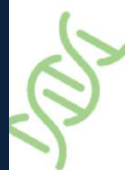
54. Animal-level factors associated with whether a dairy female is mated to a dairy or beef bull - Donagh Berry and Siobhan Ring

55. The beef merit of the sire mated to a dairy female affects her subsequent performance - Donagh Berry and Siobhan Ring

56. Genome-wide association analyses of carcass traits using copy number variants and raw intensity values of single nucleotide polymorphisms in cattle - Pierce Rafter, Claire Gormley, Deirdre Purfield, Andrew Parnell, Saeid Naderi and Donagh Berry

57. Machine learning approaches to the early detection of sub-clinical mastitis in lactating dairy cows - Arjun Pakrashi and Brian Mac Namee

58. 'Omega-3 fatty acid, carotenoid and vitamin E supplementation improves working memory in older adults: A randomised clinical trial' - Rebecca Power, John Nolan, Alfonso Prado-Cabrero, Warren Roche, Robert Coen, Tommy Power and Riona Mulcahy



## ESTIMATING SURFACE SOIL MOISTURE IN IRELAND USING REMOTE SENSING

Rumia Basu

### CONTEXT

Monitoring soil moisture is crucial for farm management strategies. It is especially important for Ireland where approx. 30% of soils are poorly drained. These poorly drained soils negatively impact plant growth and productivity, hence accurate and timely information about soil moisture status is crucial.

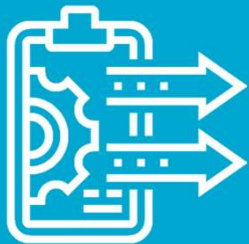


### PROBLEM STATEMENT

To estimate surface soil moisture on select HSP farms using remote sensing-based indices from Sentinel 2

### ACTIVITIES

This project makes use of optical data from Sentinel 2 from 2015 to present Vegetation indices such as NDVI, EVI, MSAVI etc. used along with information in the short-wave infrared region  
Modifications made to the OPTRAM model to estimate surface soil moisture, and validation within situ data



Modifications made to the ORIGINAL OPTRAM model to include non-linear relationships for estimating soil moisture

### OUTPUTS

### OUTCOMES

This work is novel in making modifications to the existing models for estimating soil moisture in Ireland using remote sensing-based vegetation indices and in situ soil moisture data



This research presents a methodology to estimate soil moisture in Ireland which is dominated by wet conditions for large parts of the year  
It will therefore open up avenues for further research, wherein such a model could be tested in similar sites across the world

### IMPACTS

#### Further Information:

Characterising soil moisture regimes on poorly drained soils in Ireland using optical satellite derived vegetation indices and the OPTRAM model  
Rumia Basu, Colin Brown, Eve Daly and Patrick Tuohy. 2021  
EGU General Assembly  
<https://doi.org/10.5194/egusphere-egu21-3336>

**BATTERY-LESS AND WIRELESS TEAR FLUID SENSING FOR COWS USING A SMART CONTACT LENS WITH ANTENNA AND SENSORS.**

**Melusine Pigeon**

**CONTEXT**

Timely health monitoring is essential for animal well-being and the quality of dairy products  
It would be beneficial to have a wireless system which sends health information from the smart contact lens in the eye to the farmer's phone

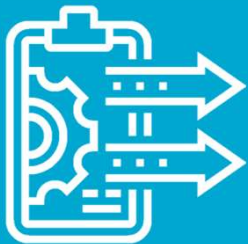


**PROBLEM STATEMENT**

Can we use the biological changes in the tear fluids of the Cows' EYE to detect vital health information?

**ACTIVITIES**

Design an antenna for a contact lens material (PMMA) which humans typically use and achieve Sensor integration capability to the antenna to detect diseases and transmit that information to farmers



We designed a circular shape antenna based on magnetic waves to work on the contact lens material and for cows' eye size

**OUTPUTS**

**OUTCOMES**

An antenna is ready to be integrated with the sensors and electronics to send information wirelessly to a smartphone



A smart contact lens for cows would help maintain animal well-being and the quality of dairy products  
The technology used in this project is low-cost and non-invasive

**IMPACTS**

**Further Information:**

NFC Sensing of Tear Fluid for Animal health Monitoring  
Melusine Pigeon, Nadeem Rather, Brendan O'Flynn and John Buckley. 2021  
2021 15th European Conference on Antennas and Propagation (EuCAP)  
<https://ieeexplore.ieee.org/document/9410985>



## UNDERSTANDING HOW THE BACTERIA WORK TOGETHER INSIDE OUR GUT TO KEEP US HEALTHY

Samitha Sulakshana Somathilaka

### CONTEXT

Bacteria form a complex interaction network in our bodies which is vital for our well-being  
Molecular communication can reveal the abnormalities of this network which is helpful in finding novel treatments for certain disorders

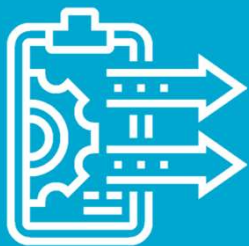


### PROBLEM STATEMENT

Can a Molecular Communication computer model reveal abnormalities in the gut bacterial interaction network?

### ACTIVITIES

Designed a bacterial Molecular Communication simulator  
Investigated bacterial interaction behaviours using the simulator and mathematical models



Developed a computer model that can simulate gut bacterial ecosystem  
Introduced a two-layer model of the bacterial ecosystem of the human gut that identifies how the abnormalities of this ecosystem affect human health

### OUTPUTS

### OUTCOMES

Specific bacterial phyla have non-linear relationships with the nutrient production inside the human gut  
Some bacterial phyla alter the metabolism in two ways, by changing their metabolic pathways and by influencing the gut bacterial ecosystem structure



The manipulation of Molecular Communications of bacteria in the human gut can be utilised as a new treatment for metabolic disorders such as obesity  
Interaction patterns of bacteria inside the human body reveal information on metabolism that can be used to diagnose a range of disorders accurately

### IMPACTS

#### Further Information:

A Graph-based Molecular Communications Model Analysis of the Human Gut Bacteriome  
Samitha Sulakshana Somathilaka, Daniel Perez Martins, Wiley Barton, Orla O' Sullivan, Paul Cotter and Sasitharan Balasubramaniam. 2021  
IEEE Journal of Biomedical and Health Informatics  
<https://ieeexplore.ieee.org/document/9705067>



## A FAST AND ACCURATE METHOD TO CLASSIFY TIME SERIES DATA

Thach Le Nguyen

### CONTEXT

Time series data (series of measurements over time) is a very common type of data. Time series classification is the task of labelling unseen data that has not been seen before. Automatic time series classification is a critical problem not only in scientific research, but also in many real-life applications.

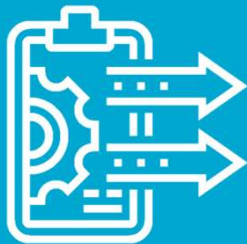


### PROBLEM STATEMENT

State-of-the-art machine learning models for time series classification are very accurate but usually expensive (time and resources) and not explainable

### ACTIVITIES

We developed a method that can train time series classification models. We named it MrSQM, and it's fast, accurate, and gives explanations. Experiments with real time series datasets (the UEA benchmark <http://www.timeseriesclassification.com/dataset.php>)



The benchmark results show our method is comparable to the state-of-the-art classifiers. Our method achieved 97.2% accuracy in the case study. It also correctly pinpointed the mistakes (e.g., when the legs are bending) of the athletes.

### OUTPUTS

### OUTCOMES

Publication in the Data Mining and Knowledge Discovery Journal (Impact Factor: 5.356). See below for more details. Open source software: <https://github.com/lnthach/Mr-SEQL>



With MrSQM, we demonstrate that our simple solution can be as good as the state-of-the-art, while being more practical (models explainable and not expensive to run). Its advantages opens for broader applications (e.g., applications on portable devices like mobile phones).

### IMPACTS

#### Further Information:

A Short Tutorial for Time Series Classification and Explanation with MrSQM  
Thach Le Nguyen and Georgiana Ifrim. 2021  
Software Impact  
<https://doi.org/10.1016/j.simpa.2021.100197>

## ENGINEERING BACTERIA AS A COMPUTING PLATFORM

Daniel Martins

### CONTEXT

Microfluidic-based chips have been applied to drug discovery and *in situ* diagnostics  
Engineered bacteria can enhance the biocompatibility and the functionality of microfluidic-based chips

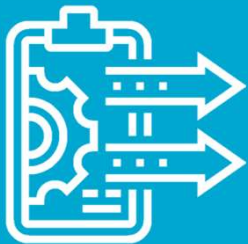


### PROBLEM STATEMENT

Can the combination of synthetic biology, molecular communications and electrochemistry result in a reliable microfluidic-based bio-computer?

### ACTIVITIES

Design and analysis of wet lab experiments to assess the performance of the proposed bio-computer  
Simulation and analysis of theoretical analysis of the exchange and detection of biomolecules



### OUTPUTS

The wet lab results correctly quantified the operation of the engineered bacterial populations  
The theoretical results show the impact of the environment on the microfluidic-based bio-computer reliability

### OUTCOMES

The fluid medium should have a pH 9 to improve the detection of molecules  
The bacteria engineered as an AND gate is shown to have a robust logic computation performance



### IMPACTS

Support the sustainability of agriculture through the development of novel bio-computing applications  
Soil and grass quality can be monitored using a network of microfluidic-based bio-computers

### Further Information:

Microfluidic-based Bacterial Molecular Computing on a Chip  
Daniel Martins, Michael Taynnan Barros, Benjamin O'Sullivan, Ian Seymour, Alan O'Riordan, Lee Coffey, Joseph Sweeney and Sasitharan Balasubramaniam. 2021  
Accepted for publication on IEEE Sensors Journal  
<http://arxiv.org/abs/2104.07341>

# THE RECEPTION OF MOLECULES IS AN IMPORTANT PROCESS FOR BACTERIAL POPULATIONS

Daniel Martins

## CONTEXT

Bacteria produces molecules based on the amount of signal they detect  
Multiple experiments are required to assess the impact of living cells' characteristics

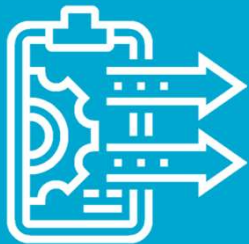


## PROBLEM STATEMENT

Can a simple method be applied to study the reception of molecules and improve the engineering of bacterial populations?

## ACTIVITIES

The bacterial signalling process was represented as a combination of capacitors, resistors and transistors  
The resistor values were modified to assess the impact of the signal binding process on the production of molecules



Unequal binding process can severely affect the emitted molecular signal concentration  
The emitted signal concentration is quite similar when applying lower input signal concentrations

## OUTPUTS

## OUTCOMES

The design of bacteria-based molecular communications systems severely depend on the bacterial binding process  
Bacterial internal signal processing should be considered when modelling bacteria-based transmitters



Rational design of novel biotechnological systems for the dairy industry can be supported by electronics  
More robust and precise bacteria-based systems can be devised for tackling the current challenges of the dairy industry

## IMPACTS

### Further Information:

Binding Process Analysis of Bacterial-based AND Logic Gates  
Daniel Martins, Paul Cotter, Orla O'Sullivan and Sasitharan Balasubramaniam. 2021  
8th ACM International Conference on Nanoscale Computing and Communication  
<https://doi.org/10.1145/3477206.3477472>

## CAN WE PROTECT THE INFORMATION EXCHANGED BY BACTERIAL POPULATIONS?

Daniel Martins

### CONTEXT

Information can be exchanged by bacterial populations in the form of molecules  
No coding technique have been proposed to protect the information exchanged by bacterial populations

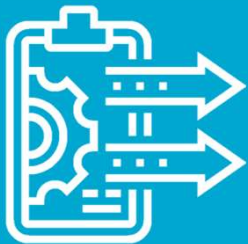


### PROBLEM STATEMENT

How the signal emitted by bacterial populations can be combined to create codes that protect them against noise and interference?

### ACTIVITIES

A coding scheme was proposed based on the emission of molecules from two bacterial populations  
Wet lab experiments were executed to validate the proposed coding scheme



### OUTPUTS

The theoretical results shows the possibility of creating eight three-bit codes  
We were able to generate four three-bit codes experimentally

### OUTCOMES

The theory behind the proposed coding scheme need to be further developed  
Experimental procedure will be reviewed to obtain more three-bit codes



### IMPACTS

Safer biocompatible monitoring systems can be designed based on this research  
Healthier soils and natural resource usage can be monitored through safer bacteria-based molecular communications systems

### Further Information:

Modulated Molecular Channel Coding Scheme for Multi-Bacterial Transmitters  
Daniel Perez Martins, Jennifer Drohan, Sarah Foley, Lee Coffey and Sasitharan Balasubramaniam. 2021  
19th ACM Conference on Embedded Networked Sensor Systems  
<http://doi.org/10.1145/3485730.3494039>



## ENVIRONMENTAL IMPACT OF GENETICALLY DIVERGENT DAIRY COWS

Ben Lahart

### CONTEXT

The economic breeding index (EBI) is used by the Irish dairy industry to breed more profitable dairy cows  
Recent environmental challenges facing the dairy industry also necessitate milk to be produced in a sustainable manner

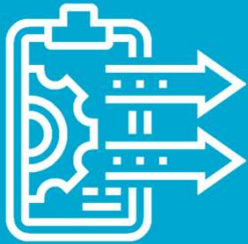


### PROBLEM STATEMENT

How does selection on the EBI impact the environmental footprint of Irish dairy production?

### ACTIVITIES

Biological data from the Next Generation Herd were used to model the greenhouse gas emissions profile and nitrogen balance of a 40 ha dairy farm carrying 110 dairy cows



Each €10 increase in EBI leads to a 1% reduction in the carbon footprint of milk production

### OUTPUTS

### OUTCOMES

Selection on the EBI reduces the carbon footprint of milk production



The results of this research have been used as a strategy by the Signpost Programme to reduce the carbon footprint of milk production on dairy farms

### IMPACTS

#### Further Information:

Greenhouse gas emissions and nitrogen efficiency of dairy cows of divergent economic breeding index under seasonal pasture-based management

Ben Lahart, Laurence Shalloo, Jonathan Herron, Donal O'Brien, Ricki Fitzgerald, Tommy Boland and Frank Buckley. 2021  
Journal of Dairy Science. <https://doi.org/10.3168/jds.2020-19618>

## GENOMIC IMPRINTING IN CATTLE

David Kenny

### CONTEXT

National genetic evaluations assume that performance and inter-animal genetic differences are due to differences in the DNA sequences of the animal's genome. The epigenome deviates from this assumption through a change in an animal's gene expression and performance without an alteration in the underlying DNA sequence.

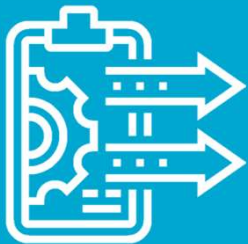


### PROBLEM STATEMENT

Does genomic imprinting impact carcass traits in beef cattle where imprinting is dictated by the parent of origin of the genome?

### ACTIVITIES

Genotypes at >600,000 locations on almost 30,000 Irish cattle used  
All animal genotypes were phased with respect to parent of origin  
Carcass traits investigated included carcass weight, conformation and fat score



### OUTPUTS

A total of 24, 339, and 316 DNA variants demonstrated imprinting associations with carcass weight, conformation and fat, respectively. No known imprinted gene in cattle was co-located with any of these detected variants demonstrating an imprinting effect.

### OUTCOMES

Since all imprinting associations detected herein were at novel loci, further investigation of these regions may be warranted. Most of the imprinted regions were on chromosome two.



### IMPACTS



Knowledge of the detected regions might be useful for improving the accuracy of genomic evaluations for these traits, as well as mate allocation systems to exploit the effects of genomic imprinting.

#### Further Information:

Detection of Genomic Imprinting for Carcass Traits in Cattle Using Imputed High-Density Genotype Data  
David Kenny, Roy Sleator, Craig Murphy, Ross Evans and Donagh Berry 2022  
Frontiers in Genetics  
<https://doi.org/10.3389/fgene.2022.951087>

## A TOOL TO RANK THE EXPECTED VALUE OF DAIRY-BORN CALVES

Fiona Dunne

### CONTEXT

Calves born in dairy herds are traded at a young age  
The expected value of a young calf is difficult to predict from visual inspection – this is important to gauge how much to pay when purchasing the calf

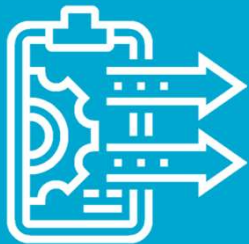


### PROBLEM STATEMENT

Can a value be applied to each calf sold nationally thus aiding farmers in their purchasing decisions?

### ACTIVITIES

Two novel monetary indexes were constructed and their predictive ability of carcass value quantified  
The developed calf transaction index included genetic and non-genetic merit for feed intake, docility, and carcass weight, conformation and fat score  
Calf index values were compared to the price paid at livestock marts



An index framework was developed to value individual calves populated by genetic and non-genetic information routinely stored for that animal in the national database

### OUTPUTS

### OUTCOMES

The dynamic index which can be generated for all animals leveraging data already available on the animal  
The dynamic nature of the index means it can be updated as new data related to the animal (or its relatives) accumulate



A commercial beef value (CBV) index was launched whereby all calves sold in livestock marts in Ireland receive the value in an attempt to aid the purchaser in paying a price for the calf commensurate with its value

### IMPACTS

#### Further Information:

Formulation of a decision support tool incorporating both genetic and non-genetic effects to rank young growing cattle on expected market value  
Fiona Dunne, Ross Evans, Mags Kelleher, Siobhan Walsh and Donagh Berry. 2021  
Animal 15 (2021) 100077  
<https://doi.org/10.1016/j.animal.2020.100077>

# DO GENETIC EVALUATIONS FOR BODY FATNESS MATERIALISE AS COWS THAT ACTUALLY DIFFER IN FATNESS

Donagh Berry

## CONTEXT

Cow fatness levels or what is called body condition score (BCS) is a known risk factor for cow health and well-being  
Body condition scoring in practice is undertaken using visual and tactile cues

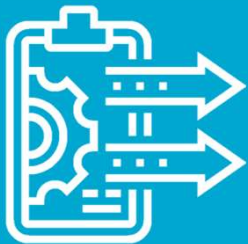


## PROBLEM STATEMENT

Do Irish national genetic evaluations for body condition score in young cows based on just visual assessment equate well with body condition score assessed using both visual and tactile cues in older cows?

## ACTIVITIES

National genetic evaluations for visually assessed body condition score available for >35,000 Irish cows who also had body condition score assessments from both visual and tactile appraisal  
Body condition score genetic merit estimates were related to phenotypic values



## OUTPUTS

A correlation of 0.10 was estimated between genetic merit for body condition score and actual cow body condition score; a strong correlation is not expected given that non-genetic factors also influence cow body condition score

## OUTCOMES

Genetic merit for body condition score which are generated from routinely available visual assessments of a selection of Irish cows can be used to breed cows nationally with improved body condition score as assessed by farmers using visual and tactile cues



## IMPACTS

Results provide confidence that genetic merit for body condition score based on a single visual assessment in first parity cows is useful to breed for cows of better body condition, irrespective of stage of lactation or parity

### Further Information:

Differences in genetic merit for visually-assessed body condition score materialises as phenotypic differences in tactile-based body condition score in commercial dairy cows  
Donagh Berry and Mags Kelleher. 2021  
Animal 15 100181. <https://doi.org/10.1016/j.animal.2021.100181>



David Kenny

## CONTEXT

Genetic evaluations separate the observed performance into its contributing genetic effects and non-genetic effects, with the former termed best linear unbiased predictions, and the latter termed best linear unbiased estimates (BLUEs)

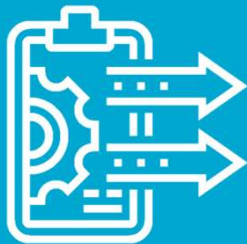


## PROBLEM STATEMENT

Can best linear unbiased estimates of herds be used in extension campaigns to help promote change?

## ACTIVITIES

Genetic evaluations on >4 million Irish cattle alongside herd-year best linear unbiased estimates of herd-years  
 Variability in best linear unbiased estimates quantified as well as contributing environmental effects (e.g., location) to these estimates



Considerable variability exist among herds in performance relative to genetic potential  
 The repeatability across years of the herd-year best linear unbiased estimates for carcass weight, conformation and fat score was 0.66, 0.59 and 0.50, respectively  
 Explaining some of this variability through differences in environmental effects is possible

## OUTPUTS

## OUTCOMES

The readily available data can be used to benchmark farmers by equalising for genetic merit of the herd  
 Results can be used to advise beef producers on the most promising strategy to improve the carcass merit of their animals



Ability now exists to generate objective metrics per herd-year as a decision support tool to provide information on whether or not a herd is realising the genetic potential of its animals for carcass merit

## IMPACTS

### Further Information:

Contribution of herd characteristics to best linear unbiased estimates of slaughter traits in beef cattle  
 David Kenny, Craig Murphy, Roy Sleator, Ross Evans and Donagh Berry. 2021  
 Animal 15: 100321  
<https://doi.org/10.1016/j.animal.2021.100321>

**SEXUAL DIMORPHISM - THE PHENOMENON WHEREBY MALES AND FEMALES OF THE SAME SPECIES ARE DISTINCTIVE IN SOME ASPECT OF APPEARANCE OR SIZE**

Jennifer Doyle

**CONTEXT**

Sexual dimorphism is the phenomenon whereby males and females of the same species are distinctive in behaviour, size, or appearance  
 This is attributable to a combination of sex-specific genes on sex chromosomes, sex specific expression of genes, and other regulatory mechanisms



**PROBLEM STATEMENT**

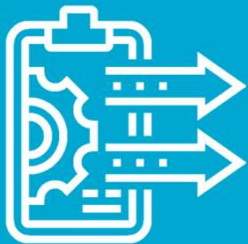
Do systematic differences exist in morphology between individuals of different sex at a genetic level?

**ACTIVITIES**

Genomic data and information on ten body conformation measures on almost 20,000 growing cattle of multiple breeds  
 The frequency of different genomic variants by gender and the strength of the association between each variant and body conformation was estimated



**OUTPUTS**



The vast majority of all segregating genomic variants had the same frequency in in both males and females  
 Dimorphic genomic variants were detected in just three traits in the Angus, seven traits in the Charolais, and three traits in the Limousin

**OUTCOMES**

Overall, sexual dimorphism exists in cattle at the genome level, but it is neither consistent by either trait or breed  
 The extent of dimorphism in regions demonstrating such a phenomenon was biologically small



**IMPACTS**



Sexual dimorphism does not need to be considered in the genetic evaluation of body-related traits in cattle in the pursuit of more accurate genetic evaluations

**Further Information:**

Identification of genomic regions that exhibit sexual dimorphism for size and muscularity in cattle  
 Jennifer Doyle, Deirdre Purfield, Tom Moore, Tara Carthy, Siobhan Walsh, Roel Veerkamp, Ross Evans and Donagh Berry. 2021  
 Journal of Animal Science, 2021, Vol. 99, No. 5, 1–19  
<https://doi.org/10.1093/jas/skab070>

## QUALITY CONTROL OF GENOMIC DATA BASED ON GENCALL STATISTIC

Donagh Berry

### CONTEXT

Quality control of data prior to downstream analysis is fundamental to ensure integrity of results

The GenCall (GC) score is a value attributed to each genotype called on an Illumina array platform providing a confidence measure to the assigned genotype

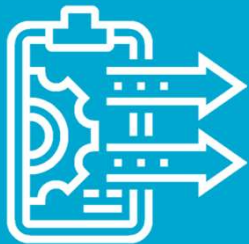


### PROBLEM STATEMENT

What minimum GenCall (GC) score should be imposed when undertaking genotype quality control?

### ACTIVITIES

Duplicate genotypes on 771 cattle (12.5 million genotypes post-editing)  
Quantified concordance between high and low GC score genotypes for the same individual



### OUTPUTS

The mean genotype concordance rate for a GC score of  $<0.300$ ,  $0.300-0.549$ , and  $\geq 0.550$  in the cattle was 0.9467, 0.9707, and 0.9994, respectively  
Hence, concordance eroded as the GC score of the called genotype reduced, albeit the impact was not dramatic and was not very noticeable until a GC score of  $<0.55$

### OUTCOMES

Recommended threshold on the minimum acceptable GC score to ensure data integrity while maximising the quantity of genomic data available for downstream analyses



### IMPACTS

The actual threshold GC score to be used in a study will depend on the objective of the study and its respective design  
Genotypes with a GC score of  $<0.55$  should be removed prior to downstream analyses

#### Further Information:

Concordance rate in cattle and sheep between genotypes differing in Illumina GenCall quality score  
Donagh Berry, Fiona Dunne, Ross Evans, Kevin McDermott and Aine O'Brien. 2021  
Animal Genetics 52: 208-213 10.1111/age.13043  
<https://doi.org/10.1111/age.13043>

## VALIDATION OF THE IRISH NATIONAL DAIRY COW BREEDING INDEX, THE ECONOMIC BREEDING INDEX (EBI)

Siobhan Ring

### CONTEXT

Bespoke breeding goals have been developed in many countries for a variety of species and production systems

Quantifying the extent of phenotypic change per unit change in the index is useful to provide confidence in the benefit of using the index

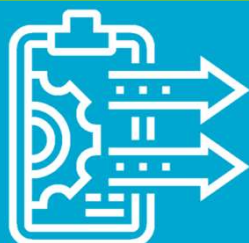


### PROBLEM STATEMENT

Does selection on the Irish breeding index, or indeed its individual components, contribute to a change in cow phenotypic performance?

### ACTIVITIES

Performance data on 536,923 Irish dairy cows from 13,399 herds were used. Association analyses between the cow's genetic merit for each individual trait included in the Irish index for dairy cows and her subsequent performance were undertaken.



Cows excelling in genetic merit for individual traits, as well as on the index, generally deliver superior phenotypic performance; examples include a greater yield and composition, despite lower milk volume, superior reproduction, better survival, improved udder and hoof health, lighter cows, and fewer calving complications.

### OUTPUTS

### OUTCOMES

Genetic selection on individual traits or the combined index will translate to improved performance.

Less than expected changes in reproductive performance were evident necessitating further exploration.



Results substantiate that breeding, especially using the Irish national breeding index, the EBI, is a sustainable strategy for improving performance in commercial dairy cattle and, by extension, profit. The national fertility genetic evaluations are to be revised.

### IMPACTS

#### Further Information:

Cross-sectional analyses of a national database to determine if superior genetic merit translates to superior dairy cow performance. Siobhan Ring, Ross Evans, Andrew Cromie, and Donagh Berry. 2021. Journal of Dairy Science 104:8076–8093. <https://doi.org/10.3168/jds.2020-19957>



## PREDICTING GENETIC MERIT FOR COW LIVE-WEIGHT AND BODY CONDITION SCORE FROM ROUTINELY AVAILABLE DATA

Donagh Berry

### CONTEXT

Accurate estimates of genetic merit for both live weight and body condition score (BCS) are useful additions to national- and herd-breeding programs. Although recording live weight and BCS is not technologically arduous, data available for use in routine genetic evaluations are generally lacking.

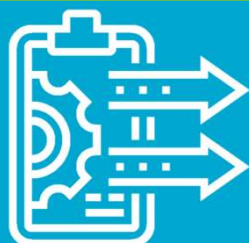


### PROBLEM STATEMENT

Can genetic merit for cow live-weight and BCS be predicted from routinely available linear type trait data and carcass records?

### ACTIVITIES

On-farm records of live weight and BCS from 33,242 dairy cows in 201 Irish herds used. Six linear type traits (stature, angularity, chest width, body depth, BCS, and rump width) and three carcass traits (carcass weight, conformation and fat score) were explored.



The genetic correlation between stature, angularity, body depth, chest width, rump width, and visually-assessed BCS with live weight was 0.68, -0.28, 0.43, 0.64, 0.61, and 0.44, respectively.

The genetic correlation between cull cow carcass weight and live weight was 0.81, and the genetic correlation between cull cow carcass fat cover and BCS was 0.44.

### OUTPUTS

### OUTCOMES

Linear type trait data are a useful source of information to predict live weight and BCS with minimal additional predictive value from also considering carcass data. In the absence of linear type trait data, information on carcass traits can be useful in predicting genetic merit for mature cow live weight.



### IMPACTS

Routinely available data can be incorporated into multi-trait genetic evaluations to predict cow genetic merit for live-weight and BCS. Prediction of cow BCS from cow carcass data is not recommended.

### Further Information:

Prediction of genetic merit for live weight and body condition score in dairy cows using routinely available linear type and carcass data  
Donagh Berry, Ross Evans and Mags Kelleher. 2021  
Journal of Dairy Science 104:6885–6896  
<https://doi.org/10.3168/jds.2021-20154>

Donagh Berry

## CONTEXT

Understanding dairy producer mind-set in bull selection can provide useful information for different junctures along the animal breeding chain. Such information can aid the targeted marketing of bulls based on farm systems and provide information for delivering bespoke extension services.

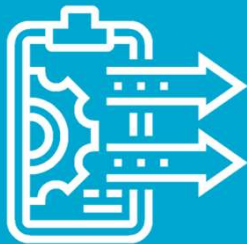


## PROBLEM STATEMENT

Do differences exist among dairy producers in their choice of dairy and beef bulls depending on the life stage at which the surplus progeny generated from such matings exit the dairy farm?

## ACTIVITIES

Analyses of fate data from 1,092,403 progeny from 4,117 Irish dairy herds. Herd-years categorised based on when the surplus progeny exited the farm as: (1) calves sold <70 days of age, (2) cattle sold as yearlings, (3) prime cattle sold for finishing, or (4) prime cattle sold for immediate slaughter.



Of the beef bulls used in herds that sold their surplus progeny as calves, their mean genetic merit for carcass weight and carcass conformation score was just 2.00 kg and 0.11 scores (15-point scale) inferior to the beef bull used in herds that sold their surplus progeny as prime cattle for immediate slaughter. Similar trends, albeit of smaller magnitude, were evident for dairy bulls.

## OUTPUTS

## OUTCOMES

Provide insights into the mind-set of dairy producers depending on the market of their surplus animals in that dairy producers who sell surplus progeny as young calves use, on average, beef and dairy bulls that are expected to produce marginally lighter and less-well conformed carcasses; this is due to a combination of both within- and across-breed selection.



While the differences in genetic merit of bulls used by farmers operating different systems exist, the differences were biologically very small.

## IMPACTS

### Further Information:

Dairy Producers Who Market Their Surplus Progeny as Calves Use Germplasm With Slightly Lighter and Less-Conformed Carcasses Than Producers Who Rear Their Surplus Progeny Beyond Weaning  
Donagh Berry and Siobhan Ring. 2021  
Frontiers in Veterinary Science 8: 731894. <https://doi.org/10.3389/fvets.2021.731894>

## CHARACTERISATION OF BEEF BULLS USED IN DAIRY HERDS

Donagh Berry

### CONTEXT

Understanding the preferences of dairy cattle producers when selecting beef bulls for mating can help inform beef breeding programs as well as provide default parameters in mating advice systems

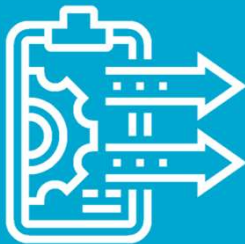


### PROBLEM STATEMENT

What are the characteristics of beef bulls used in Irish dairy herds and how does this differ by herd characteristics?

### ACTIVITIES

A total of 2,733,524 mating records from 928,437 females in 5,967 Irish dairy herds  
Sire genetic merit and associated reliability values for calving performance and carcass traits based on national genetic evaluations from prior to the insemination were used



The mean calving difficulty genetic merit of the beef bulls used was 1.85 units higher than that of the dairy bulls but with >3 times greater variability  
Mean calving difficulty genetic merit of dairy bulls used increased from 1.39 in heifers to 1.79 in first-parity cows and to 1.82 in second-parity cows  
Mean calving difficulty genetic merit of the beef bulls increased consistently with parity

### OUTPUTS

### OUTCOMES

Results demonstrate a clear difference in the mean acceptable genetic merit of beef AI bulls relative to dairy AI bulls but also indicates that these acceptable limits vary by herd characteristics



The mean parameters estimated can be used by farm advisors, and in mating advice programs when recommending bulls for use by different farmer types

### IMPACTS

#### Further Information:

Choice of artificial insemination beef bulls used to mate with female dairy cattle  
Donagh Berry, Siobhan Ring, Alan Twomey, and Ross Evans. 2021  
Journal of Dairy Science 103:1701–1710  
<https://doi.org/10.3168/jds.2019-17430>

## VALIDATING THE IRISH DAIRY-BEEF INDEX – AN INDEX FOR RANKING BEEF BULLS BASED ON SUITABILITY FOR DAIRY FEMALES

Donagh Berry

### CONTEXT

An index to rank beef bulls for suitability on dairy females was constructed and is available to Irish dairy farmers for use – the index is called a dairy-beef index (DBI). Validation studies of total merit indexes used to select beef sires for use on dairy females are lacking.

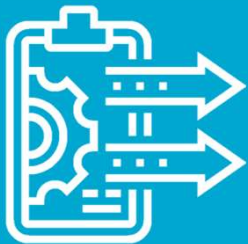


### PROBLEM STATEMENT

What is the difference in animal performance of beef × dairy progeny where the sire excels in either a total merit index encompassing calving performance and beef performance traits or excels in an index based solely on calving performance?

### ACTIVITIES

A total of 123,785 calving records in 3,065 Irish dairy herds were used. Used beef sires were stratified into 5 groups based separately on their dairy-beef index (DBI) or an index constructed of calving difficulty plus gestation length (CALV).



### OUTPUTS

Of the bulls that ranked highest on the CALV index, only 52% ranked highly on DBI. The percentage of primiparae requiring any assistance at calving was 2 to 3 percentage units greater for the higher DBI sires relative to the higher CALV beef sires or dairy sires. No difference in progeny gestation length between the high DBI or high CALV beef sires existed. The progeny of higher DBI bulls had a 4 to 10% greater probability of achieving the minimum carcass conformation required.

### OUTCOMES

More balanced progeny can be generated using the Irish DBI, helping meet the requirements of both dairy and beef producers.



### IMPACTS



Ignoring market failure across sectors, using higher DBI sires could increase dairy herd profit by 3 to 5% over and above the status quo approach to selection in dairy (i.e., selection on calving difficulty and gestation length).

### Further Information:

Observed progeny performance validates the benefit of mating genetically elite beef sires to dairy females  
Donagh Berry and Siobhan Ring. 2021  
Journal of Dairy Science 103:2523–2533  
<https://doi.org/10.3168/jds.2019-17431>



## ANIMAL-LEVEL FACTORS ASSOCIATED WITH WHETHER A DAIRY FEMALE IS MATED TO A DAIRY OR BEEF BULL

Donagh Berry

### CONTEXT

When serving a female, the producer must decide whether to mate her to a dairy or beef bull

Tools assisting in this decision could be a useful component of the decision process  
No cattle-based study exists in the scientific literature on the factors associated with whether a dairy female is mated to a beef or a dairy bull

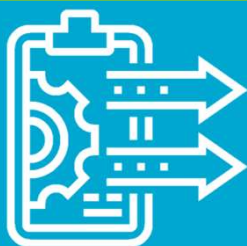


### PROBLEM STATEMENT

What factors are associated with the likelihood of a dairy female being mated to a beef bull versus being mated to a dairy bull?

### ACTIVITIES

2,283,100 artificial inseminations from 806,725 dairy females was used  
Risk factors considered were parity, period since calving, period of the breeding season, calendar week of calving, service number, cow genetic merit, milk solids yield in the previous lactation, somatic cell count in the previous lactation, calving difficulty, and cow breed



The probability of being inseminated with a beef bull increased with each service and as the breeding season progressed. An older cow had greater odds of being served with a beef bull, as did cows that calved later in the year, had recently experienced dystocia, were a longer time calved, or were of a poor overall genetic merit compared with herdmates. Cows with low somatic cell count in the previous lactation were less likely to be mated to a beef bull, as were cows that yielded relatively higher milk solids in the previous lactation.

### OUTPUTS

### OUTCOMES

Useful default parameters for inclusion in decision support mating advice tools.  
These parameters can be used in conjunction with decision support tools that identify females suitable for culling.  
Combined, the females on a given farm can be allocated to culling, breeding to a beef bull, or for consideration as a parent of the next generation of dairy females



The model probability estimates can form the back-end system supporting decisions on mating type for a female within a sire mating advice system but also in risk analysis of farm management

### IMPACTS

#### Further Information:

Animal-level factors associated with whether a dairy female is mated to a dairy or beef bull  
Donagh Berry and Siobhan Ring. 2021  
Journal of Dairy Science 103:8343–8349  
<https://doi.org/10.3168/jds.2020-18179>

## IMPACT OF SERVICE SIRE ON SUBSEQUENT PERFORMANCE OF HIS DAIRY FEMALE MATE

Donagh Berry

### CONTEXT

Many dairy producers are increasingly mating beef sires to dairy females  
 Much of the research on dairy × beef matings has focused only on the greater revenue attainable from these beef-cross calves  
 The repercussions of the beef-cross pregnancies on the subsequent performance of the dairy female have not been thoroughly investigated

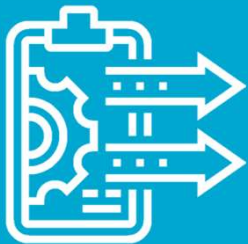


### PROBLEM STATEMENT

Does the choice of bull used impact the milk and reproductive performance of his mate in the ensuing lactation in the absence of reported calving difficulty?

### ACTIVITIES

Cross-sectional study of 346,765 calving events from 3,604 Irish dairy herds  
 Performance traits of interest were those associated with milk production, including somatic cell count, as well as female reproductive performance



Relative to a Holstein-Friesian sire, the mean 305-d milk yield (in kg) was 45.22, 62.0, 65.4, 101.1, 36.7, 51.5, 53.3, and 43.3 less for cows that gave birth to Angus-, Aubrac- Belgian Blue-, Charolais-, Hereford-, Limousin-, Saler-, or Simmental-sired calves, respectively  
 Service sire accounted for only 1% of the observed variability in subsequent cow milk production

### OUTPUTS

### OUTCOMES

Although statistically significant associations existed between sire beef merit and both milk and reproductive performance of the mate, the actual size of the associations were biologically small



There is no real value of considering in breeding indexes the expected impact of the service sire on the subsequent milk production of his mate

### IMPACTS

#### Further Information:

The beef merit of the sire mated to a dairy female affects her subsequent performance  
 Donagh Berry and Siobhan Ring. 2021  
 J. Dairy Sci. 103:8241–8250  
<https://doi.org/10.3168/jds.2020-18521>

# COPY NUMBER VARIANTS AND THEIR ASSOCIATION WITH CARCASS PERFORMANCE IN CATTLE

Pierce Rafter

## CONTEXT

The vast majority of genomic association studies have limited their investigation to single nucleotide polymorphism (SNP) allele count data. Other types of genetic variants such as copy number variants (CNVs) exist; these genetic variants are formed by duplication or deletion of segments of DNA.

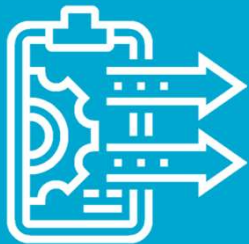


## PROBLEM STATEMENT

Do copy number variants contribute to the underlying variability in carcass traits of cattle?

## ACTIVITIES

A total of 712,555 single nucleotide polymorphisms variants from 923 Holstein-Friesian, 945 Charolais, and 974 Limousin bulls. The traits explored were carcass weight, conformation, and fat.



The copy number of 16 CNVs were associated with at least one of the three carcass traits in at least one of the three cattle breeds. None of the detected associations were detected using traditional association analyses based on SNP allele counts.

## OUTPUTS

## OUTCOMES

Copy number variant data can be used to detect genomic regions associated with carcass traits in cattle providing information on genes over and above those detected using just SNP allele counts, as is the approach typically employed in genome-wide association analyses.



While associations between copy number variants and carcass traits were detected, the importance in genomic predictions is small.

## IMPACTS

### Further Information:

Genome-wide association analyses of carcass traits using copy number variants and raw intensity values of single nucleotide polymorphisms in cattle

Pierce Rafter, Claire Gormley, Deirdre Purfield, Andrew Parnell, Saeid Naderi and Donagh Berry. 2021

BMC Genomics 22:757. <https://doi.org/10.1186/s12864-021-08075-2>

# YEARLY PREDICTION OF THE ONSET OF SUB-CLINICAL MASTITIS IN DAIRY COWS

Arjun Pakrashi

## CONTEXT

Mastitis is the most important disease globally in dairy cows  
Mastitis is not only of economic importance, but also affects animal welfare

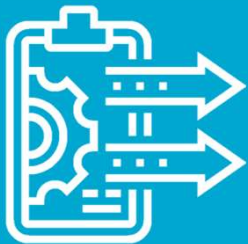


## PROBLEM STATEMENT

Can we predict the onset of sub-clinical mastitis, early enough to take remedial action?

## ACTIVITIES

Used detailed milk and cow-level data from research farms  
Applied machine learning algorithms and extensively validated the results



Ability to predict the onset of sub-clinical mastitis in dairy cows within the next 7 days using generally readily accessible data

## OUTPUTS

## OUTCOMES

A system that farmers can use on a daily basis to predict the likelihood of different cows succumbing to sub-clinical mastitis  
A system that milking machine manufacturers can deploy



Personalised cow management based on predicted likelihood of subclinical mastitis  
Information to trigger non-medicinal treatments for mitigating the onset of sub-clinical mastitis

## IMPACTS

### Further Information:

Machine learning approaches to the early detection of sub-clinical mastitis in lactating dairy cows  
Arjun Pakrashi, Donagh Berry and Brian Mac Namee



**MAINTAINING A GOOD DIET, RICH IN FRUITS, VEGETABLES AND OILY FISH CAN KEEP YOUR MEMORY HEALTHY WHEN YOU GROW OLDER**

**Rebecca Power**

**CONTEXT**

The health benefits of the macular carotenoids and omega-3 fatty acids has been studied for several years



**PROBLEM STATEMENT**

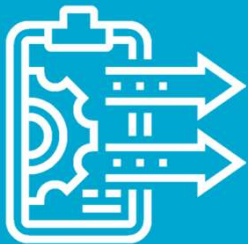
Elderlies use to suffer from memory issues, and have increasing risk of suffering dementia, including Alzheimer's disease

**ACTIVITIES**

Human trial where elderlies consumed capsules with carotenoids, omega-3 fatty acids and vitamin E  
Assessment of nutrients consumed in serum and the assessment of memory performance in the participants in the study



**OUTPUTS**



The human trial has been published

**OUTCOMES**

The possibility of continuing the study of the effect of these nutrients in elderlies, including Alzheimer's patients



**IMPACTS**



Raising more awareness of the importance of maintaining a good dietary habit among the population

**Further Information:**

Omega-3 fatty acid, carotenoid and vitamin E supplementation improves working memory in older adults: A randomised clinical trial  
Rebecca Power, John Nolan, Alfonso Prado-Cabrero, Warren Roche, Robert Coen, Tommy Power and Riona Mulcahy. 2021  
Clinical Nutrition  
<https://doi.org/10.1016/j.clnu.2021.12.004>



# 2020

59. Electrochemical detection of free-chlorine in water samples facilitated by in-situ pH control using interdigitated microelectrodes - Ian Seymour, Benjamin O' Sullivan, Pierre Lovera, James Rohan and Alan O' Riordan

60. Good Counterfactuals and Where to find them: A Case-Based Technique for Generating Counterfactuals for Explainable AI (XAI) – Mark Keane and Barry Smyth

61. Elimination of Oxygen Interference in the Electrochemical Detection of Monochloramine, using In Situ pH Control at Interdigitated Electrodes - Ian Seymour, Benjamin O' Sullivan, Pierre Lovera, James Rohan and Alan O' Riordan.

62. On Generating Plausible Counterfactual and Semi-Factual Explanations for Deep Learning – Eoin Kenny and Mark Keane

63. Feed and production efficiency of young crossbred beef cattle stratified on a terminal total merit index - David Kelly, Stephen Conroy, Craig Murphy, Roy Sleator and Donagh Berry

64. Large variability in feeding behaviour among crossbred growing cattle - David Kelly, Roy Sleator, Craig Murph, Stephen Conroy, Michelle Judge and Donagh Berry

65. Hydrogel-based Bio-nanomachine Transmitters for bacterial Molecular Communications - Daniel Martins, Huang Q.-O'Reilly, Lee Coffey, Paul Cotter and Sasi Balasubramaniam

66. The effects of sustained fitness improvement on the gut microbiome: A longitudinal, repeated measures case-study approach - Wiley Barton, Owen Cronin, Isabel Garcia-Perez, Ronan Whiston, Elaine Holmes, Trevor Woods, Catherine Molloy, Michael Molloy, Fergus Shanahan, Paul Cotter and Orla O'Sullivan



# 2020

67. Gut microbes from the phylogenetically diverse genus *Eubacterium* and their various contributions to gut health - Arghya Mukherjee, Cathy Lordan, Paul Ross and Paul Cotter.

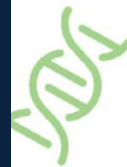
68. On-farm net benefit of genotyping candidate female replacement cattle and sheep - Jo Newton and Donagh Berry

69. The achievement of a given carcass specification is under moderate genetic control in cattle - David Kenny, Michelle Judge, Roy Sleator, Craig Murphy, Ross Evans and Donagh Berry

70. Extracting Pasture Phenotype and Biomass Percentages using Weakly Supervised Multi-target Deep Learning with Small Dataset - Badri Narayanan, Mohamed Saadeldin, Paul Albert, Kevin McGuinness and Brian MacNamee

71. On Generating Plausible Counterfactual and Semi-Factual Explanations for Deep Learning - Eoin Kenny and Mark Keane

72. On Generating Plausible Counterfactual and Semi-Factual Explanations for Deep Learning - Eoin Kenny and Mark Keane



## DEVELOPMENT OF AN ELECTROCHEMICAL METHOD OF QUANTIFYING RESIDUAL CHLORINE IN WATER

Ian Seymour

### CONTEXT

The amount of residual chlorine in a water system can indicate the presence or absence of organic contamination  
Electrochemical point of care testing can enable early identification of serious issues in drinking water systems

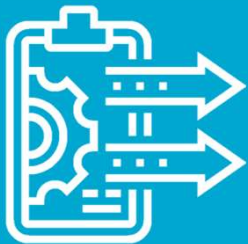


### PROBLEM STATEMENT

Residual chlorines exist as a ratio of hypochlorous acid to hypochlorite depending on sample pH, the latter of which is less active

### ACTIVITIES

A pH control method was developed with electrochemical sensors to minimise the variability of sample pH  
Ensured that the pH was constant in each measurement eliminates the inactive molecules by converting them to hypochlorous acid



This work has been presented at the 2019 IEEE Sensors conference

### OUTPUTS

### OUTCOMES

Further publications have arisen as a result of this initial pH control work, such as for the detection of silver ions and the detection of monochloramine



This work enabled the development of pH control simulations, which have greatly informed sensor design for this sensing approach  
This work allows for the elimination of pH as a variable without the need for additional chemical reagents

### IMPACTS

#### Further Information:

Electrochemical detection of free-chlorine in water samples facilitated by in-situ pH control using interdigitated microelectrodes  
Ian Seymour, Benjamin O' Sullivan, Pierre Lovera, James F. Rohan, and Alan O' Riordan. 2020  
Sensors and Actuators B: Chemical  
<https://doi.org/10.1016/j.snb.2020.128774>



## HOW TO GET BETTER OUTCOMES BASED ON EXPLANATIONS THAT TELL WHAT MIGHT HAVE BEEN

Mark Keane

### CONTEXT

This paper proposed a completely novel method for automatically counterfactual explanations to explain the predictions of artificial intelligence (AI) systems; these explanation methods are being developed to support the explanation of decision support systems in precision agriculture.

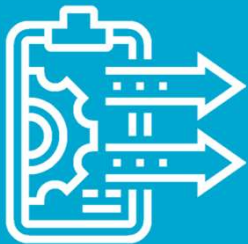


### PROBLEM STATEMENT

Imagine an AI model that generates predictions for crop growth based on climate, soil, and farm-management variables. The model predicts that in the coming month crop yield will be 30 kgs/Ha/per day and the farmer asks the system how this yield can be improved.

### ACTIVITIES

Artificial intelligence modelling model testing



Novel data sets showing counterfactual explanations for benchmark datasets.

### OUTPUTS

### OUTCOMES

Proposed an instance-based method for computing these counterfactual explanations, that adapts historical cases from a given farm



The algorithm has been used in other work to predict climate change, using data augmentation

### IMPACTS

#### Further Information:

Good Counterfactuals and Where to find them: A Case-Based Technique for Generating Counterfactuals for Explainable AI (XAI)  
Mark Keane and Barry Smyth. 2020

International Conference on Case-Based Reasoning (pp. 163-178) Lecture Notes in Computer Science. Springer, Champagne, Illinois, USA.  
[https://doi.org/10.1007/978-3-030-58342-2\\_11](https://doi.org/10.1007/978-3-030-58342-2_11)

## ELIMINATING THE INTERFERENCE OF OXYGEN IN THE DETECTION OF DISINFECTANTS IN WATER

Ian Seymour

### CONTEXT

Measurement of residual disinfectant molecules, for example monochloramine is crucial to ensuring water is safe for consumption  
Electrochemical sensors offer a fast and reagent free analysis approach that is easily made portable

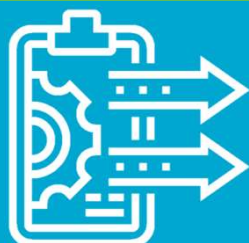


### PROBLEM STATEMENT

The use of electrochemical sensors in the detection of the disinfectant monochloramine is hindered by the presence of dissolved oxygen

### ACTIVITIES

A pH control method was developed to convert monochloramine to dichloramine, its acidic counterpart, at the electrode surface  
Detection of dichloramine is unaffected by the presence of oxygen, simplifying the analysis without additional reagents



This work was published in the American chemical society journal 'Sensors'

### OUTPUTS

### OUTCOMES

The developed pH control technique has been further studied and is used for the detection of a variety of other analytes in water and milk



Simplification of sensing approaches for various molecules of interest will reduce turnaround time for analysis  
Portable electrochemical sensors can ensure quality and improve sustainability

### IMPACTS

#### Further Information:

Elimination of Oxygen Interference in the Electrochemical Detection of Monochloramine, using In Situ pH Control at Interdigitated Electrodes  
Ian Seymour, Benjamin O' Sullivan, Pierre Lovera, James F. Rohan, and Alan O' Riordan. 2020  
ACS Sensors  
<https://doi.org/10.1021/acssensors.0c02264>

CONVINCING FARMERS AN ARTIFICIAL PREDICTION IS GOOD WITH SEMI-FACTUAL EXPLANATIONS

Eoin Kenny

**CONTEXT**

SmartAg suffers from user retention of artificial intelligence systems, so we aim to make people trust the AI system more.

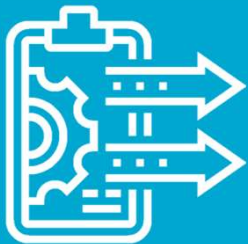


**PROBLEM STATEMENT**

How to generate plausible counterfactual and semi-factual explanations

**ACTIVITIES**

The method models the statistical distribution of learned latent features in a convolutional neural network, then probabilistic inferences are made to fill in feature values and guide the explanation process with a generative model



The framework successfully generated appropriate semi-factual explanations (i.e., the algorithm can make large and plausible changes to a query without changing the outcome). For farmers such an explanation can now say “Even if you use 50% less nitrogen than you’re planning, the crop yield will be the same”, thus allowing better on farm management and helping to protect the environment.

**OUTPUTS**

**OUTCOMES**

More people are aware of semi-factual explanations



Semi-factual explanations will help people trust these systems more

**IMPACTS**

Further Information:

On Generating Plausible Counterfactual and Semi-Factual Explanations for Deep Learning  
 Eoin Kenny and Mark Keane. 2020  
 Association for the Advancement of Artificial Intelligence  
<https://doi.org/10.48550/arXiv.2009.06399>



# VALIDATION OF A TOOL WHICH ENABLES THE BREEDING OF MORE EFFICIENT CATTLE FOR BEEF PRODUCTION

David Kelly

## CONTEXT

Growing focus on the sustainability of Irish beef and concerns around whether the industry should be directly breeding for more feed and production efficient beef cattle. The equivalence of including a feed efficiency trait or its components in a breeding index has not been comprehensively proven using actual cattle performance data.

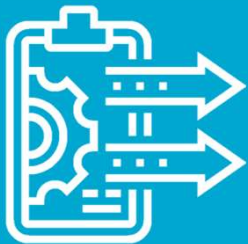


## PROBLEM STATEMENT

Routine validation of cattle breeding tools is crucial to maintain stakeholder confidence in such tools ability to enable the generation of profitable and more efficient cattle.

## ACTIVITIES

Analysis of a national cattle database hosted by the Irish Cattle Breeding Federation  
 Validate that beef cattle divergent on a terminal total merit index are more feed and production efficient



Verification that, relative to low genetic merit cattle on a terminal total merit index, cattle excelling on the index: 1. Eat less feed per day, 2. Are slaughtered at a younger age, 3. Yield heavier and more valuable carcasses, 4. Produce both better conformed and leaner carcasses

## OUTPUTS

## OUTCOMES

Confidence among stakeholders in the contribution of animal breeding to simultaneous improvements in individual cattle performance and efficiency  
 More certainty among beef farmers that using the Irish terminal index enables the generation of more profitable beef cattle



Knowledge that current beef terminal breeding goals are going in a favourable direction in terms of cattle performance. Reassurance to the wider agricultural industry and society that current cattle breeding goals are enabling the selection of more economically and environmentally sustainable beef cattle.

## IMPACTS

### Further Information:

Feed and production efficiency of young crossbred beef cattle stratified on a terminal total merit index  
 David Kelly, Stephen Conroy, Craig Murphy, Roy Sleator and Donagh Berry. 2020  
 Translational Animal Science  
<https://doi.org/10.1093/tas/txaa106>



## USEFULNESS OF FEEDING BEHAVIOUR INFORMATION IN CATTLE

David Kelly

### CONTEXT

Feeding behaviour traits, such as the daily time spent at the feed bunk, are relatively easy to measure and so could be useful to predict resource demanding traits like feed intake or efficiency in growing cattle

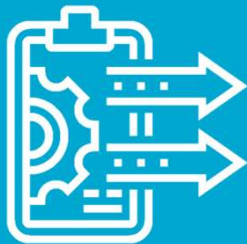


### PROBLEM STATEMENT

Can feeding behaviour information be useful to predict genetic merit for feed intake and efficiency?

### ACTIVITIES

Analysis of a national cattle database  
Derived several feeding behaviour traits in growing crossbred cattle to gain a better understanding of their inter-relationships as well as their relationships with common performance and efficiency traits



Demonstration of the significant observable variation existed between growing cattle in a plethora of repeatable feeding behaviour traits

### OUTPUTS

### OUTCOMES

Better understanding of the complex inter-relationships between feeding behaviour and feed intake and efficiency  
Knowledge of the significant contribution of feeding behaviour to the variability in feed intake in a relatively large population of cattle



Identification of potentially easier to measure feeding behaviour proxy traits useful for the prediction of important but difficult-to-measure feed intake and efficiency  
Cattle feeding behaviour data may have downstream application in animal breeding and precision livestock management

### IMPACTS

#### Further Information:

Large variability in feeding behaviour among crossbred growing cattle  
David Kelly, Roy Sleator, Craig Murphy, Stephen Conroy, Michelle Judge and Donagh Berry. 2020  
Journal of Animal Science  
<https://doi.org/10.1093/jas/skaa216>

## A SAFER INTRABODY NANOSENSOR IS OBTAINED BY ENCASING BACTERIAL CELLS

Daniel Martins

### CONTEXT

Bacteria have been investigated to design communications systems that sense and compute molecules  
A safer containment that does not affect the performance of such systems is required for intra-body applications

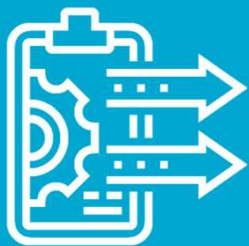


### PROBLEM STATEMENT

Can hydrogel be applied to encase engineered bacterial populations and not affect their communications performance?

### ACTIVITIES

Design of a bio-nanomachine transmitter model using engineered bacterial populations encased in hydrogel  
Theoretical and experimental performance analysis of a hydrogel-based bio-nanomachine transmitter



The impact of hydrogel encasing on the communications performance of bacterial populations  
The produced molecular signal is detected in a region around each bacterial population

### OUTPUTS

### OUTCOMES

Propagation directivity and communications performance is affected by the hydrogel's viscosity value  
Better molecular signal propagation through a hydrogel with higher viscosity



Proof-of-concept of a bacteria-based nanomachine transmitter for biosensing applications  
Kickstart idea for the development of animal health and environmental biosensors

### IMPACTS

#### Further Information:

Hydrogel-based Bio-nanomachine Transmitters for Bacterial Molecular Communications  
Daniel Martins, Huong Q.-O'Reilly, Lee Coffey, Paul Cotter and Sasitharan Balasubramaniam. 2020  
1st ACM International Workshop on Nanoscale Computing, Communication, and Applications  
<http://dx.doi.org/10.1145/3416006.3431271>

## SIX MONTHS, A NEW YOU, A NEW MICROBIOME

Wiley Barton

### CONTEXT

The gut microbiome of two individuals intensely examined over six months of fitness training. Healthy adults undergoing training programme

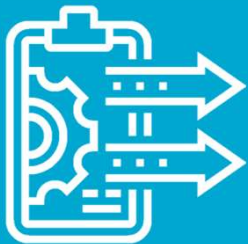


### PROBLEM STATEMENT

Can longer periods of intense training change the gut microbiome?

### ACTIVITIES

Bi-weekly sampling of numerous health parameters  
Analysis of all data collected over six months



### OUTPUTS

Dataset generated describing the six month course

### OUTCOMES

Even more evidence that the gut microbiome responds to intense physical activity and life events  
Basis for additional research



### IMPACTS

Better understanding of the gut microbiome  
Broader awareness of the area

#### Further Information:

The effects of sustained fitness improvement on the gut microbiome: A longitudinal, repeated measures case-study approach  
Wiley Barton, Owen Cronin, Isabel Garcia-Perez, Ronan Whiston, Elaine Holmes, Trevor Woods, Catherine Molloy, Michael Molloy, Fergus Shanahan, Paul Cotter and Orla O'Sullivan. 2020  
Translational Sports Medicine. <https://doi.org/10.1002/tsm2.215>

**MICROBES FROM THE GENUS EUBACTERIUM HAVE REPEATEDLY BEEN ASSOCIATED WITH POSITIVE GUT HEALTH. WHAT DO WE DO ABOUT THEM?**

**Arghya Mukherjee**

**CONTEXT**

In the past decade, intense research in gut microbiology has identified a group of gut microbes previously unknown to be positively associated with good gut health, including microbes from the genus Eubacterium

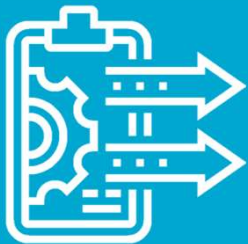


**PROBLEM STATEMENT**

The genus Eubacterium and its various members, their phylogeny and various contributions to host health have never been reviewed although there is substantial evidence of them being positively associated with host health

**ACTIVITIES**

The phylogeny of the genus Eubacterium, their taxonomic affiliations and the contribution of different members of this genus to human health was reviewed and discussed in detail



The findings of the research were published in a high impact, peer-reviewed journal

**OUTPUTS**

**OUTCOMES**

Increased and better understanding of the impact of this newly identified health associated microbe on human health



Benefit the understanding of gut microbe(s) and related research among the general public in what is now a field of intense research with significant interest among the general public

**IMPACTS**

Further Information:

Gut microbes from the phylogenetically diverse genus Eubacterium and their various contributions to gut health  
 Arghya Mukherjee, Cathy Lordan, Paul Ross and Paul Cotter.  
 Gut Microbes.  
<https://doi.org/10.1080/19490976.2020.1802866>





## A TOOL TO QUANTIFY THE BENEFIT OF GENOTYPING ANIMALS

Jo Newton

### CONTEXT

The net benefit from investing in any technology is a function of the cost of implementation and the expected return in revenue  
Producers are now routinely DNA-testing their animals – however, the cost benefit of such, which is farm-specific, has not been quantified

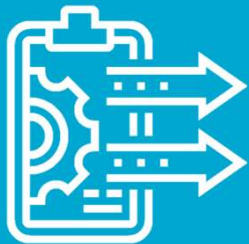


### PROBLEM STATEMENT

How much should farmers pay to genotype their females?

### ACTIVITIES

A deterministic model was developed to calculate the net monetary benefit from genotyping commercial females  
As a case study, the model was populated with parameters representing Irish cattle and sheep populations



Net benefit improved as the reliability of the genomic evaluations improved and, in fact, a negative net benefit of genotyping was less frequent when the reliability of the genomic evaluations was high  
The net benefit of genotyping female selection candidates reduced as replacement rate increased

### OUTPUTS

### OUTCOMES

Using prevailing parameters of most Irish dairy herds, the net benefit of genotyping an average dairy herd was €4,548.50  
The breakeven cost of genotyping for the average Irish dairy farmer is €63



A freely available excel based tool was developed which can be populated with population-specific parameters for any index or species to calculate the value of genotyping

### IMPACTS

#### Further Information:

On-farm net benefit of genotyping candidate female replacement cattle and sheep  
Jo Newton and Donagh Berry. 2020  
Animal (2020), 14:8, pp 1565–1575  
<https://doi.org/10.1017/S1751731120000208>

## BREEDING CATTLE TO ACHIEVE A DESIRABLE CARCASS SPECIFICATION

David Kenny

### CONTEXT

Desirable metrics are stipulated by beef processors in accordance with market signals from consumers, via the wholesalers, as well as the direct processing cost incurred per individual carcass  
Therefore, the ability to consistently produce beef carcasses with optimum yield and quality metrics is highly desirable

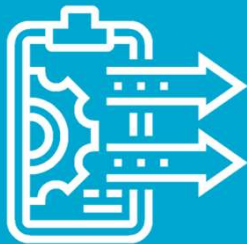


### PROBLEM STATEMENT

Can breeding help improve the proportion of carcasses achieving the desired specifications of the beef processing industry?

### ACTIVITIES

The desired specifications were those stipulated by Irish beef processors, in accordance with the EUROP carcass grading system, and were represented by a carcass weight between 270 and 380 kg, a fat score between 2+ and 4=, and a conformation score of O= or better  
Data from 58,868 beef carcasses were used



Of the specification traits investigated, 5% to 19% of whether or not an animal achieved the carcass specification was due to genetic effects  
A validation exercise demonstrated the ability of using the developed genetic evaluations in predicting whether or not an animal will achieve the specification

### OUTPUTS

### OUTCOMES

The genetic parameters estimated in the study signify that potential exists to breed cattle that more consistently achieve desirable carcass metrics at slaughter



It is possible, using the results from this study, to generate genetic evaluations for individual animals on whether or not they are likely to achieve certain carcass specifications

### IMPACTS

#### Further Information:

The achievement of a given carcass specification is under moderate genetic control in cattle.  
David Kenny, Michelle Judge, Roy Sleator, Craig Murphy, Ross Evans, and Donagh Berry. 2020  
Journal of Animal Science, 2020, Vol. 98, No. 6, 1  
<https://doi.org/10.1093/jas/skaa158>

# A SIMPLE APPROACH TO QUANTIFY THE GRASS, CLOVER AND WEEDS BIOMASS FROM A CANOPY PICTURE

Mohamed Saadeldin

## CONTEXT

Obtaining a proper grass/clover ratio in a cow's feed is important to ensure the quality of the produced milk

A fast estimation would lead to more frequent estimations and a smarter use of the fertilisers, leading to better environmental management



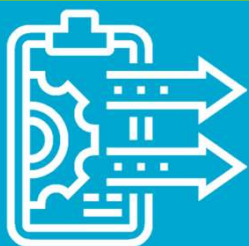
## PROBLEM STATEMENT

How to estimate a biomass composition from a photo of a field of grass and clover

## ACTIVITIES

Developed a deep learning approach to accurately predict biomass composition with limited data

Tested the performance of the algorithm using a publicly available benchmark



There are two grassland datasets collected at Moorepark research farm  
There is a trained deep learning model that can estimate total herbage mass and percentages of the biomass components (clover, grass, weed) with high accuracy

## OUTPUTS

## OUTCOMES

better proposed baseline will attract newer contributions to the field



In the future we should be able to propose a mobile application for farmers in Ireland to use and help fertilise their fields better and more responsibly  
Promote the use of AI for responsible management of our environment and for smart farming technologies

## IMPACTS

### Further Information:

Extracting Pasture Phenotype and Biomass Percentages using Weakly Supervised Multi-target Deep Learning with Small Dataset  
Badri Narayanan, Mohamed Saadeldin, Paul Albert, Kevin Mcguinness and Brian Macnamee. 2020  
Irish Machine Vision and Image Processing Conference Proceedings: IMVIP 2020  
<https://doi.org/10.48550/arXiv.2101.03198>

# EXPLAINING IMAGE CLASSIFIERS WITH COUNTERFACTUAL AND SEMI-FACTUAL EXPLANATIONS

Eoin Kenny

## CONTEXT

Explaining deep neural networks for image classification is difficult  
Presenting a contrasting image (counterfactual or semi-factual) about how things could change the outcome is a possible method of explanation

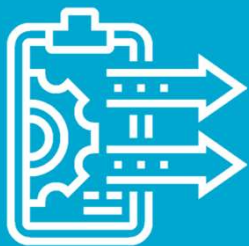


## PROBLEM STATEMENT

Can we use “exceptional features” to make good counterfactual and semi-factual explanations?

## ACTIVITIES

We tested our method “PIECE” on a few hundred test images from popular datasets  
The method identified “exceptional features” and generated counterfactual and semi-factual explanations



## OUTPUTS

The method “PIECE” successfully generated the best counterfactual explanations compared to baselines  
PIECE also generated significantly better semi-factual images than baselines

## OUTCOMES

The research community is now beginning to appreciate the importance of “exceptional features” in counterfactuals  
This is also the first instance of semi-factual usage in artificial intelligence, which may be important going forward



## IMPACTS

potential usage of semi-factuals and exceptional features in explanations for AI is huge  
Applications include SmartAg (e.g., grass growth prediction), and hand-written digit classification. However, it is applicable to anything involving an AI which needs explanations

### Further Information:

On Generating Plausible Counterfactual and Semi-Factual Explanations for Deep Learning  
Eoin Kenny and Mark Keane. 2020  
<https://arxiv.org/pdf/2009.06399.pdf>.



Eoin Kenny

## CONTEXT

SmartAg suffers from user retention of AI systems, so we aim to make people trust the AI system more

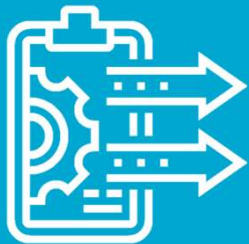


## PROBLEM STATEMENT

How to generate plausible counterfactual and semi-factual explanations

## ACTIVITIES

The method models the statistical distributions of learned latent features in a convolutional neural network, then probabilistic inferences are made to fill in feature values and guide the explanation process with a generative model



## OUTPUTS

The paper was published in one of the world's top AI conferences

## OUTCOMES

More people are aware of semi-factual explanations  
Paper reached a huge international audience



## IMPACTS

People have trouble trusting automated AI decision support systems, especially in SmartAg  
Semi-factual explanations will help people trust these systems more

### Further Information:

On Generating Plausible Counterfactual and Semi-Factual Explanations for Deep Learning  
Eoin Kenny and Mark Keane. 2020  
Association for the Advancement of Artificial Intelligence  
<https://doi.org/10.48550/arXiv.2009.06399>

# 2019

73. How herd best linear unbiased estimates affect the progress achievable from gains in additive and non-additive genetic merit – Fiona Dunne, Sinead McPartland, Margaret Kelleher, Sinead Walsh and Donagh Berry

74. Quality and Capacity Analysis of Molecular Communications in Bacterial Synthetic Logic Circuits – Daniel Martins, Michael Taynnan Barros and Sasi Balasubramaniam

75. Feed efficiency and carcass metrics in growing cattle - David Kelly, Craig Murphy, Roy Sleator, Michelle Judge, Stephen Conroy and Donagh Berry

76. A mating advice system in dairy cattle incorporating genomic information - Tara Carthy, John McCarthy and Donagh Berry

77. A breeding index to rank beef bulls for use on dairy females to maximise profit - Donagh Berry, Peter Amer, Ross Evans, Tim Byrne, Andrew Cromie and Fiona Hely

78. Prediction of 24-hour milk yield and composition in dairy cows from a single part-day yield and sample - Sinead McParland, Brian Coughlan, Brian Enright, Mary O'Keeffe, Rossarri O'Connor, Laurence Feeney and Donagh Berry

79. Interpretable time series classification using linear models and multi-resolution multi-domain symbolic representations - Thach Le Nguyen, Severin Gsponer, Iulia Ilie, Martin O'Reilly and Georgiana Ifrim

80. Predicting Grass Growth for Sustainable Dairy Farming: A CBR System Using Bayesian Case-Exclusion and Post-Hoc, Personalised Explanation-by-Example (XAI) - Eoin Kenny, Elodie Ruelle, Anne Geoghegan, Laurence Shalloo, Micheál O'Leary, Michael O'Donovan and Mark Keane



# 2019

81. How Case Based Reasoning Explained Neural Networks: An XAI Survey of Post-Hoc Explanation-by-Example in ANN-CBR Twins - Mark Keane and Eoin Kenny

82. Genetic similarity of biological samples to counter bio-hacking of DNA-Sequencing functionality - Mohid Siblee Islam, Stepan Ivanov, Eric Robson, Triona Dooley-Cullinane, Lee Coffey, Kevin Doolin and Sasi Balasubramaniam

83. Trojan Bio-Hacking of DNA-Sequencing Pipeline - Mohid Siblee Islam, Stepan Ivanov, Kevin Doolin, Lee Coffey, Triona Dooley-Cullinane Donagh Berry and Sasi Balasubramaniam



**ANIMAL PERFORMANCE IS BASED ON THE ANIMAL'S GENETICS AND THE ENVIRONMENT THEY PERFORM IN**

**Fiona Dunne**

**CONTEXT**

When estimating what an animal's genetic merit will contribute to any given trait, we assume they will be performing in the average environment  
Yet every animal is not performing in the average environment

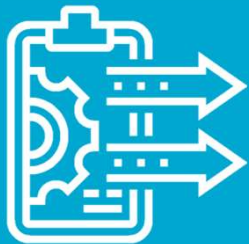


**PROBLEM STATEMENT**

Can we tailor the predicted contribution an animal's genetic merit will have on its performance based on the environment it is performing in?

**ACTIVITIES**

Analysis of the genetic predictions and environmental metrics routinely generated from national cattle genetic evaluations run by the Irish Cattle Breeding Foundation



**OUTPUTS**

Higher producing herds had a 20% greater response to changes in genetic merit for milk production  
Conversely, the improvement in reproductive performance per unit change in genetic merit was greater in herds performing poorer overall for reproduction

**OUTCOMES**

An approach to enable farmers to evaluate how an animal will perform under their own management system and within their herd environment



**IMPACTS**

The potential of more pertinent genetic evaluations tailored for each individual herd  
Providing bespoke decision-support to Irish farmers

**Further Information:**

How herd best linear unbiased estimates affect the progress achievable from gains in additive and non-additive genetic merit  
Fiona Dunne, Sinead McPartland, Margaret Kelleher, Sinead Walsh and Donagh Berry. 2019  
Journal of Dairy Science  
<https://doi.org/10.3168/jds.2018-16119>



## A "BIT" OF A QUALITY CONVERSATION AMONG BACTERIAL POPULATIONS

Daniel Martins

### CONTEXT

Bacteria can be engineered to process molecules as logic gates  
Molecular communications can model the exchange of signals diffused by engineered bacterial populations

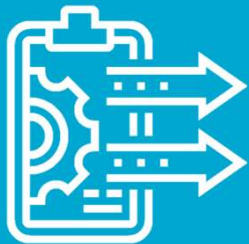


### PROBLEM STATEMENT

Can an engineered bacteria-based synthetic circuit have a high quality and capacity communications performance?

### ACTIVITIES

Investigation of synthetic biology models to characterise synthetic logic gates using bacteria  
Design of a molecular communications model to describe the interconnection of the synthetic logic gates using bacteria



### OUTPUTS

The molecular concentration produced by the bacteria follows the related literature  
The communications model accurately represents the exchange of molecules by the engineered bacterial populations

### OUTCOMES

The system's accuracy varies accordingly to the considered molecular input signals  
There is an inverse relationship between accuracy and communications capacity for this bacteria-based circuit



### IMPACTS

Synthetic biology and molecular communications should be combined to design bacteria-based circuits  
More accurate and capable bacteria systems are the initial step towards their application in the agriculture sector

#### Further Information:

Quality and Capacity Analysis of Molecular Communications in Bacterial Synthetic Logic Circuits  
Daniel Martins, Michael Taynnan Barros and Sasitharan Balasubramaniam. 2019  
IEEE Transactions on Nanobioscience.  
<http://dx.doi.org/10.1109/TNB.2019.2930960>

David Kelly

## CONTEXT

With the increasing focus on the sustainability of Irish beef, novel efficiency traits are required which better reflect production efficiency in cattle destined for slaughter. Replacing live weight with carcass weight in the derivation of feed efficiency traits has not been previously explored in cattle.

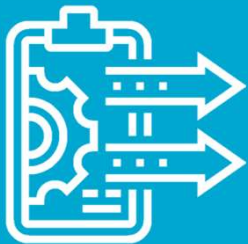


## PROBLEM STATEMENT

Live weight is included in the derivation of current feed efficiency traits but producers finishing cattle for slaughter are paid based on carcass weight.

## ACTIVITIES

Analysis of a national cattle database hosted by the Irish Cattle Breeding Federation. Derivation of novel feed efficiency traits in cattle as well as their associations with other feed efficiency and carcass traits.



Derivation of traits which identify cattle that partition a greater proportion of their feed energy into more valuable carcass weight as opposed to the '5th quarter'.

## OUTPUTS

## OUTCOMES

One of the largest studies to date to report phenotypic and genetic associations between feed efficiency and carcass traits in beef cattle. Demonstration of the benefits of using carcass information when defining efficiency of feed utilisation in beef cattle.



Novel feed efficiency traits could be used by breeders as a tool to market cattle as more production efficient.

## IMPACTS

### Further Information:

Feed efficiency and carcass metrics in growing cattle  
David Kelly, Craig Murphy, Roy Sleator, Michelle Judge, Stephen Conroy and Donagh Berry. 2019  
Journal of Animal Science  
<https://doi.org/10.1093/jas/skz316>

## MATING ADVICE SYSTEM FOR MATING DAIRY BULLS TO DAIRY FEMALES

Tara Carthy

### CONTEXT

Mating programs provide a support tool for breeders and producers, facilitating identification of the best combination of parental matings to maximise long-term genetic gain in their herds within the constraints of biology

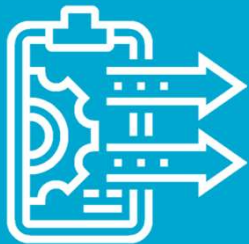


### PROBLEM STATEMENT

Can a decision support tool be developed to advise which dairy bulls to mate to which dairy females?

### ACTIVITIES

A total of 54,535 Holstein-Friesian cattle with >0.5m genotypes each  
 Mating allotment investigated: (1) random mating, (2) sequential mating based on maximising only the expected total merit index of the progeny, (3) linear programming to maximise an index constructed to maximise genetic merit and minimise expected progeny inbreeding as well as intra- and inter-progeny variability in genetic merit.



Using genome-based relationships between mates resulted in lower average herd expected inbreeding levels compared with using just recorded ancestry  
 Inter-progeny variability in performance was reduced using linear programming

### OUTPUTS

### OUTCOMES

Computer system developed which collates all necessary information from the national database and chooses the top three mating choices  
 Pipeline developed used as the basis for the beef-on-dairy sire advice system also now operational in Ireland



Developed sire advice system now deployed through the Irish Cattle Breeding Federation Herdplus service and actively used by thousands of dairy farmers when making mating decisions

### IMPACTS

#### Further Information:

A mating advice system in dairy cattle incorporating genomic information  
 Tara Carthy, John McCarthy and Donagh Berry. 2019  
 Journal of Dairy Science 102:8210–8220  
<https://doi.org/10.3168/jds.2019-16283>

Donagh Berry

## CONTEXT

The desire to increase profit on dairy farms necessitates consideration of the revenue attainable from the sale of surplus calves for meat production. Calves that are expected to excel in efficiency of growth and carcass merit must not be generated to the detriment of more difficult calving.

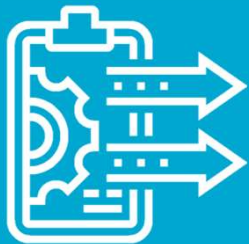


## PROBLEM STATEMENT

Can beef bulls be ranked on suitability for mating to dairy females considering both beef and calving performance?

## ACTIVITIES

Index of traits and relative economic importance constructed. Traits considered were (1) calving difficulty; (2) gestation length; (3) calf mortality; (4) feed intake; (5) carcass merit reflected by carcass weight, conformation, and fat and the ability to achieve minimum standards for each; (6) docility; and (7) whether the calf was polled.



The correlation between the developed dairy-beef index and an index of genetic merit for calving difficulty plus gestation length was 0.74. Superior carcass and growth performance can be achieved with the appropriate selection of beef bulls for use on dairy females with only a very modest increase in collateral effect on cow performance.

## OUTPUTS

## OUTCOMES

An index framework which, when populated by the publicly available estimates of genetic merit for individual bulls, can be used by Irish (and foreign) dairy farmers to identify suitable beef bulls.



Dairy-beef index value now available for all beef bulls nationally and actively used by dairy farmers.

## IMPACTS

### Further Information:

A breeding index to rank beef bulls for use on dairy females to maximise profit  
 Donagh Berry, Peter Amer, Ross Evans, Tim Byrne, Andrew Cromie, and Fiona Hely. 2019.  
 Journal of Dairy Science 102:10056–10072  
<https://doi.org/10.3168/jds.2019-16912>



## PREDICTING 24-HOUR MILK YIELDS FROM ONLY PART-DAY SAMPLES

Sinead McParland

### CONTEXT

Farmer recording of milk weight and milk samples per milking (twice per day) can be onerous, especially during the busy milking session; hence, being able to base comparisons of cows on just one milk sample would be advantageous

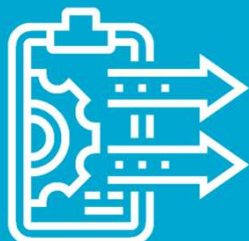


### PROBLEM STATEMENT

Can 24-hour milk, fat and protein yields be predicted from just morning or evening milkings?

### ACTIVITIES

A calibration dataset of 37,481 test-day records with both morning and evening yields and composition was used to generate the prediction equations; equations were validated using 4,644 test-day records  
Prediction models were developed within stage of lactation and parity while accounting for the inter-milking time interval



The correlation between the predicted 24-hour yields and composition and the respective actual values was 0.97 when based on just an AM milk yield and composition with a correlation of 0.95 when based on just a PM milk yield and composition. The regression of predicted 24-hour yield and composition on the respective actual values varied from 0.97 to 1.01 with the exception of 24-hour fat percentage predicted from a PM sample (1.06)

### OUTPUTS

### OUTCOMES

A single morning or evening sample is useful to predict 24-hour milk yield and composition when the milking interval is known  
The continued recording of two milk weights and two milk samples from a (small) selection of herds should continue to help maintain model accuracy



Equations now integrated into Irish milk recording system to predict 24-hour yields from part-day samples

### IMPACTS

#### Further Information:

Prediction of 24-hour milk yield and composition in dairy cows from a single part-day yield and sample  
Sinead McParland, Brian Coughlan, Brian Enright, Mary O'Keefe, Rossarri O'Connor, Laurence Feeney and Donagh Berry. 2019  
IJAFR 58: 66-70 10.2478/ijafr-2019-0007  
<https://t-stor.teagasc.ie/handle/11019/1891>

## AN EXPLAINABLE TIME SERIES CLASSIFICATION METHOD

Thach Le Nguyen

### CONTEXT

Labelling time series (time series classification) is a critical problem  
State-of-the-art time series classification (TSC) methods are slow and often not interpretable

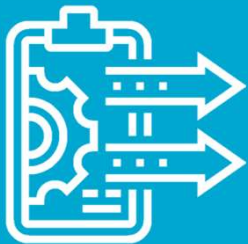


### PROBLEM STATEMENT

Can we train an interpretable time series classification model that is as accurate as the state-of-the-art methods?

### ACTIVITIES

Developed MrSQL, a novel method using symbolic representations of time series (i.e., converting sequences of numbers to sequences of alphabet characters)  
Benchmark the method with 85 time series datasets  
Case Study: Assessed forms of athletes who performed a counter-movement jump



Github: <https://github.com/lnthach/Mr-SEQL>

### OUTPUTS

### OUTCOMES

The benchmark results show our method is comparable to the state-of-the-art classifiers  
Our method achieved 97.2% accuracy in the case study. It also correctly pinpointed the mistakes of the athletes



### IMPACTS



We propose an explainable method for the task of labelling time series data.  
The method is reliable and practical  
It can be an effective solution where it is important to explain the decision-making process

#### Further Information:

Interpretable time series classification using linear models and multi-resolution multi-domain symbolic representations  
Thach Le Nguyen, Severin Gsponer, Iulia Ilie, Martin O'Reilly and Georgiana Ifrim. 2019  
Data mining and knowledge discovery  
<https://doi.org/10.1007/s10618-019-00633-3>

## PREDICTING AND EXPLAINING GRASS GROWTH TO FARMERS

Mark Keane

### CONTEXT

PastureBase Ireland (PBI) provides grass budgeting support for Irish dairy farms and aims, in the future, to provide predictions for grass growth (e.g., for the coming week). Accurate budgeting is critical to sustainable farming, as it allows farmers to minimise use of supplements and fertiliser (when it is not needed).

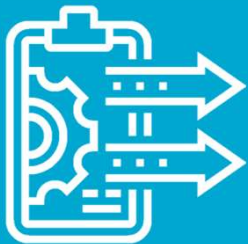


### PROBLEM STATEMENT

The problem is to develop accurate predictive models, using AI techniques and other methods; we are looking at existing historical datasets gathered from existing farms over many years

### ACTIVITIES

Developing a new algorithm to achieve a certain level of accuracy (<10DM kg/Ha) and can provide same-farm explanations of predictions  
Looking at the wider use of this data for predicting grass growth in the face of climate disruption



### OUTPUTS

Paper published in a leading international AI conference, ICCBR-19 (ranked B+), for which we received Best Paper Award

### OUTCOMES

Paper was featured at invited presentation at IJCAI-20, Japan, (A\* conference, 86% rejection rate) under the Best Paper Track, reaching an audience of 10,000+ AI researchers  
Paper has been downloaded 414 times from Springer site (June 2020)  
Paper awarded Best Paper Award at ICCBR-19



### IMPACTS

We aim to impact the uptake and use of this predictive model in PastureBase Ireland (PBI), to provide accurate budgeting supports for the Irish dairy sector, directly supporting the farmer end-user. Support the Origin Green initiative on sustainable production for the Irish food and drink sector, and support Ireland's position as a leading location for responsible AI.

#### Further Information:

Predicting Grass Growth for Sustainable Dairy Farming: A CBR System Using Bayesian Case-Exclusion and Post-Hoc, Personalised Explanation-by-Example (XAI).

Eoin Kenny, Elodie Ruelle, Anne Geoghegan, Laurence Shalloo, Micheál O'Leary, Michael O'Donovan and Mark Keane. 2019 International Conference on Case-Based Reasoning. [https://link.springer.com/chapter/10.1007/978-3-030-29249-2\\_12](https://link.springer.com/chapter/10.1007/978-3-030-29249-2_12)

## REVIEWING THE METHODS FOR EXPLAINING DECISION MAKING BY AI SYSTEMS

Mark Keane

### CONTEXT

Currently, artificial intelligence programs are contributing to significant decision making in everyday life (e.g., financial decisions), but we cannot see what led the program to the decision made. The area of explainable artificial intelligence (XAI) aims to develop new algorithms to make black box AI models more transparent, to allow us (humans) to challenge them and determine when they are working correctly and fairly.

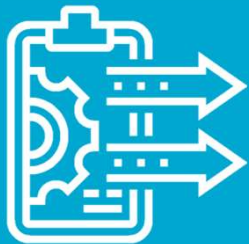


### PROBLEM STATEMENT

How to make Artificial Intelligence programs transparent to human users, to enable them to be queried, debugged and judged on their fairness and accuracy

### ACTIVITIES

Developing new algorithms than can be applied to any artificial neural network (ANN) or black box deep learning to allow them to be explained  
Testing this new algorithm on a wide range of datasets to show that the method has wide applicability



### OUTPUTS

Novel algorithms made available on github repository for general dissemination in the community

### OUTCOMES

The lead-funder of the DARPA XAI initiative (Dr. David Aha, Director, Navy Center for Applied Research in AI, Naval Research Laboratory, Washington) featured this work in a review of world-wide work in XAI. Provision of novel methods to the AI research community to be used across many application areas (e.g., already adverted for AI posts for twin systems in Spain)



### IMPACTS

Better methods for making AI systems more transparent and fair to end users; raising consciousness of this issues and allowing them to provide better decision support to end users. Cement Ireland's position as a leading country for responsible AI

#### Further Information:

How Case Based Reasoning Explained Neural Networks: An XAI Survey of Post-Hoc Explanation-by-Example in ANN-CBR Twins  
Mark Keane and Eoin Kenny. 2019

Bach K., Marling C. (eds) Case-Based Reasoning Research and Development. ICCBR 2019. Lecture Notes in Computer Science, vol 11680. Springer, Cham. [https://link.springer.com/chapter/10.1007/978-3-030-29249-2\\_11](https://link.springer.com/chapter/10.1007/978-3-030-29249-2_11)



# GENETIC SIMILARITY OF BIOLOGICAL SAMPLES TO COUNTER BIOHACKING OF DNA-SEQUENCING FUNCTIONALITY

Mohid Siblee Islam

## CONTEXT

The use of DNA sequencing and the applications of DNA sequencing is increasing significantly over time. DNA is considered as future storage medium for showing promise of storing large amount of data . Bacteria are proposed to use as a data carrier by encoding information into plasmid DNA for nano and micro scale communications.

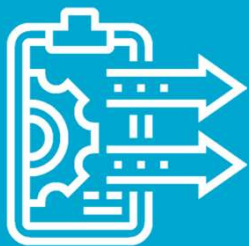


## PROBLEM STATEMENT

Can we come up with an end-to-end scenario where a DNA sequence will be designed and injected into bacteria for buffer overflow vulnerability exploit? How can we evaluate such scenarios? What is the solution to counter such attacks?

## ACTIVITIES

A web lab experiment was conducted to construct malicious DNA sequence in lab and insert them into bacteria. The bacteria was sprayed on various materials and collected as a sample then sequenced. We analyse the recovery of rates of the constructed malicious DNA sequences considering those material to conduct feasibility study of such attack in our described scenario.



We got promising results for malicious DNA recovery from bacteria containing the sequence, which were also sprayed over various materials. The detection results was also promising, and the accuracy increased with the increment in number of cases in the case library. A simple explainable solution has been proposed to counter the problem.

## OUTPUTS

## OUTCOMES

An end-to-end evaluation was done for buffer overflow exploit attack in DNA sequence pipeline by synthesising a specially designed DNA, where the DNA will be disguised in bacteria. It successfully demonstrate how a perpetrator can hide their identity. A simple explainable AI technique is used successfully as a detection mechanism.



Social awareness regarding this new way of attacks. Much research will be conducted to explore other possible attacks in DNA sequencing pipeline using specially designed DNA We will be ready to counter the disaster before it happens

## IMPACTS

### Further Information:

Genetic similarity of biological samples to couter bio-hacking of DNA-Sequencing functionality  
Mohid Siblee Islam, Stepan Ivanov, Eric Robson, Triona Dooley-Cullinane, Lee Coffey, Kevin Doolin and Sasi Balasubramaniam. 2019  
Scientific reports, Nature  
<http://doi.org/10.1038/s41598-019-44995-6>

## TROJAN BIO-HACKING OF DNA-SEQUENCING PIPELINE

Mohid Siblee Islam

### CONTEXT

The use of DNA sequencing and the applications of DNA sequencing is increasing significantly over time. DNA is considered as future storage medium for showing promise of storing large amount of data. Bacteria are proposed to use as data carrier by encoding into plasmid DNA for nano and micro scale communications.



### PROBLEM STATEMENT

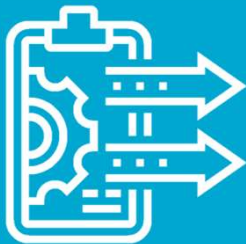
What might be a different attack in DNA sequencing pipeline beside buffer overflow exploit?  
Can we come up with an attack that is too difficult to detect?

### ACTIVITIES

We came up with a novel attack scenario in DNA sequencing pipeline. The scenario considers that a Trojan software will be implanted in the pipeline and will do legitimate work and only be activated for the malicious work if it received a specially designed DNA sequence. Cryptography and fragmentation is applied on the trigger message before encoding it into DNA and injected it into another DNA. We measured the success rate of such an attack, our measured estimations were compared with the simulated results.



### OUTPUTS



We have demonstrated the scenario of trigger based Trojan attack in DNA sequencing pipeline. We have managed to fragment, encrypt and encode the trigger message for activating the Trojan  
We have achieved promising results to estimate success rates of such as attack considering read error rates in sequencers

### OUTCOMES

We come to know how novel attack scenarios in DNA sequencing pipelines  
Our work also shows how the perpetrators can secure the message applying steganography before the DNA synthesis process so that they can hide their identity



### IMPACTS



Social awareness regarding this new way of attacks  
Much research will be conducted to explore other possible attacks in DNA sequencing pipelines using specially designed DNA

### Further Information:

Trojan Bio-Hacking of DNA-Sequencing Pipeline  
Mohid Siblee Islam, Stepan Ivanov, Kevin Doolin, Lee Coffey, Triona Dooley-Cullinane Donagh Berry and Sasi Balasubramaniam. 2019 NANOCOM '19; Proceedings of the Sixth Annual ACM International Conference on Nanoscale Computing and Communication, Sept 2019. <https://doi.org/10.1145/3345312.3345474>





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