AI in practice: Advancing intelligent pig breeding with AI-driven image extraction

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Extracting high-quality phenotypic data from live pigs is essential in modern breeding programs, as it provides the critical foundation for accurate genetic evaluation, precise selection, and industrial advancement. Reliable measurement of key traits—such as intramuscular fat content, body weight, and growth patterns—directly influences the efficiency and success of breeding strategies.[1] However, traditional methods depend largely on post-slaughter analysis, manual weighing, or subjective visual assessment, which are invasive, labor-intensive, stressful to animals, and unsuitable for real-time, large-scale, or repeatable screening. These persistent limitations have become major obstacles hindering progress in pig breeding.

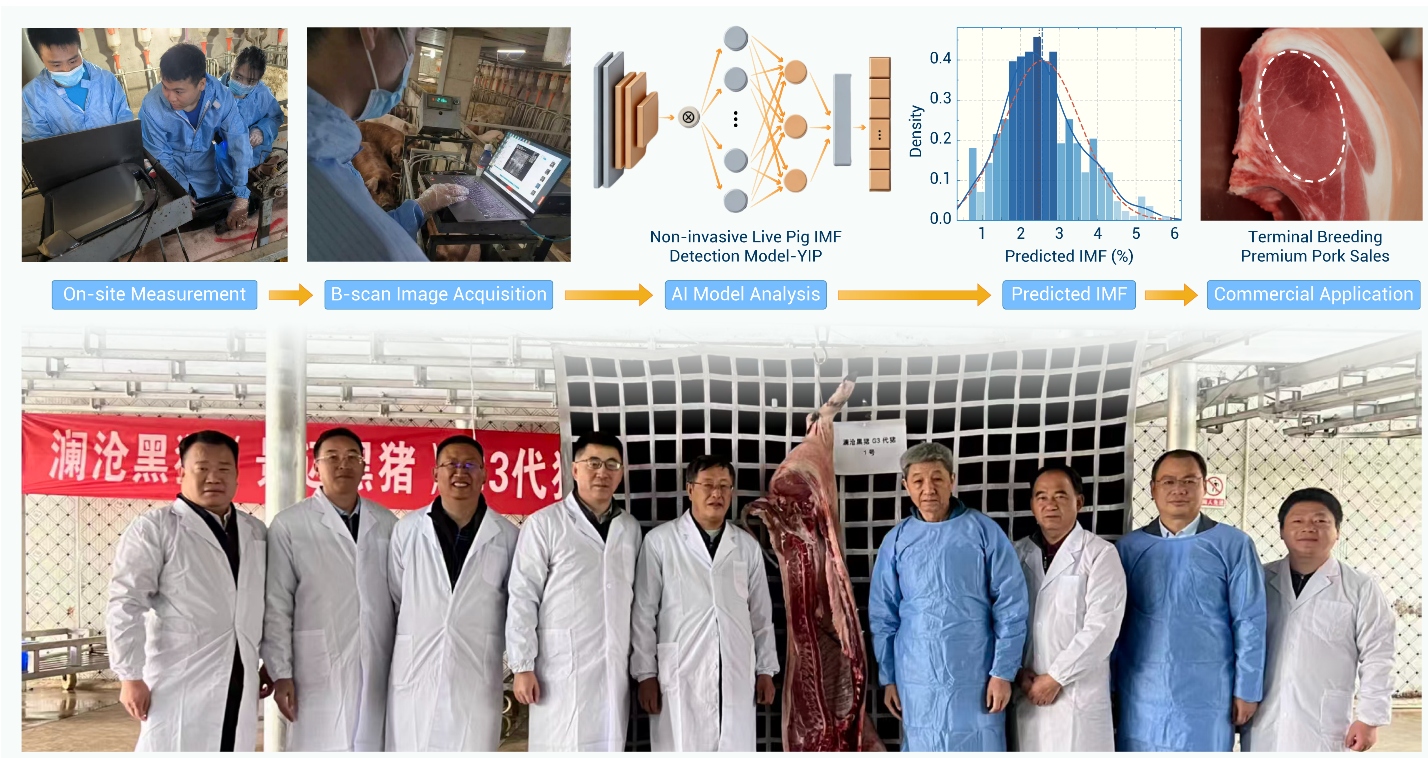

Figure 1. Process of the AI-assisted pork quality evaluation and the research team.

In recent years, advances in artificial intelligence and imaging technology have opened a new chapter in intelligent and non-invasive trait extraction.[2] Yulong Yin, a leading scientist at the Institute of Subtropical Agriculture, Chinese Academy of Sciences, has led his team to significant progress, including the development of the YIP deep learning model for accurately predicting intramuscular fat from B-ultrasound images and an Automatic Intelligent Weighing System that monitors body weight in freely moving pigs. Together, these AI-driven technologies enable the non-invasive and precise extraction of phenotypic traits from live pigs, laying a solid foundation for the next generation of intelligent pig breeding (Figure 1).

AI PREDICTS MARBLING IN LIVE PIGS

One of the key breakthroughs in AI-assisted pork quality evaluation is the YIP Model, jointly developed by Professor Kejun Wang's research team and Academician Yulong Yin's group. YIP is an optimized deep learning framework built on YOLOv11-seg, designed for non-invasive, high-precision intramuscular fat (IMF) percentage prediction in live pigs using ultrasound imaging. The model integrates instance segmentation, multi-scale feature fusion, and synergistic attention mechanisms—including channel, spatial, and global context attention—to automatically extract phenotypic features from ultrasound images and enable accurate IMF quantification. By leveraging a fine-tuned YOLOv11-seg, YIP precisely segments the loin region, effectively reducing interference from noisy ultrasound data. It employs selective multi-scale feature fusion from key network layers to minimize redundant information and enhance feature representation. In validation tests, YIP achieved a coefficient of determination (R^2) of 0.9511.[3] With only 2.83 million parameters, it offers a lightweight architecture well suited for on-farm deployment.

The YIP Model enables real-time, non-invasive, and large-scale IMF evaluation with a prediction accuracy exceeding 95%, offering a reliable tool for intelligent pork quality assessment and precision pig breeding. The system has been adopted by breeding enterprises in Central China—including Tangrenshen Group, Hunan Agricultural Development & Investment Group, and Jiangxi Jiada Group—and has been applied to evaluate IMF traits in over 3,000 breeding pigs. This adoption has substantially improved the efficiency of germplasm selection and enhanced the economic benefits of farms.

ROBOT PATROLS AUTOMATE WEIGHT MONITORING

Complementing AI-driven meat quality evaluation is the AI-powered, non-contact Automatic Intelligent Weighing System (AIWS), which integrates orbital patrol robots to overcome a persistent bottleneck in pig weight monitoring. Traditional manual weighing methods are not only labor-intensive and stressful for animals—often leading to reduced feed intake or injury—but also pose biosecurity risks due to frequent human-animal contact. Although numerous non-contact weighing technologies have been reported in academic studies, most remain at the laboratory stage and lack practical applicability for real-world farming environments.

To bridge this gap, Yin's team developed an AIWS that integrates 3D depth cameras, orbital patrol robots, and BotNet regression networks. Mounted on overhead I-beams, the 3D depth cameras capture top-view images of freely moving pigs, with patrol robots operating at two-hour intervals to collect image data. Field validation in large-scale commercial farms demonstrated high precision for pigs weighing 50–120 kg, achieving a mean absolute error (MAE) of 3.48 kg, a mean absolute percentage error (MAPE) of 3.71%, and a coefficient of determination (R^2) of 0.8854, indicating an extremely significant correlation with manual weighing ($p < 0.001$). Daily weight data acquired by the AIWS enables superior growth curve fitting, with the Logistic model (inflection point: 164.46 days of age, 93.45 kg body weight; maximum growth rate: 831.66 g/d) outperforming manual weighing methods. This provides critical data support for precision feeding and optimal marketing decisions.[4]

DEEP LEARNING SHARPENS GENOMIC PREDICTIONS

In the field of genomic selection, Yin's team has developed and applied the CNN-ResNet deep learning model, which significantly improves the prediction accuracy for reproductive and economic traits compared to conventional methods such as GBLUP. By integrating multi-dimensional genomic data with high-quality phenotypic features extracted by AI imaging systems, CNN-ResNet effectively identifies favorable genetic variations and enhances the reliability of genomic estimated breeding values (GEBVs).

Building on these advances, integration with other AI frameworks—such as the NTLS machine learning system developed by the Chinese Academy of Agricultural Sciences—has further enhanced prediction performance for key traits including growth rate and backfat thickness. These technologies also contribute to the genetic improvement of indigenous pig breeds, which are highly regarded for their desirable meat quality and strong environmental adaptability. A notable example cited by the research team is the Chuweixiang Black Pig, developed through AI-assisted breeding strategies. This breed is reported to achieve higher lean meat percentage and improved feed efficiency while preserving the desirable meat quality traits characteristic of local varieties.

GROWING PAINS: CHALLENGES TO SCALING UP

Despite the promising performance of YIP, AIWS, and CNN-ResNet in intelligent pig breeding, critics argue that the current technological framework still faces significant barriers to large-scale industrial application. They note that the 3D-vision-based AIWS depends on fixed orbital patrol hardware and stable environmental conditions, which increases infrastructure costs and restricts its feasibility in small-scale or retrofitted barns. Furthermore, they argue that key factors such as long-term operational stability, sensor durability, and comprehensive cost–benefit analyses have yet to be systematically evaluated, limiting the potential for widespread adoption in commercial production.

THE FUTURE OF FARMING: SMARTER PIG BREEDING, SUSTAINABLE SYSTEMS

Looking ahead, deeper integration of artificial intelligence, genomic selection, and gene-editing technologies will further accelerate innovation in pig breeding, according to Yin. Emerging tools—such as real-time AI health monitoring and automated phenotyping platforms—will enable continuous tracking of animal behavior, growth, and physiological status, supporting more scientific and precise breeding and management decisions.[5] Researchers are also exploring multi-gene editing strategies targeting immune-related genes to develop highly disease-resistant pig lines, thereby enhancing the sustainability and resilience of the swine industry. As the world's largest pork producer and consumer—with an annual hog slaughter exceeding 720 million head in 2025—China is leading the global transition toward data-driven, intelligent, and green pig farming.

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DECLARATION OF INTERESTS

The author declares no competing interests.