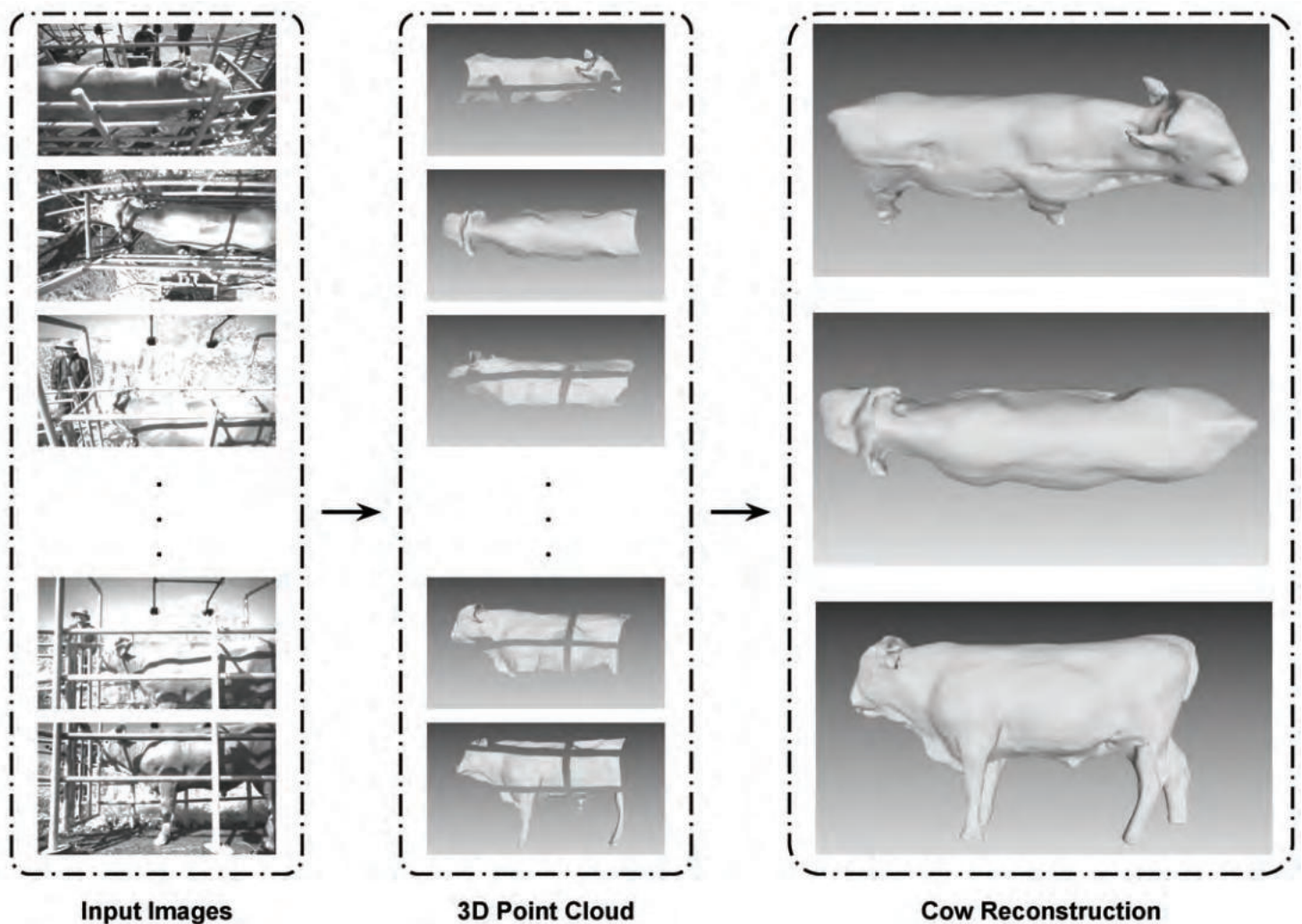


From manual measurement to Remote Phenotyping

What the future holds



Dr Japie van der Westhuizen



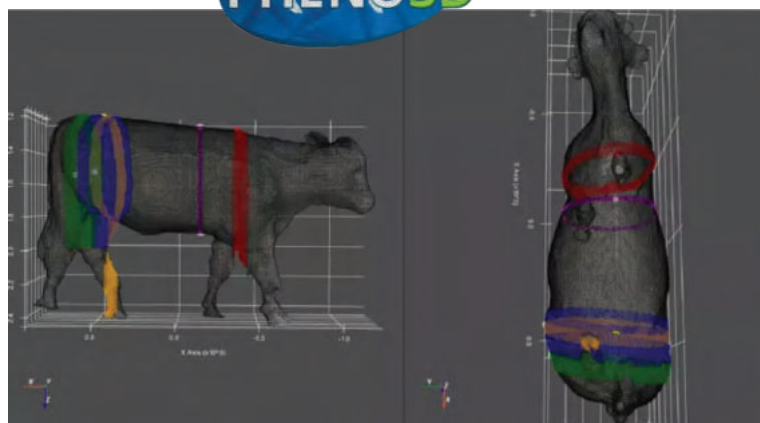
Traditional live-animal measurements, especially body dimensions, body condition scoring, and visual conformation assessment, require handling, restraint of animals and trained observers. Measurements are therefore normally infrequent, requires effort and time, is in effect very expensive (time and travel). Furthermore, observer effects are unavoidable, often bias, especially for subjective assessments. For breeding purposes, these factors not only limits data volume, but also consistency, repeatability and accuracy.

Remote phenotyping technologies aim to overcome these constraints through non-contact measurement. Using combinations of RGB (visible light) cameras, depth sensors, and structured light or laser systems, animals can be reconstructed as 3D models from which body dimensions, volume, and shape descriptors are automatically extracted.

Although one of the main aims are automation, the ability to measure animals repeatedly and objectively without increasing labour or stress is also of paramount importance. Phenotype recordings then become continuous data rather than isolated (once-off) observations.

Globally research and development takes place at public funded institutions as well as part of commercial ventures. The rapid developments of machine learning as building blocks for artificial intelligence is currently fast tracking these developments.

PHENO3D: A Breeding-Oriented Example



The PHENO3D project, being developed within the French beef cattle performance recording system, illustrates a decisive shift in focus. Rather than developing imaging technology in isolation, PHENO3D was designed explicitly to support genetic evaluation.

The system uses a multi-sensor 3D imaging corridor through which calves pass during routine handling, typically at weaning.

Depth cameras reconstruct the animal's full body surface, and algorithms automatically extract:

- live weight estimates,
- linear body measurements,
- morphological descriptors related to conformation,
- and volumetric traits derived from body shape.

The primary objective is not to create entirely new traits, but to automate the collection of traits already used in breeding schemes while removing scorer subjectivity and reducing labour constraints.

This distinction is important. Many imaging studies demonstrate technical feasibility under controlled conditions. PHENO3D addresses scalability, integration with existing recording structures, and compatibility with national genetic evaluation systems. A transition from engineering research to trustworthy operational phenotyping.

Current Areas of Progress

Automated body measurement and growth monitoring

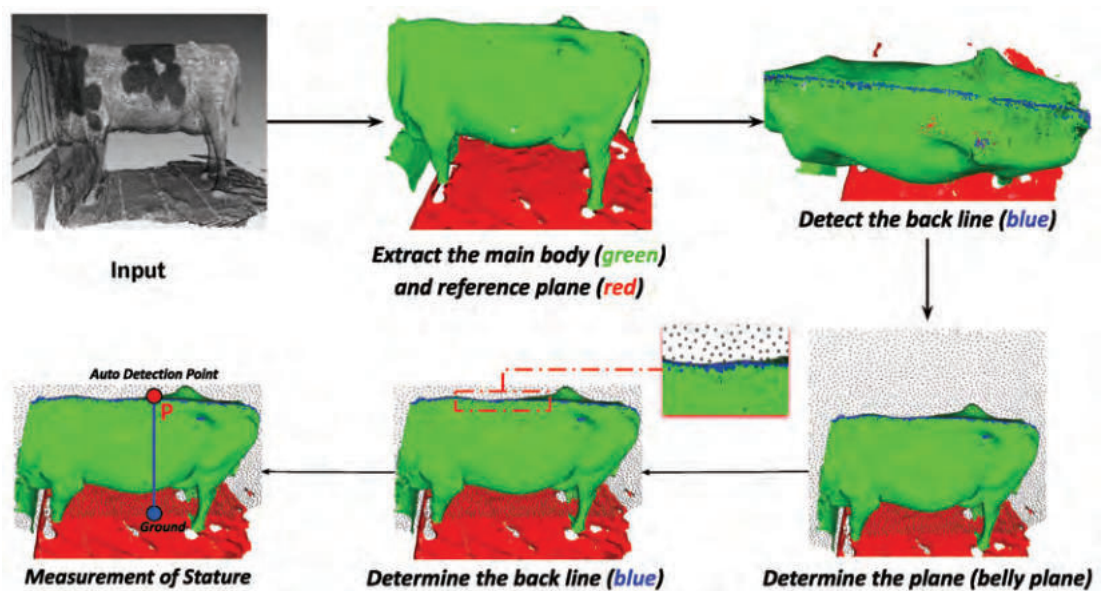


3D imaging systems now estimate live weight and growth trajectories from body volume with accuracy approaching conventional weighing under controlled conditions. In dairy systems, overhead depth cameras installed in parlours or passageways allow repeated measurements throughout lactation.

For breeders, repeated measurements are more informative than single records. Growth curves, maturity patterns, and condition changes over time become measurable phenotypes rather than inferred characteristics.

Objective body condition scoring

Body condition scoring has long suffered from inter-observer variation, therefore a lack of true objectivity. Depth imaging systems can quantify anatomical regions associated with fat deposition and produce consistent estimates across farms and time. This improves the reliability of functional traits linked to fertility and robustness.



Individual identification and longitudinal data

Advances in computer vision allow identification of individual animals through visual features or depth profiles. This enables continuous phenotyping without manual data capture, which is essential if high-frequency measurements are used to contribute meaningfully to breeding programmes.

Lessons from Carcass Imaging

Automated carcass grading systems demonstrated decades ago that imaging can generate economically relevant measurements at scale. The emerging difference is that phenotypes are now captured earlier in life.

Projects such as PHENO3D create the possibility of linking live-animal morphology directly with carcass outcomes. If validated, this allows earlier selection decisions and improved prediction of slaughter performance. However, these relationships still require large datasets and careful validation.



Technical and Biological Limitations

Despite rapid progress, several limitations remain:

- posture and movement still affect measurement precision,
- environmental conditions influence image quality,
- equipment costs remain significant for extensive systems,
- and trait definition is not yet standardised across different platforms.

A more fundamental issue is biological interpretation. Imaging systems measure geometry; breeding programmes require traits with economic and biological meaning. Without validation against production efficiency, fertility, or carcass value, increased measurement precision alone does not improve genetic progress.

PHENO3D is an example that partially addresses this by focusing on traits already embedded in breeding objectives, but long-term value will depend on demonstrating genetic correlations with economically relevant outcomes.

Implications for Livestock Breeders

For breeders, the importance of remote phenotyping lies in scale and consistency rather than being a technological novelty.

The main advantages are:

1. Larger numbers of objectively measured animals.
2. Reduced subjective scoring bias.
3. Repeated measurements across life stages.
4. Improved compatibility with genomic selection, where prediction accuracy depends heavily on phenotype quality and quantity.

A gradual transition from limited data collection to high-frequency phenotypic datasets is anticipated. This advancement enhances the capacity to identify emerging traits, such as growth dynamics or morphological

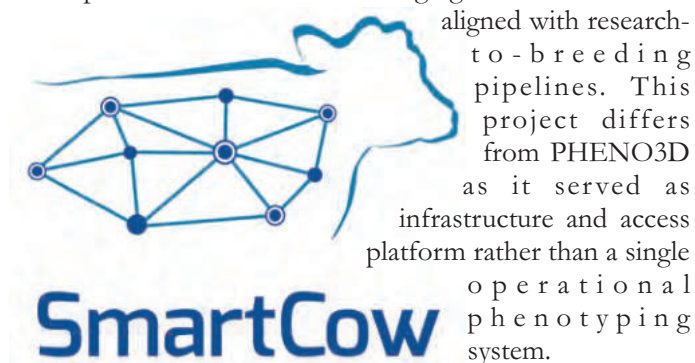
development. However, it also necessitates rigorous statistical analysis to ensure biological signals are distinguished from measurement “noise”.

Other systems

While PHENO3D presently stands as the most advanced solution for automating the processes from usable phenotypes to genetic merit, it is important to acknowledge that other approaches also warrant mentioning.

SmartCow (EU Horizon 2020 project)

SmartCow was a European research infrastructure initiative integrating cattle research facilities to enable high-quality phenotyping and data collection across systems. It was aimed at infrastructure for advanced phenotyping, support for the development of sensor and imaging-derived traits and



Breed4Food (Netherlands)

Breed4Food is a long-running Netherlands public–private research programme linking Wageningen University, breeding companies, and industry partners. It focuses on high-throughput phenotyping, sensor-derived functional traits and the integration of phenotypes into genomic evaluation. This system can possibly be described as representing the dairy-sector equivalent of PHENO3D's philosophy. Therefore, moving from experimental measurements toward traits usable in genetic evaluation. The emphasis is more on functional and efficiency traits than on 3D morphology.



National or institutional 3D imaging platforms (France, Ireland, Nordic countries)

Several groups are running multi-camera 3D scanning corridors, automated conformation scoring research and imaging-based weight prediction systems.

These are often not branded projects but research platforms within national recording schemes. PHENO3D is notable because it has moved further toward operational deployment.

USA

Parallel initiatives, particularly in North America, are focusing on integration of sensor and farm data streams for management decision support. These programmes differ from projects such as PHENO3D in that their primary objective is operational optimisation rather than generation of standardised phenotypes for breeding.

ICAR-aligned imaging and phenotyping initiatives

Beyond the named projects and initiatives, the International Committee for Animal Recording (ICAR) has become increasingly important in standardisation discussions involving automated body measurement, imaging-derived conformation traits and validation protocols for sensor-based phenotypes.

This is strategically important because breeding adoption depends on standardised trait definitions.

Outlook

Remote phenotyping is unlikely to replace conventional evaluation methods in the very near future. Its more realistic role is to expand the range and reliability of measurable traits in live animals. Dairy systems, with controlled animal flow, are likely to adopt these technologies first, followed by beef systems as costs decline and robustness of repeated measurements improves.

Programs such as PHENO3D show that the main challenge is no longer proving the effectiveness of 3D measurement, but rather how to incorporate it into breeding systems where phenotypic data guide selection choices. Ultimately, the lasting impact will rely less on imaging technology itself and more on how well these data streams are converted into selection criteria that are both biologically insightful and economically valuable.