1 團隊與成員介紹

本團隊由國立中山大學資訊工程學系黃英哲教授成立的「數位內容及多媒體技術研究中心」組成的團隊，本團隊致力於開發應用於蝦隻養殖之人工智慧水下影像辨識及智慧投餌技術，希望以 AI 智慧科技幫助養殖漁業節省人力、降低風險、提升產值與效益，將臺灣養殖漁業帶入智慧化的新世代。

團隊曾獲得 2021 年未來科技獎及 2022 第 19 屆國家創新獎。願景是藉由提供獨特的軟硬體及雲端技術技術方案而成為水產養殖界的 Google，提供最優質的水產養殖數據服務，以及漁業養殖產銷系統數據庫。

1.1 團隊獲獎經歷與專利成果

1.1.1 獲獎經歷

年份	獎項
111	【第十九屆國家新創獎-學研新創獎】 得獎作品：眼見為憑-應用於蝦隻養殖之 人工智慧水下影像辨識及智慧投餌技術 計畫主持人：黃英哲 共同主持人：鄭獻榮、張雲南、劉莉蓮 
110	科技部「2021 未來科技獎」 參展技術名稱：眼見為憑-應用於蝦子養殖之人工智慧水下監控養殖系統  (註：全國報名參展技術總計 495 件，100 件技術獲獎並線上展出，154 件技術入圍並線上展出)
107	科技部「2018 未來科技突破獎」 參展技術名稱：人體生理訊號感測裝置與智慧衣 資工系黃英哲、郭可驥；電機系 Robert Reiger

	 (註：本獎項為科技部 2018 未來科技展(2018/12/13-15) 在全國各科技領域總計 400 多件技術報名參展，81 件技術獲獎並展出)

1.1.2 相關專利成果

類別	專利名稱	國別	專利號碼	發明人	專利權人	專利核准日　期
發明專利	智慧養殖系統與方法	中華民國	I736950	黃英哲 洪慶章 張雲南	國立 中山大學	2021/08/21
發明專利	智慧養殖系統與方法	美國	US 11,399,520 B2	黃英哲 洪慶章 張雲南	國立 中山大學	2022/06/14
發明專利	水產生物的計數系統與方法	中華民國	I757025	黃英哲	國立 中山大學	2022/03/01
新型專利	智能養殖系統	中國大陸	CN211048177U	黃英哲 洪慶章 張雲南	國立 中山大學	2020/07/21
新型專利	水下觀察裝置	中華民國	M627450	黃英哲	國立 中山大學	2022/05/21
新型專利	水下觀察裝置	中國大陸	CN218594539U	黃英哲	國立 中山大學	2023/3/10
新型專利	水下觀察裝置	中華民國	M637748	黃英哲	國立 中山大學	2023/2/11

1.2　團隊組成

團隊由多領域的人才組隊，包含物聯網行銷、資訊工程、水產養殖等跨領域人才。相關人員如下：

姓名/職稱	專業項目

	莊大謙 研究生 國立中山大學資訊工程學系
	Alexander Munyaev 博士生 國立中山大學資訊工程學系
	林大為 專案經理 / 商業佈局、運作規劃、國際市場開發 經歷： 1.擔任新創團隊行銷經理 獲選進駐台北 FinTechSpace 基地 2.擔任新創團隊行銷經理 主導參展 COMPUTEX 國際資訊大展 3.曾任 厦门声连网信息科技股份有限公司 測試部主任
	蔡昌儒 硬體開發工程師 / 負責系統硬體開發 經歷： 1.國立中山大學資訊工程碩士 2.智慧養殖系統開發(6 年) 3.2018 魚客松競賽高雄組第二名 2022 中華電信 5G 創新應用大賽決賽入圍

	繆愼紘 軟體開發工程師 / 負責系統軟體開發 經歷： 1.參與 3 項國內人工智慧、智慧農業與養殖相關大型專案研究計畫開發經驗(機器閱讀系統、智慧監控農業物聯網、智慧養殖管理系統) 2.參與 6 篇國際人工智慧與智慧農業研究論文之發表經驗 3.參與 1 篇國內文字探勘相關研究論文之發表經驗

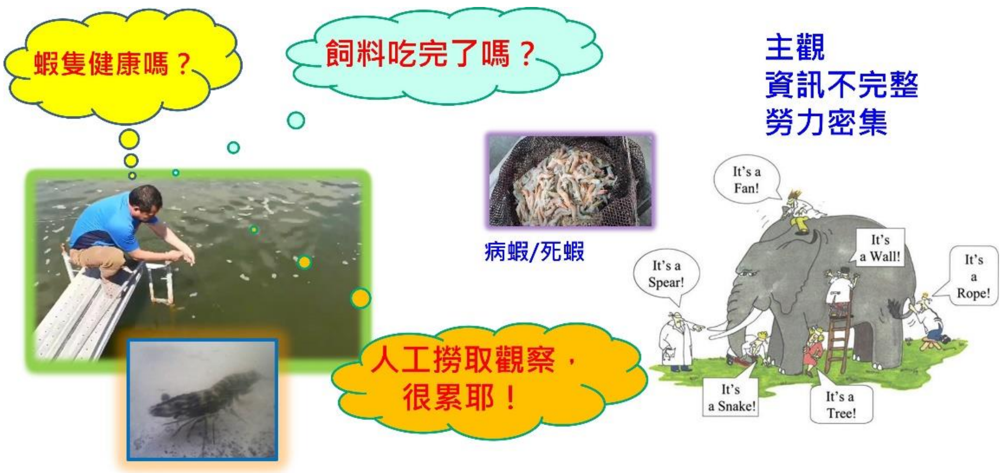
2 構想動機及創意說明

2.1 構想動機

臺灣為全球電機及資訊科技領先全球的國家，論半導體研發製造、人工智慧產業發展均為全世界極富影響力的科技大國，同時，臺灣產業鏈的另一端「傳統產業」，亦是首屈一指，以傳統產業養殖業為例，臺灣部分物種產值、技術在全世界居於領導地位。例如臺灣過去即因草蝦產量與技術居冠於全世界，因而有草蝦王國之稱。然而，在臺灣電機與資訊科技領域隨全球脈動推進之時，臺灣傳統產業卻面臨科技化轉型困難、轉為夕陽產業，生產量降低轉而採進口替代。本團隊欲以臺灣卓越的電機資訊技術，深入臺灣傳統產業「白蝦養殖業」一隅，探究其面臨的產業困境，以電資技術創造蝦養殖方案，期能為臺灣打造下一個養殖王國、再創造臺灣傳統產業體質。

2.2 創意說明

傳統白蝦養殖，因蝦子生活在池底，水質混濁，無法掌握池中狀況，蝦農都是靠肉眼觀察蝦隻成長狀況，並據此進行養殖決策及擬定投餌策略。由於肉眼觀察方式的限制，存在缺點包括觀察量少、目測準確度低、個人經驗主觀判斷無固定標準、資訊不完整，無法建立系統性數據供比對。



綜合上述目前白蝦養殖在管理技術上的困難點，黃英哲教授找出養殖技術的關鍵拼圖，就是即時觀察水下蝦隻狀況。即使現行已有許多幫助改善養殖的

方式，例如無特定病源之蝦苗育種、飼料配方、益生菌、自動控制設備(水車、自動投餌機、自動進排水)、水質感測設備等，但只有看到蝦隻吃餌的狀況如何，才能真正確認上述所有改善辦法是否奏效。如下圖所示，本創新成果為智慧養殖最後一塊拼圖。

本團隊開發的【人工智慧水下影像辨識及智慧投餌技術】已能夠有效地解決上述缺失，可 24 小時即時觀察水下生物狀況，並以 AI 大數據分析為蝦農補上完整的生物資訊。

我團隊運用影像辨識及 AI 技術開發的智慧養殖系統水下生物監控產品，具有【AI 智慧投餌】、【AI 量測蝦隻大小】、【腸線觀察】、【活動力觀察】等功能，能夠準確且全面地掌握白蝦養殖最關鍵的餌料消耗過程、蝦隻腸線健康狀況、蝦隻成長趨勢及蝦隻活動力狀況。

其中【智慧投餌專利技術】及【蝦隻腸線健康狀況】是本計畫在市場上獨有的功能與技術，在市場上具有極高的競爭力。

值得一提的是智慧投餌專利技術是我團隊經過訪問十多位資深白蝦養殖業者並參考「農委會水產試驗所特刊第 30 號--白蝦繁殖及生物安全防疫管理」所開發出來的專利技術，顯示出我團隊掌握市場需求、開發新功能的能力。

3 設計特色及功能介紹

本團隊創新解決方案，即提供養殖者「水下智慧眼與智慧腦」。

A. 水下攝影機 / 水下觀察裝置：防水防鏽抗水壓之特殊水下攝影機。提供清晰24小時即時水下影像。

B. 雲端運算 / 邊緣運算：即時且多項 AI 水下影像辨識，資料收集與分析，提供蝦農即時養殖策略。

C. 雲端伺服器 / 養殖管理中控台：將資料以圖表展示，提供蝦農最即時的蝦池資訊。可以電腦或手機操作，撥放即時影像或回放歷史影像。

3.1 關鍵特色與創新性

我團隊的技術核心能力，是以 AI 技術應用於白蝦水下影像監控，技術項目包含以下五項：

A. AI 深度學習

B. 智慧養殖系統與方法

C. 單鏡頭估算蝦隻長度系統

D. 水質濾清機構

E. 智慧投餌

我團隊的核心技術【人工智慧水下影像辨識及智慧投餌技術】，為水下攝影機、雲端中空平台、雲端 AI 分析服務，用以補足目前市面上智慧養殖系統缺少的水下影像生物觀察監控部分，例如吃餌、活動力等。

而完整的智慧養殖系統，包含生物資訊(AI 水下影像監測—中山領先技術)、水質環境資訊，以及設備控制等各環節，達到 AI 觀察、分析/決策、控制/採取行動的智慧科技養殖模式(圖 B)。

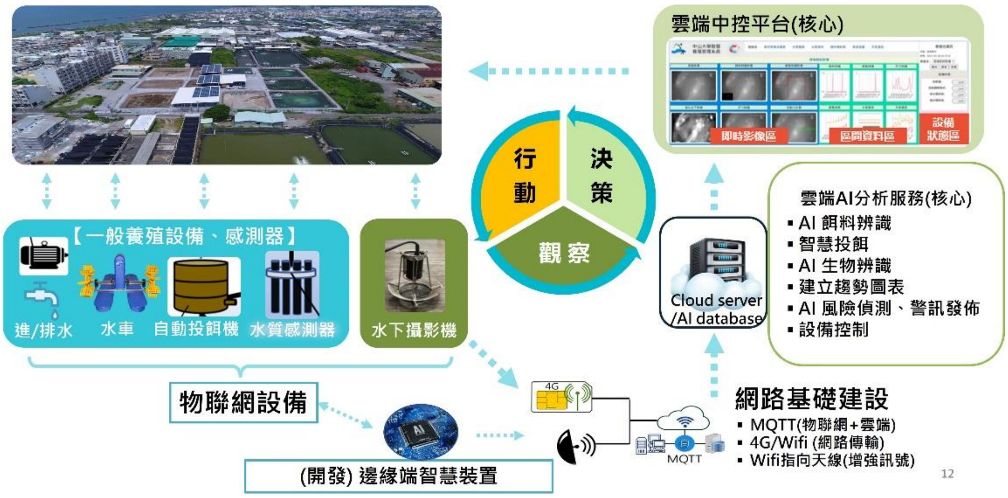


圖 A.養殖場物聯網智慧養殖系統架構圖

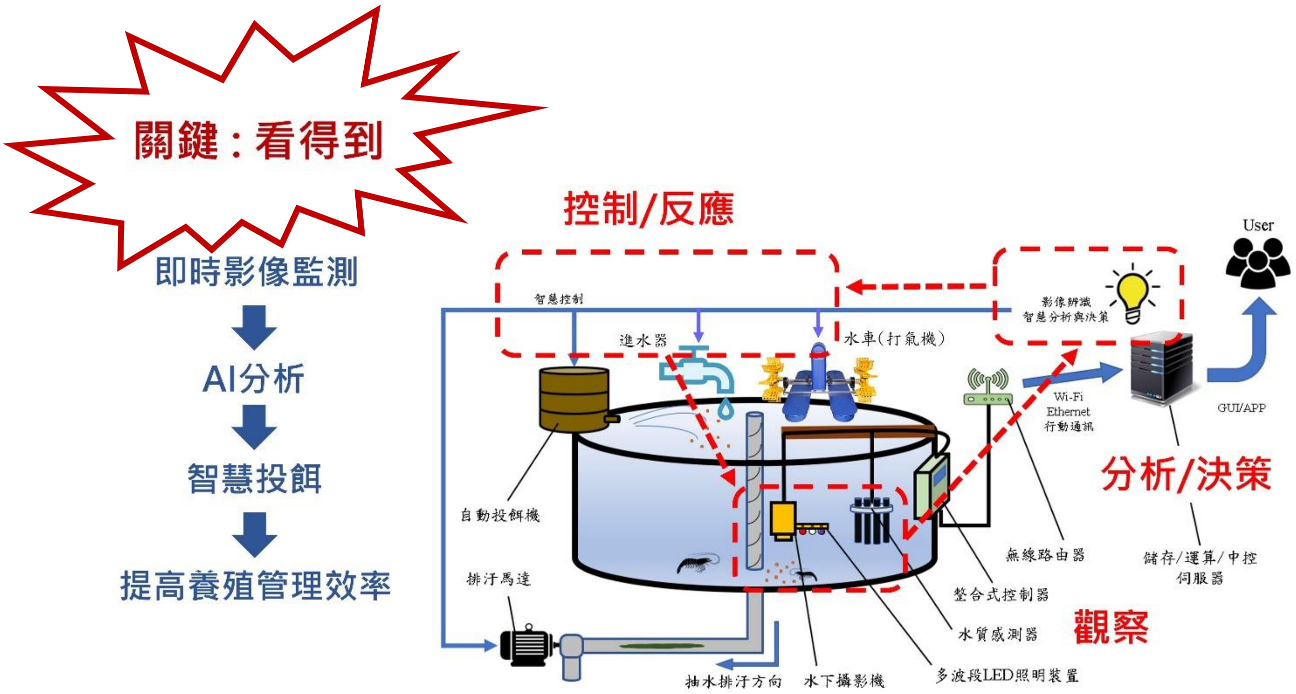


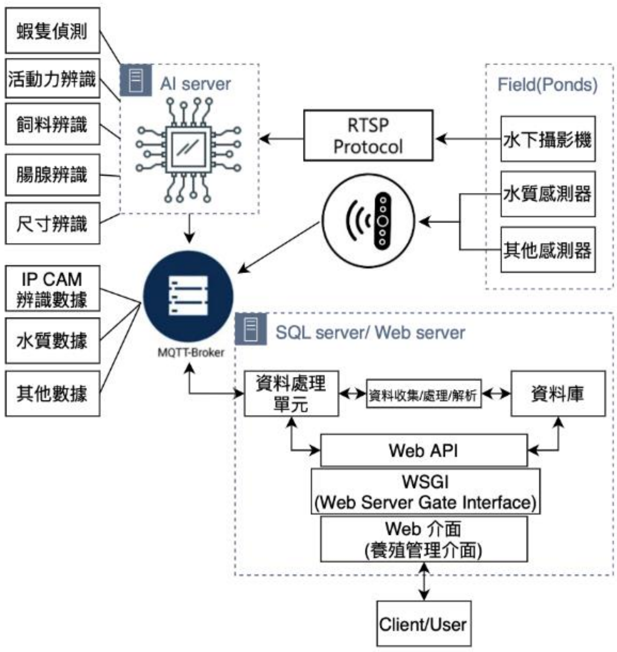
圖 B.中山大學人工智慧水下監控系統技術架構圖

我團隊 AI 影像辨識核心技術，已經克服養殖池各種不同的水色、混濁度等影響，可 24 小時全天候即時觀看蝦隻在池底的吃餌及活動狀態，AI 影像辨識技術已領先業界可即時估算餌料殘量，AI 影像辨識準確度達 90%，同時可 AI 量測蝦隻大小，建立蝦隻成長趨勢。

以下內容將說明我團隊 AI 影像辨識技術應用在產業之獨特性、創新關鍵優勢利基。

3.2 軟體技術關鍵特色與創新性

本系統的軟體架構流程圖，如右圖所示。場域裝置的感測數據與訊號分別藉由 RTSP 協定與路由器傳輸至 AI 伺服器和 MQTT-Broker，而 AI 伺服器辨識運算後也將數據傳送至 MQTT-Broker，再分別訂閱（Subscribe）對應的來源硬體識別 ID 來接收數據封包，最後才將各式數據彙集、解析，儲存於資料庫中，並在數據分析後，於養殖管理系統網站介面中顯示。



第一部分是場域裝置，包含安裝在養殖池中的多個水下攝影機、水質感測器與其他感測器(餵食器)。

第二部分是 AI 運算伺服器，我們將所接收到的影像資料進行 AI 辨識，藉由本團隊開發的數支運算程式（蝦隻偵測程式、活動力辨識程式、飼料

辨識程式、腸腺辨識程式、尺寸辨識程式）進行運算，以「尺寸辨識」、「飼料辨識」為養殖關鍵決策。

此技術仍必須藉由數據統合與分析才能掌握蝦隻成長狀況和預期趨勢。因此，第三部分是資料庫伺服器與養殖管理網站伺服器，其中包含資料處理單元串接資料庫與串接網站 API，提供了前端網頁擷取的必要資訊並其他程式組態資訊的擷取介面，使用者將可以在養殖管理介面檢視即時資訊。

3.2.1 AI 技術：蝦隻偵測

蝦隻偵測功能可即時在攝影機畫面中偵測並框出蝦子的位置及數量。如右圖所示。

本功能採用單個卷積神經網絡來預測多個 bounding boxes 和類別，不但提高辨識準確率，更大幅改善了辨識速度，實現端到端的物品檢測。該方法檢測速非常快，在 GeForce GTX TITAN X 顯示卡上實作，基礎版可以達到 45 幀/s 的實時偵測，快速版可以達到 155 幀/s。

其網路架構分為三部分，分別是 Backbone、FPN、Prediction Net， Backbone 提取影像特徵後，FPN 將不同尺寸下的影像特徵結合 3 個影像特徵並輸入至 Prediction Net，Prediction Net 會利用這三個影像特徵分別辨識出不同的 bounding box，此網路架構加入了 FPN 提取不同尺寸下的影像特徵，幫助網絡學習較細微的特徵，而這些特徵有助於辨識小物體，提升其在不同大小的物體下的辨識準確度。

本系統已於高雄、花蓮及屏東等場域收集養殖池水下影像進行蝦隻偵測功能之訓練及驗證，每次投入訓練驗證之影像數量至少為 500 張圖片以上，其中三分之一將作為驗證之用，mAP 可達 90%以上。

3.2.2 AI 技術：飼料辨識

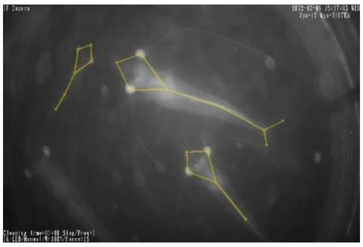
飼料辨識功能可標示出目前畫面中的飼料，並於畫面左上角顯示即時及最近平均飼料量，使用者可藉此了解目前養殖池的殘料量。如下圖所示。

本功能所使用的神經網路，整體網路的訓練方式及架構參考 FCNs，由生成器及辨別器組成，其中生成器又由編碼器及解碼器構成。

生成器的模型架構參考了 HED 及 VGG16 並根據 Auto Encoder 的架構將模型設計為編碼器與解碼器。每一層向下取樣輸出的特徵圖都會經過一次向上取樣還原成原始圖片大小以保留不同感受野(receptive field)抓取的特徵，然後將所有還原大小的特徵圖拼接成原始尺寸多通道的特徵圖後再透過卷積取樣整合所有特徵圖的內容便可得到最終輸出的結果圖。

由於我們使用的資料集不只兩類場域，所以一般只分兩類的 GAN 架構辨別器無法使用，所以辨別器部分參考 DrLIM，將降維模型取代 GAN 辨別器的分類用途，不論輸入的資料有幾類都可以適應。在使用養殖池的水下影像進行測試的情況下，IOU 可達 58.54%(紅外線)、57.91%(可見光)，MAE 為 0.108(紅外線)、0.095(可見光)。

3.2.3 AI 技術：尺寸辨識



尺寸辨識功能所採用之網路架構參考自輕量化的關鍵點辨識網路結構，同時為了避免 mobilenet 過濾掉大部分的影像特徵，加入 FPN 分別將不同尺寸的影像特徵接入個別的 initial stage，兩個 initial stage 分別利用不同尺寸的影像特徵初步的找尋 PCM 與 PAF，此時所產生的 PCM、PAF 分別代表了不同解析度下的關鍵點資訊，但仍有許多誤判，而輸出結果經過數層 refinement stage 可以有效的減少誤判，因此再將兩種尺寸的輸出結果合併，並輸入至兩層的 refinement stage，將兩個不同解析度所得到的結果進一步的 refinement，提昇 PCM、PAF 的精準度。而各 stage 的架構採用輕量化關鍵點辨識網路的設計，讓我們的網路架構提升精準度的同時依然保留良好的運算速度。在使用實際養殖場域的水下影像進行訓練測試後，我們的網路架構相較其他常見的網路架構在準確率及 FPS 的綜合評估上有更好的表現(AP=60.3%(T=0.6), FPS=18)，更可適用於養殖池的即時串流水下影像辨識。

本功能可辨識出畫面中蝦子身上的關鍵點（眼睛、額角、內臟、身體及尾扇等），透過這些關鍵點資訊，可計算出蝦子身體部位的長度，再依據蝦子身體各部位與全身長度的比例推算出該蝦子身體全長，如 1-3 尺寸便是附圖所示。不同於一般的物件辨識，本團隊所開發的尺寸辨識功能不需要看到整隻蝦子，只要蝦子有一部份的身體出現在畫面中即可推算其體長。另外我們也加入了物件深度校正，透過蝦子身體反射攝影機紅外光的強度來對其與攝影機之距離進行校正，可更進一步減少推算出的長度誤差。

3.2.4 AI 技術：活動力辨識

活動力辨識功能為蝦隻偵測功能的延伸，可追蹤畫面中出現的蝦子，並計算其移動速度，最終於畫面左上角顯示一段時間內全部蝦子的平均移動速度以及辨識到的蝦隻累積總數，如圖所示。

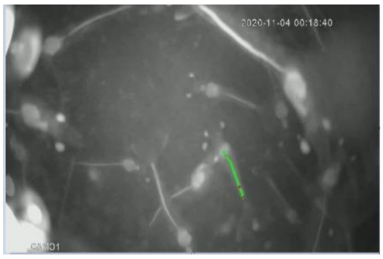
活動力辨識中包含了三大部分，分別為蝦隻追蹤、蝦隻離場計算以及活動力計算，分別敘述如下：

A. **蝦隻追蹤**：蝦隻追蹤是以物件檢測器回傳的 bounding box 做分析來實現追蹤的效果，分析方式為計算蝦隻的移動方向、bounding box 形狀及蝦隻在 frame 之間的距離，並依據條件給予其分數，加總後根據分數更新該蝦子的位置及方向。

B. **蝦隻離場計算：**根據蝦子目前的行徑方向計算對應邊及頂點的距離並除以蝦子速度，對照該蝦子最後一次的 frame 與當前 frame 的相差 frame 數，若前者小於後者，則判斷此蝦子已離開視野範圍。

C. **活動力計算：**在追蹤到蝦子後，計算其在兩個 frame 之間移動的 pixels 數，即可得到蝦隻的移動速度，並視其為活動力。

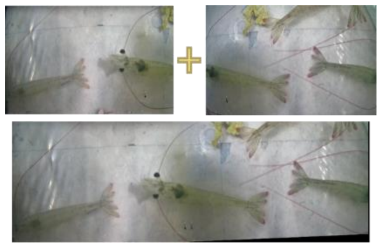
3.2.5 AI 技術 : 腸線辨識



腸線功能為延續尺寸辨識結果的延伸應用，由預測的關鍵點中提取出內臟以及尾巴兩個點，並辨識出蝦子的腸線以及是否有空腸的情，可進一步計算出空腸的比例。

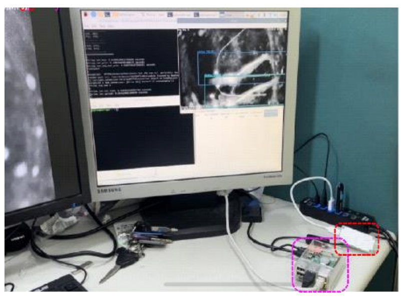
白蝦的腸線在紅外線影像中為白色，將紅外線水下影像轉為黑白後，從尾巴的座標朝著內臟座標向量的區塊，找出鄰近像素局部最大值（local maximum），找到座標後再重複朝著內臟座標方向找局部最大值，最後所有找到的座標依序相連後將成為腸線，如圖。並可再**AI 技術 :**依據 pixel 的亮度條件找出腸線上空缺的部分。

3.2.6 AI 技術 : 水下影像拼接



水產養殖場域池水經常處於混濁狀態，低能見度使得水下攝影機的可視距離與範圍受限，因此需要借助影像拼接產生更寬廣的水下視野。然而傳統影像拼接技術運算複雜度相當高，難以在邊緣裝置完成影像拼接的任務，因此我們在攝影機端使用邊緣裝置進行影像同步的前置處理，並且判斷影像是否適合拼接，再將影像傳送至雲端伺服器進行拼接處理。此外，我們也針對養殖池影像能見度低以及背景單調的特性，調整並簡化影像拼接的方法與流程，在可接受的品質下達到較為快速的水下影像拼接，以有效擴大水下攝影機的可視範圍，同時取得更多的水下影像資訊。

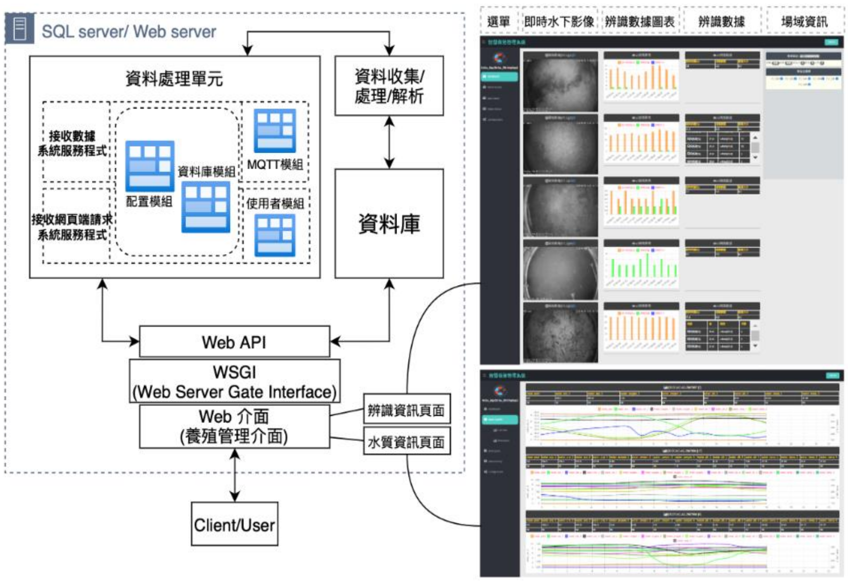
3.2.7 深度卷積神經網路邊緣運算技術



水下攝影機擷取的影像資料數量龐大，如果直接將所有影像上傳雲端進行處理與分析，將會佔用大量網路頻寬，因此我們採用邊緣運算(Edge Computing)的概念，並且引入低成本邊緣運算裝置，例如

Raspberry Pi 加上 Google Coral Edge TPU，將取得的影像資料透過攝影機端的深度卷積神經網路進行處理與分析，再將處理結果或是必要的資料上傳雲端進行後續的分析、判斷及決策，大幅降低需要的網路頻寬以及雲端處理成本。此外，我們採用模型量化技術，將 32 位元的浮點數量化成 8 位元的整數，以減少邊緣運算裝置需要的運算成本、儲存空間與功率消耗。另一方面，我們也採用量化感知訓練(Quantization Aware Training)，使得神經網路模型在進行推論時仍然能夠維持足夠的準確性。

3.2.8 智慧養殖系統之雲端中控台



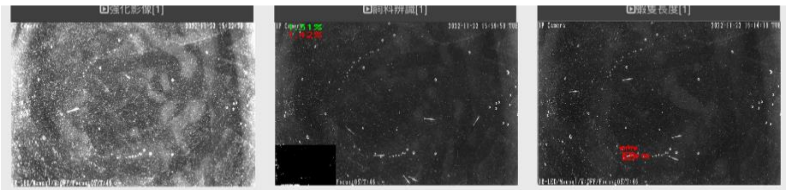
我團隊設計養殖系統中控台，用以串接資料庫並顯示數據。由圖所示，在資料庫伺服器與養殖管理網站伺服器中，以兩種系統服務程式為優先。第一種是以「接收數據」，第二種是以「接收網頁端請求」，作為串接資料、解析資料、儲存資料與顯示資料的整合功能。此兩種系統服務程式區分且涵蓋了數據接收程式（MQTT 模組）、數據解析與資料庫程式（資料庫模組）、網站運作程式（基本配置模組與使用者需求模組）等多個程式單元。運作這些單元可以進行接收數據的解析、運算、統計與數據檢查，然後將各類數據儲存於資料庫中，

尤其，後台程式會定時自動計算、統計所接收到的影像辨識數據與水質數據存放於資料庫中，有助於建立數據查詢功能的基礎元素。所開發的養殖管理網站中，主要包含影像資訊、水質資訊與統計資訊，也可以提供使用者查詢。管理介面（中控台）提供了選單、即時水下影像、辨識數據圖表、辨識數據與場域資訊等功能，使得養殖資訊一目瞭然，提供使用者檢視，具體功能羅列並說明如下：

A. 即時影像：水下攝影機取得之水下影像經由影像伺服器，依照使用者所擁有之場域分類，並將其場域對應之水下即時影像顯示於

系統儀表板中(如圖紅框處)，使用者可以最快的速度瀏覽並掌握池中影像資訊。

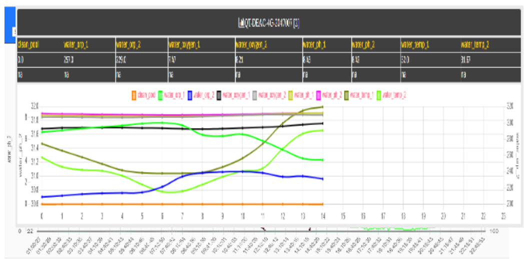
B. 辨識影像：伺服器所處理之各種辨識影像，即時顯示於介面中，使用者僅須點擊攝影機即時影像旁之 Icon(紅框中箭頭處)便可觀看不同項目之辨識影像，可掌握目前辨識功能之大概準確度。



C. AI 辨識圖表：各項辨識功能所產生之數據以長條圖及折線圖的方式顯示於介面中，以即時影像附圖藍框處為例，近期所取得之辨識數據將顯示於對應攝影機之即時影像旁，使用者可依此掌握最近之飼料殘餘量及蝦子長度等。此外，本系統介面也提供使用者查詢過往辨識數據紀錄，透過選擇對應攝影機及日期，使用者可追溯該攝影機過去取得之歷史資訊，並可追蹤以往之飼料消耗量及蝦隻尺寸成長紀錄。

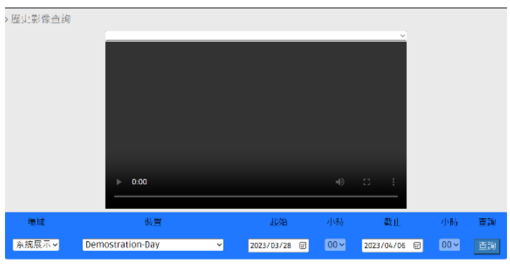
D. AI 辨識數據：除圖表外，使用者可另外於儀表板中觀看最新的辨識數據，並可設置飼料警戒值，當飼料量辨識結果超過此數值時便會於儀表板中顯示其數據(如即時影像附圖綠框處)，提醒使用者注意目前飼料量已超標，須注意管理殘料量及水質。

E. 水質數據圖表：本系統可整合不同廠牌之水質感測器數據，即使養殖戶使用不同廠商之感測器，也可與水下影像同時呈現於介面中，養殖戶無須另外開啟感測器之其他軟體頁面，有利於其統一管理水下影像及水質數據。右上圖為當日之水質數據圖，養殖戶可藉此觀察當天的水質變化。



而右下圖為水質歷史資料查詢頁面，使用者除可選擇日期來顯示該時間段的水質趨勢圖外，還可下載該區段之水質數據報表，對照相應時段之天氣及養殖操作後可了解其對水質之影響。

F. 歷史影像查詢：除即時影像資訊外，本系統介面可查詢並下載過往歷史影像(每 15 分鐘為一單位)，養殖戶可分析以往之影像及其對應水質及辨識數據，了解該期養殖過程中是否有異常狀況產生(例如透過影像清晰度變化可知池水之濁度變化，並



可推測是否有倒藻之現象發生)，並可於下期養殖時依此為參考依據制定養殖策略，以達鑑往知來之效。

3.3 硬體技術關鍵特色與創新

3.3.1 水下攝影機

種類	IP camera
防水等級	IP68，可在海水環境持續正常運作三個月以上
解析度	主碼流：1080P、720P 子碼流：704*576、640*480、320*240 1/2.8" SONY CMOS sensor Color 0.001Lux F1.2 black/white 0.0001Lux F1.2
照明	紅外線、白光
對焦方式	電動變焦(0.05~4 米)
拍攝模式	一般模式、夜間模式(紅外光或白光)；感光切換、定時切換、手動切換
圖像顏色	白光：全彩；紅外光：自動切換為黑白
通訊協定	使用 RTSP、RTMP、HTTP
影像編碼	H.264、MJPEG
耐壓深度	50 米
FPS	1~30(可調)
FOV	橫向約 105°

本系統所配合之水下攝影機須具備高強度且持久之防水能力，其防水防塵規格將高於一般市售之水下攝影機，具體規格如下：

3.3.2 多鏡頭水下攝影機

為提升水下攝影機於濁水中的視野， 以及提供觀測目標之距離資訊，我們預計將開發多鏡頭水下攝影機，其結構為多個水下鏡頭模組連接一控制運算模組，並將鏡頭模組並排或組成陣列，透過此陣列將可取得同一時間點內之多個水下影像，再經由控制模組建立拼接影像或立體視覺，可提供更大範圍的水下影像及觀測物件距離資訊。

3.4 商品價值與市場性

3.4.1 生產效益：有效提升 26%之產量

室內循環池	對照池(B1)	AI 試驗池(B2)
密度(隻/㎡)	300	300
初重(g)	0.06	0.06
末重(g)	22.3	20.6

經水產試驗所東港生技研究中心於

存活率(%)	62.6	84.7(+22.1%)
產量(kg/㎡)	4.2	5.3(+26%)

2021 年至 2022 年期間，裝設本團隊智慧養殖管理系統後，證實引入循環設備系統能實際改善環境生態與養殖品質，並驗證系統導入可有效提升養殖產量達 26%之效益。(見右表)

3.4.2 養殖收入：增加 15%之收入

本創新成果 2022 年在水試所東港生技研究中心進行場域實證，獲得育成率提升 20%，換肉率改善 6%，產量提升 26%之成果。

以建置規模 12 池(每池約 0.8 分地) 為估算模型進行養殖效益分析，一年新增收益以至少 15%計算。

3.4.3 養殖成本：增加 3%之成本

在成本方面，一分地放養一次的成本以每台斤 80 元計算，成本約為 24 萬元新台幣。如下表所示，由於智慧化投餌與管理，可避免過度投餌與節省用電，因此能降低飼料與電費的支出，雖因設備增加使成本微幅增加 3%。

養殖成本項目	傳統養殖		智慧養殖		差額
	金額	比例	金額	比例	
飼料(1 公斤飼料約 55 元)	148,500 (FCR 1.5)	62%	118,800 (FCR 1.2)	50%	29,700
電費	56,000	23%	43,200	18%	12,800
工資	19,000	8%	19,000	8%	0
蝦苗	9,500	4%	9,500	4%	0
其他	7,000	3%	7,000	3%	0
智慧養殖設備折舊(20 萬元分 2 年 4 次攤提)	--	--	50,000	21%	+50,000
合計	240,000	100%	247,500	103%	+7,500

3.4.4 智慧養殖可為全台灣創造的價值

根據上述，可有效提升 26%之產量，進而增加 15%之收入、3%之成本。

飼養白蝦 1 年 1 分地池子養 2 次之實賺分析，利潤增加 40%。依據上述白蝦養殖的收入及成本，試算如下表：

	一般養殖	智慧養殖
收入	36 萬元*2 次=72 萬元	41.7 萬元*2 次=83.4 萬元
成本	24 萬元*2 次=48 萬元	24.8 萬元*2 次=49.6 萬元

實賺	72 萬元-48 萬元=24 萬元	83.4 萬元-49.6 萬元=33.8 萬元 (33.8 萬元-24 萬元=9.8 萬元) 利潤增加 40% (9.8 萬/24 萬)

以全台白蝦放養面積 725 公頃(約 7,479 分地)來計算，一般養殖一年實賺 17.9 億元新台幣(1 分地 1 年實賺 24 萬元*全台放養面積 7,479 分地)，則智慧養殖實賺為 25.3 億元新台幣(1 分地 1 年實賺 33.8 萬元*全台放養面積 7,479 分地)，預估增加產值 7.4 億元新台幣。

3.5 市場性

SOFIA（The State of World Fisheries and Aquaculture, SOFIA）報告提供全球魚類產品供應趨勢，並依據物種、區域及野生捕獲或養殖等分類方式來統計。2018 年全球魚類產品產量達到 1.79 億公噸，銷售值約 4,010 億美元，其中水產養殖產品佔總產量 46％。中國大陸為全球第 1 大魚類產品生產國，自 1991 年起其水產養殖產量較其他國家總和還高。

全球水產養殖將持續擴大，預估未來 10 年在全球消費及貿易的比例將持續成長，其中非洲水產養殖產量估計約成長 48％。魚類產品消費佔全球蛋白質攝取量的 1／6，在部分國家甚至佔比超過 1／2 以上，例如孟加拉、柬埔寨、甘比亞、迦納、印尼、獅子山、斯里蘭卡及若干開發中島嶼國家。

另外，根據 SOFIA 對全球的統計議題及以下數據：漁產品銷售值達 4,010 億美元，其中水產養殖漁產品為 2,500 億美元。全球漁產品產量進入國際貿易者佔 38％，漁產品總出口值為 1,640 億美元。放眼全球市場，作為水產養殖之智慧解決方案，發展空間仍是一片充滿機會的藍海。

4 綠色設計理念及訴求

4.1 綠色理念緣起：國際與臺灣碳交易市場崛起，我國致力養殖碳足跡追蹤

全球溫室效應，已造成高緯度冰川消融、低緯度土地遭淹沒，也產生劇烈的氣候變遷，造成全球經濟、生命受到損失。身處地球村的每一個人無法置身事外、責無旁貸。本團隊欲響應全球潮流及響應政府碳排政策，期通過將蝦養殖碳足跡標示，使消費者有意識地進行食物綠色消費、也作為碳排放養殖產業教育場域。希望通過綠色設計實踐，能為 2050 淨零排放共盡心力、為臺灣打造低碳排的綠色生產與消費生態。

低碳經濟已成為全球潮流，碳權交易在國際市場蓬勃發展。本國也在 2023 年 4 月由總統正式宣告，台灣將成立自主碳交易平台進行國內碳權買賣，以實現 2050 年淨零碳排目標。根據媒體報導，我國將由證交所與國發基金共同出資成立「臺灣碳權交易所」，並於今年(2023)完成設立登記。其中服務內容包含「國內碳權交易」、「國外碳權服務」、「碳諮詢服務」三大面向。

且於近十年，根據行政院農業委員會漁業署研究報告指出，本國農漁業亦逐漸重視對於產品的碳足跡標示，並已針對養殖蝦類、貝類碳排放盤查相關資訊。根據111年行政院農業委員會發行「農政予農情」中更進一步表示，我國漁政單位，欲建立「符合臺灣產業特性之海洋碳匯計算模式」，透過以上可得知我國欲於水產養殖及漁業，投入碳排、降低溫室氣體之決心。

為參與全球低碳排運動，團隊將以兩個面向實踐力行低碳排。首先，在生產技術方面，投入創新的水下智慧養殖設備，讓養殖者能透過水下攝影機掌握蝦隻健康與攝食情形，有效投料、避免蝦料浪費及汙染水源。再者，通過掌握碳排路徑，於場域、合作蝦農之產品包裝，標示養殖科技下的低碳排數據與碳排路徑，透過創意結合行銷的手法，成為「教育消費者」的銷售手段，傳播綠色水產的理念、創造消費者購買綠色水產的習慣，也進一步透過消費者，推進臺灣水產養殖產業，增進我國水產養殖業者升級科技化生產，進而提升我國水產養殖產業鏈。本綠色設計方案，將從技術升級、消費者購買習慣、上游產業鏈面相滲入，創造綠色水產消費與生產。進一步有關綠色理念如何實踐，將於下一個段落進行說明。

4.2 綠色設計理念

4.2.1 低碳排放生產：優化蝦隻養殖，降低養殖投料消耗

蝦隻養殖業者的養殖手法扮演碳排高或低的關鍵因素。隨著蝦養殖業者以何種手法養殖，將決定該養殖是否「有效降低」碳排，又或因非環保的養殖方式，造成更多的環境破壞。另，根據環境資訊中心刊登報導亦指出，水產養殖碳足跡的關鍵，在於業者經營方式，水產養殖業能省下漁船出海產生的大量碳排，相對而來的打氣裝置、溫控設備、飼料產生的碳排，則會依照養殖方式大相逕庭。

依據「國立海洋大學海洋環境與生態研究所」提出的一則研究數據顯示，以白蝦為例，其生產的碳排放量排名，由高而低排序，各別為電力、飼料、間接原料、廢棄物處理、運輸與製冷劑。本團隊致力以「水下智慧養殖技術」，透過科技化養殖，提高蝦養殖效率、減少飼料浪費，藉此降低碳排放足跡，創造環保蝦養殖產業鏈。本團隊透過水下養殖設備與技術，降低水產養殖碳排。

4.2.2 低碳水產養殖品牌認證：推廣低碳生產、綠色養殖

探究臺灣蝦養殖產業，目前臺灣養殖漁業正積極推廣養殖產業科技化及綠色養殖，然而卻較為缺乏養殖科技化、綠色養殖的系統化認證與市場標示。綜觀目前蝦養殖產業的養殖方案，包含: 無特定病源之蝦苗育種、飼料配方、益生菌、自動控制設備(水車、自動投餌機、自動進排水)、水質感測設備等。團隊欲以水下智慧養殖設備推廣，鼓勵合作蝦養殖業者將碳排放足跡展示於蝦養殖場、並於蝦隻包裝標示購買AI養殖蝦對於氣候的益處，將科技養殖水產、綠色養殖蝦隻對於環境的益處，通過商品行銷，使消費者選擇購買科技養

殖、綠色養殖蝦隻，影響消費者購買習慣，進而向上影響蝦供應源的養殖蝦農。

與本團隊合作之養殖業者，我們將由團隊水產養殖專家，提供水產養殖產業者產業輔導，針對蝦隻定期給予健檢與養殖建議。而欲進行合作之廠商，須同意以綠色養殖手法、提供蝦隻健康無毒的養殖環境，並於場域進行碳足跡展示。商品將允許提供健康無毒蝦認證標章，並具名該蝦隻養殖碳排放足跡，讓消費者了解購買綠色養殖水產，對於當今棘手的全球暖化問題將有所貢獻，亦即消費者日常購買選擇，舉手之勞，將對於全球性環境議題產生潛移默化的影響。進一步，影響消費者的購買習慣，也將刺激臺灣蝦養殖產業選擇改以「科技化」、綠色養殖模式。進而將臺灣早期產業鏈的蝦池汙染問題改善，創造臺灣的綠色養殖風氣。

深耕臺灣、佈局全球，本團隊期待將綠色生產技術與理念，以臺灣為起始點，跨足全球蝦養殖國家。將智慧養殖技術及綠色養殖認證理念，推展至全世界蝦養殖產業。目前全球養殖業者，已有越南、印度、印尼合作，欲了解綠色養殖智慧養殖方案，甚至有機會進一步洽談合作事宜。

1. Team and Members Introduction

The team is led by Prof. Ing-Jer Huang of the Department of Information Engineering at National Sun Yat-sen University. The team is dedicated to developing artificial intelligence underwater image recognition and intelligent baiting technology for shrimp farming, hoping to help the fishery industry save manpower, reduce risk, and increase production value and efficiency with AI intelligent technology, bringing Taiwan's fishery industry into a new generation of intelligence.

The team was awarded the Future Technology Award 2021 and the 19th National Innovation Award 2022. Our vision is to become the Google of aquaculture by providing unique hardware, software and cloud technology solutions to provide the best aquaculture data services and a database of fishery aquaculture production and marketing systems.

1.1 Award-winning Experience and Patent Achievements Of the Team

1.1.1 Award-winning Experience

Year	Awards
2022	19th We, Innovators - Innovation Award (第十九屆國家新創獎-學研新創獎) Title： Seeing is Believing: Artificial Intelligence Underwater Image Detection and Smart Feeding Technology for White Shrimp Farming (眼見為憑-應用於蝦隻養殖之 人工智慧水下影像辨識及智慧投餌技術) Project Director：Ing-Jer Huang Co-Director：Shiann-Rong Kuang.、 Yun-Nan Chang、Li-Lian Liu   
2021	Ministry of Science and Technology 2021 FutureTech Award (科技部「2021 未來科技獎」) Title：Artificial Intelligence Underwater Monitoring and Management System (眼見為憑-應用於蝦子養殖之人工智慧水下監控養殖系統)   

	(Note: The total number of technologies registered for the exhibition is 495, 100 technologies were awarded and exhibited online. 154 technologies were shortlisted and exhibited online)
2018	Ministry of Science and Technology 2018 Futuristic Breakthrough Technology Award (科技部「2018 未來科技突破獎」) Title：Integrated EMG/ECG Sensing and Smart Clothing (人體生理訊號感測裝置與智慧衣) Department of Computer Science and Engineering Ing-Jer Huang、Ko-Chi Kuo； Department of Electrical Engineering Robert Reiger
	 (Note: In total, more than 400 technologies in various fields of science and technology were registered for the exhibition, and 81 technologies were awarded and exhibited.)

1.1.2 Patent Achievements of the Team

Category	Title of Invention	Country	Patent Number	Investors	Assignee	Date of Patent
Invention Patent	SYSTEM AND METHOD FOR SMART AQUACULTUR 智慧養殖系統與方法	Republic of China	I736950	Ing-Jer Huang, Chin-Chang Hung, Yun-Nan Chang	National Sun Yat-sen University	2021/ 08/21
Invention Patent	SYSTEM AND METHOD FOR COUNTING AQUATIC CREATURE	the United States	US 11,399,520 B2	Ing-Jer Huang, Chin-Chang Hung, Yun-Nan Chang	National Sun Yat-sen University	2022/ 06/14
Invention Patent	SYSTEM AND METHOD FOR COUNTING AQUATIC CREATURE 水產生物的計數系統與方法	Republic of China	I757025	Ing-Jer Huang	National Sun Yat-sen University	2022/ 03/01

Category	Title of Invention	Country	Patent Number	Investors	Assignee	Date of Patent
Utility Model Patent	智能養殖系統(原:水產養殖系統/Aquaculture System)	the People's Republic of China	CN211048177U	Ing-Jer Huang, Chin-Chang Hung, Yun-Nan Chang	National Sun Yat-sen University	2020/07/21
Utility Model Patent	UNDERWATER OBSERVATION DEVICE 水下觀察裝置(原:具有過濾機構的水下觀察設備)	Republic of China	M627450	Ing-Jer Huang	National Sun Yat-sen University	2022/05/21
Utility Model Patent	水下觀察裝置	the People's Republic of China	CN218594539U	Ing-Jer Huang	National Sun Yat-sen University	2023/03/10
Utility Model Patent	A FLITERING MECHANISM FOR Underwater Monitoring system 水下觀察裝置	Republic of China	M637748	Ing-Jer Huang	National Sun Yat-sen University	2023/02/11

1.2 Team Composition

The team is composed of talents from various fields, including Internet of Things marketing, information engineering, aquaculture and other cross-disciplinary talents. The relevant personnel are as follows.

Name/Position	Professional Projects
	Da-Cian, Jhuang Graduate Student / Department of Computer Science and Engineering, National Sun Yat-sen University 1. Participate in program of NSTC (Proposal Title : Benthos Farming: Smart Equipment Development, Farm Practice and Aquaculture Eco-System Integration) 2. Participate in program of Ministry of Education Republic of China (Proposal Title: To Enhance the Systemic Thinking, Information Exploration and Language Expression Skills of University Students and High School Students From Resource-Poor Areas)

	Da-Wei, Lin Project Manager Business planning, operations planning, international market development Experience . 1. Marketing manager of new start-up team selected to be in Taipei FinTechSpace base 2. Served as the marketing manager of the start-up team and directed the participation in COMPUTEX International Information Exhibition 3. Served as the director of testing department of Xiamen Soundlink Information Technology Co.
	Chang-Ru, Tsai Hardware Development Engineer / Responsible for system hardware development Experience : 1. Master of Information Engineering, National Sun Yat-sen University 2. Smart farming system development (6 years) 3. 2nd place in the Kaohsiung Group of the 2018 Fishermen's Song Competition Finalist of 2022 Chunghwa Telecom 5G Innovation Application Competition
	Shen-Yun, Miao Software Development Engineer / Responsible for system software development Experience : 1. Participated in 3 large domestic research projects related to artificial intelligence, intelligent agriculture and farming (machine reading system, intelligent monitoring agricultural internet of things, intelligent farming management system) 2. Participated in the publication of 6 international research papers on artificial intelligence and intelligent agriculture. 3. Participated in the publication of one domestic research paper related to text exploration

2 Idea Motivation and Creative Descriptions

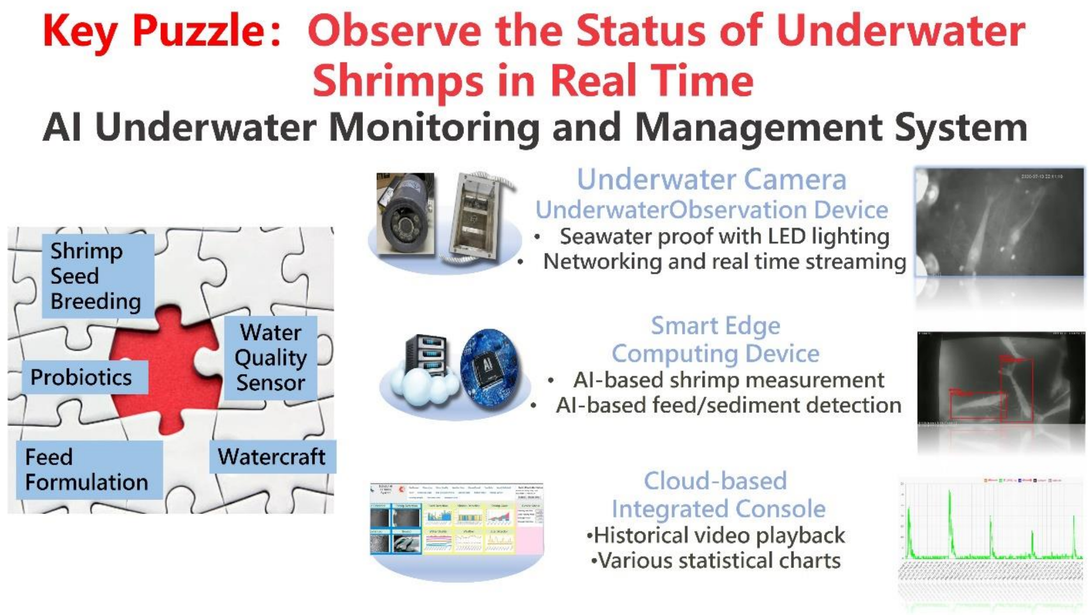
2 Idea Motivation

Taiwan is the world's leading country in electrical and information technology, and it is an influential technology power in the world in terms of semiconductor research and development, manufacturing, and artificial intelligence industry development. For example, Taiwan used to be known as the kingdom of grass shrimp because of its world-leading production and technology. However, while Taiwan's electrical and information technology fields are advancing with the global pulse, Taiwan's traditional industries are facing difficulties in technological transformation and have become sunset industries, with production volumes decreasing and substitution by imports. The team would like to use Taiwan's excellent electrical and information technology to delve into the "white shrimp farming industry" of Taiwan's traditional industry and explore the industrial difficulties it is facing, and create a shrimp farming solution with electrical technology, hoping to build the next farming kingdom for Taiwan and create the body of Taiwan's traditional industry again.

2.1 Creative Descriptions

The traditional white shrimp farming, because the shrimp live in the bottom of the pond, the water quality is turbid, it is impossible to grasp the condition of the pond, shrimp farmers rely on the naked eye to observe the growth of shrimp, and based on this to make breeding decisions and baiting strategy. The limitations of the visual observation method include the small amount of observation, low accuracy of visual inspection, no fixed standard of personal experience and subjective judgment, incomplete information, and the inability to establish systematic data for comparison.

Summarizing the above-mentioned difficulties in the management technology of white shrimp farming, Prof. Ying-Cheh Huang identified the key puzzle of farming technology, which is to observe the condition of underwater shrimp in real time. Even though there are many existing methods to help improve the culture, such as disease-free shrimp fry breeding, feed formulation, probiotics, automatic control equipment (water truck, automatic bait dispenser, automatic intake and discharge), and water quality sensing equipment, etc., only by seeing how well the shrimp are eating the bait can we truly confirm that all of the above methods are working. As shown in the picture below, this innovation is the last piece of the smart farming puzzle.



The artificial intelligence underwater image recognition and intelligent baiting technology developed by our team has been able to effectively solve the above-mentioned shortcomings, and can observe the underwater biological condition 24 hours a day and supplement the complete biological information for shrimp farmers with AI big data analysis.

Our team uses image recognition and AI technology to develop smart farming system underwater biological monitoring products, with functions such as AI intelligent baiting, AI shrimp size measurement, intestinal line observation, and mobility observation, which can accurately and comprehensively grasp the most critical bait consumption process, shrimp intestinal line health status, shrimp growth trend and shrimp mobility status of white shrimp farming.

Among them, Smart Baiting Patented Technology and Shrimp Intestinal Line Health Status are the unique functions and technologies of this project in the market, which are highly competitive in the market.

It is worth mentioning that the patented technology of intelligent baiting was developed by our team after interviewing more than ten experienced white shrimp farmers and referring to the "Special Issue No. 30 of the Experimental Institute of Aquatic Products of the Council of Agriculture - White Shrimp Breeding and Biosafety Prevention Management", which shows our team's ability to grasp the market demand and develop new functions.

3 Design Features and Function Introduction

The team's innovative solution is to provide breeders with "underwater intelligent eyes and intelligent brains".

A. **Underwater Camera / Underwater Observation Device :** Waterproof, rustproof and water pressure resistant special underwater camera. Provides clear 24-hour real-time underwater images.

B. **Cloud Computing / Edge Computing :** Real-time and multiple AI underwater image recognition, data collection and analysis to provide shrimp farmers with real-time farming strategies.

C. **Cloud Server / Cultivation Management Center Console :** The data is displayed in a chart to provide shrimp farmers with the most up-to-date information on shrimp ponds. It can be operated by computer or cell phone to play live images or playback historical images.

3.1 Key Features and Innovativeness

The core competency of our team is the application of AI technology for underwater image monitoring of white shrimp, with the following five technical projects .

A. AI Deep Learning

B. Smart Farming System and Method

C. Single-lens Shrimp Length Estimation System

D. Water Quality Filter

E. Intelligent Baiting

The core technology of our team, Artificial Intelligence Underwater Image Recognition and Intelligent Baiting Technology, is an underwater camera, cloud hollow platform, and cloud AI analysis service to complement the underwater image biological observation and monitoring part, such as baiting, activity, etc., which is lacking in the current smart breeding system in the market. The complete intelligent aquaculture system includes biological information (AI underwater image monitoring - a leading technology in Zhongshan), water quality and environmental information, and equipment control to achieve the AI observation, analysis/decision making, and control/action of the intelligent technology aquaculture model (Figure B).

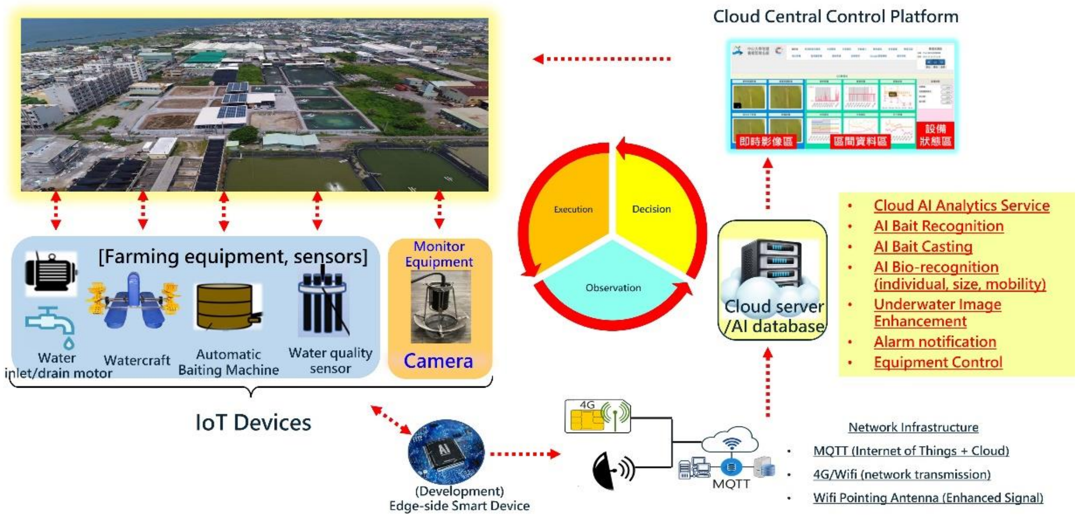


Fig. A. The architecture of the IoT intelligent farming system

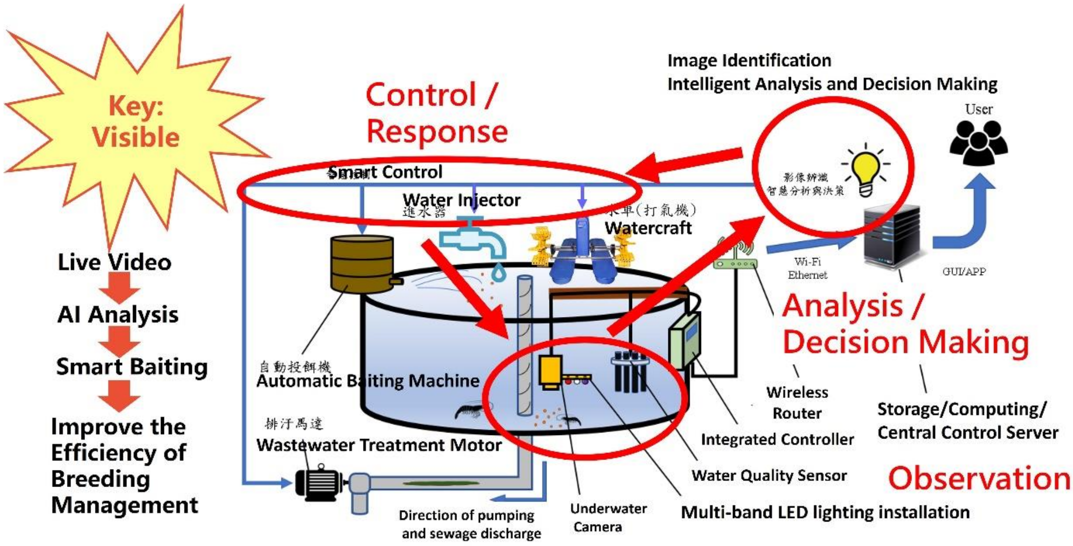
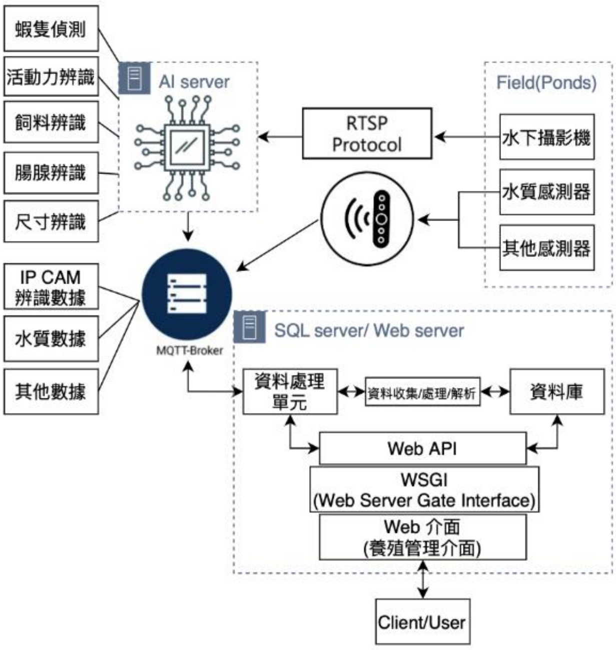


Fig. B. Technical architecture of the underwater monitoring system of artificial intelligence at Sun Yat-sen University

Our team's AI image recognition core technology has overcome the effects of different water colors and turbidity in aquaculture ponds, allowing us to observe the baiting and activity status of shrimp on the bottom of the pond 24 hours a day, and AI image recognition technology has led the industry in estimating the amount of bait residue in real time with an AI image recognition accuracy of 90%, while AI can measure shrimp size and establish shrimp growth trends.

3.2 Software Technology Key Features and Innovations

The software architecture of this system is shown in the diagram on the right. The sensing data and signals from the field devices are transmitted to the AI server and MQTT-Broker via RTSP protocol and router respectively, and the AI server recognizes the computation and sends the data to the MQTT-Broker, and then subscribes to the corresponding source hardware identification ID to receive the data packets. After data analysis, the data is displayed in the web interface of the farming management system.



The first part is the field device, which contains multiple underwater cameras, water quality sensors and other sensors (feeders) installed in the breeding pool.

The second part is the AI computation server. We use the received image data for AI recognition and several computation programs developed by our team (shrimp detection program, mobility recognition program, feed recognition program, gut gland recognition program, and size recognition program) to perform the computation, with "size recognition" and "feed recognition" as the key decisions for breeding.

This technology still requires data integration and analysis in order to understand the growth status and expected trends of shrimp. Therefore, the third part is a database server and a farming management web server, which contains a data processing unit to link to the database and a link to the web API, providing the necessary information to be retrieved from the front-end web pages and an interface to retrieve other programmatic information, so that users will be able to view real-time information in the farming management interface.

3.2.1 AI Technology : Shrimp Detection

The shrimp detection function detects and frames the location and number of shrimp in the camera screen in real time. As shown in the picture on the right.

This feature uses a single convolutional neural network to predict multiple bounding boxes and categories, which not only improves the recognition accuracy, but also significantly improves the recognition speed to achieve end-to-end item detection.

The detection speed of this method is very fast, and the base version can reach 45 frames/s real-time detection and the fast version can reach 155 frames/s when implemented on GeForce GTX TITAN X graphics card.

The network architecture is divided into three parts, namely, Backbone, FPN, and Prediction Net. Prediction Net will use these three image features to identify different bounding boxes. This network architecture incorporates FPN to extract image features at different sizes to help the network learn more subtle features, and these features help to identify small objects and improve their recognition accuracy at different sizes.

The system has been used in Kaohsiung, Hualien and Pingtung to collect underwater images of aquaculture ponds for training and verification of shrimp detection functions.

3.2.2 AI Technology : Feed Recognition

The feed recognition function indicates the current feed in the screen and displays the current and recent average feed amount in the upper left corner of the screen, so that users can know the current residual feed amount in the breeding pool. As shown in the picture below.

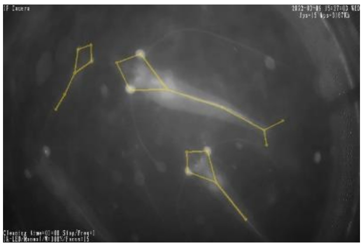
The neural network used in this function is trained and structured according to FCNs, and consists of a generator and a discriminator, where the generator is composed of an encoder and a decoder.

The model architecture of the generator is based on HED and VGG16, and the model is designed as an encoder and decoder according to the architecture of Auto Encoder. Each layer of down-sampled feature map is restored to its original size by up-sampling to preserve the features captured by different receptive fields, and then all the restored feature maps are stitched together to form a multi-channel feature map of original size, and the final output is obtained by integrating the contents of all feature maps through convolution sampling.

Since we use more than two types of fields in the dataset, the general GAN framework discriminator with only two categories cannot be used. Therefore, the discriminator part refers to DrLIM and replaces the classification purpose of the GAN discriminator with a dimensionality reduction model, which can be adapted to all types of data regardless of the input data. In the case of the test using underwater images from the aquaculture pond, the IOU can reach 58.54% (infrared) and 57.91% (visible light), and the MAE is 0.108 (infrared) and 0.095 (visible).

3.2.3 AI Technology : Size Recognition

The network structure used for the size recognition function is based on the lightweight keypoint recognition network structure, and in order to avoid the mobilenet from filtering out most of the image features, the FPN is added to connect different size image features to individual initial stages, and the two initial stages use different size image features to initially find PCM and PAF respectively. The resulting PCM and PAF represent the key point information at different resolutions, but there are still many misjudgments, and the output results can be effectively reduced by passing through several layers of refinement stages. The results obtained from the two different resolutions are further refined to improve the accuracy of PCM and PAF. The design of each stage is based on a lightweight key point identification network, which allows our network architecture to improve accuracy while retaining good computing speed. After training and testing with underwater images from actual aquaculture sites, our network architecture performed better than other common network architectures in terms of accuracy and FPS (AP=60.3% (T=0.6), FPS=18), and is more suitable for real-time streaming underwater image recognition in aquaculture ponds.



This function identifies key points on the shrimp's body (eyes, forehead, internal organs, body, tail fan, etc.) and through these key points, the length of the shrimp's body parts can be calculated, and then the full length of the shrimp's body can be deduced based on the ratio of each part of the shrimp's body to the length of the whole body, as shown in the attached figure. Unlike normal object recognition, the size recognition function developed by our team does not need to see the whole shrimp, as long as a part of the shrimp's body appears on the screen, its body length can be calculated. In addition, we also added the object depth correction, which corrects the distance between the shrimp and the camera by the intensity of the infrared light reflected by the body of the shrimp, so as to further reduce the error of the projected length.

3.2.4 AI Technology : Activity Recognition

The activity recognition function is an extension of the shrimp detection function, which can track the shrimp appearing on the screen and calculate their movement speed, and eventually display the average movement speed of all shrimp over a period of time and the cumulative total number of shrimp recognized in the upper left corner of the screen, as shown in the picture.

Three major components are included in the activity recognition, namely, shrimp tracking, shrimp departure calculation, and activity calculation, which are described as follows:

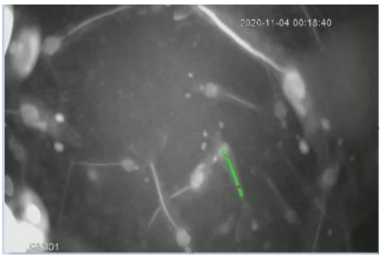
A. **shrimp tracking**：The shrimp tracking is done by analyzing the bounding box returned from the object detector to achieve the tracking effect. The analysis method is to calculate the direction of movement of the shrimp, the shape of the bounding box and the distance between the shrimp in the frame, and to give it a score according to the conditions.

B. **shrimp departure calculation**：According to the current direction of travel of the shrimp to calculate the distance between the corresponding edge and the top point and divided by the speed of the shrimp, the difference between the last frame of the shrimp and the current frame number. If the former is smaller than the latter, then the shrimp has left the field of vision.

C. **activity calculation**： After tracking the shrimp, the number of pixels it moves between two frames is counted to get the shrimp's movement speed, and it is considered as the activity.

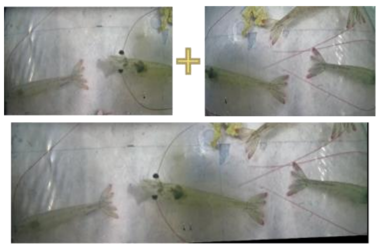
3.2.5 AI Technology : Gut Line Observation

Gut Line Observation is an extension of the Size Recognition results. The gut and tail points are extracted from the predicted key points, and the intestinal line of the shrimp is identified, and the proportion of empty intestine can be further calculated.



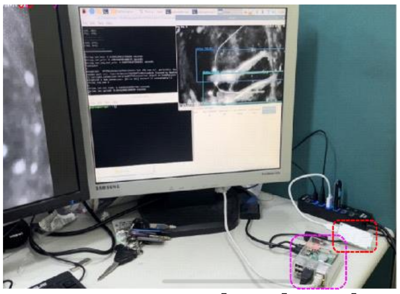
The white shrimp's gut line is white in the infrared image. After converting the infrared underwater image to black and white, find the local maximum of the neighboring pixels from the tail coordinates toward the vector of the visceral coordinates, find the coordinates and then repeat the search for the local maximum in the direction of the visceral coordinates, and finally all the coordinates found are connected in order to become the intestine, as shown in the figure. And then the AI technology can find the vacant part of the intestine line according to the brightness condition of the pixel.

3.2.6 AI Technology : Underwater Image Splicing



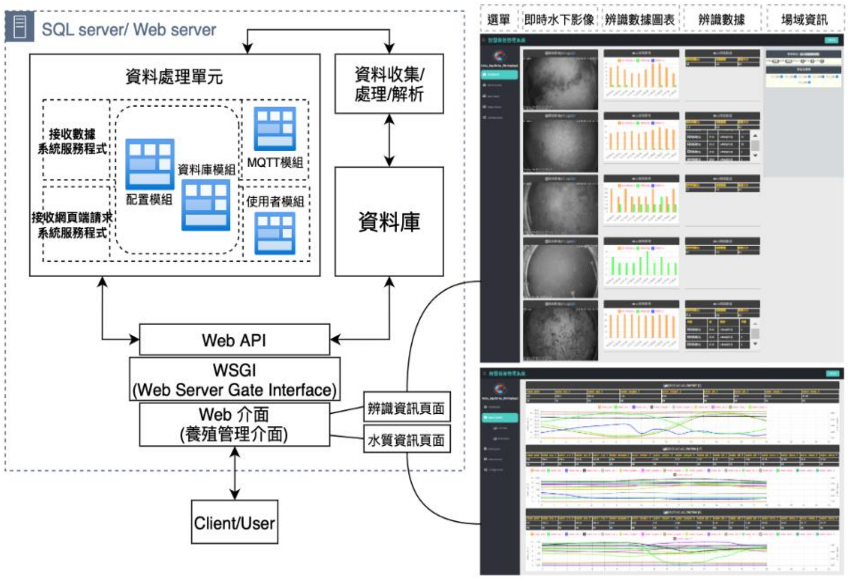
The aquaculture field pool water is often in turbid state, low visibility makes the underwater camera's viewable distance and range is limited, so it is necessary to use image splicing to produce a broader underwater vision. However, the complexity of traditional image splicing technology is very high, and it is difficult to complete the image splicing task at the edge device, so we use the edge device at the camera side for image synchronization pre-processing, and judge whether the image is suitable for stitching, and then send the image to the cloud server for splicing processing. In addition, we also adjust and simplify the image splicing method and process to achieve faster underwater image splicing with acceptable quality to effectively expand the viewable range of underwater cameras and obtain more underwater image information, taking into account the characteristics of low visibility and monotonous background of aquaculture pool images.

3.2.7 Deep Convolutional Neural Network Edge Computing Techniques



The amount of image data captured by underwater cameras is huge, and if all the images are directly uploaded to the cloud for processing and analysis, it will take up a lot of network bandwidth, so we adopt the concept of Edge Computing and introduce low-cost Edge Computing devices, such as Raspberry Pi with Google Coral Edge TPU, to process and analyze the acquired image data through the deep convolutional neural network on the camera side, and then upload the processing results or necessary data to the cloud for subsequent analysis, judgment, and decision making. The image data is processed and analyzed through a deep convolutional neural network on the camera side, and then the processing results or necessary data are uploaded to the cloud for subsequent analysis, judgment, and decision making, significantly reducing the required network broadband and cloud processing costs. In addition, we use model quantization techniques to quantize 32-bit floating point numbers into 8-bit integers to reduce the computational cost, storage space and power consumption of the edge computing device. On the other hand, we also use Quantization Aware Training to maintain the accuracy of the neural network model when making inferences.

3.2.8 Cloud Center Console of AI Underwater Monitoring and Management System

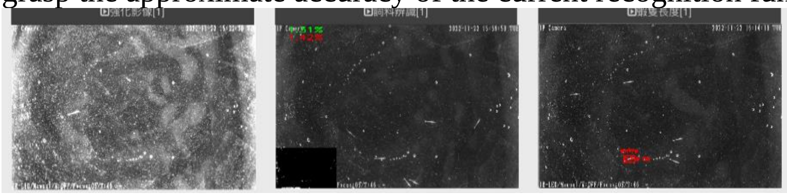


Our team designed the central console of the farming system to interface with the database and display data. As shown in the figure, there are two system service programs that take priority in the database server and the farming management web server. The first one is to "receive data" and the second one is to "receive web requests" as an integrated function to link data, parse data, store data and display data. These two types of system service applications distinguish and cover several programming units such as data receiving application (MQTT module), data parsing and database application (database module), and website operation application (basic configuration module and user requirements module). These units are used to parse, compute, count, and check incoming data, and then store the various types of data in the database.

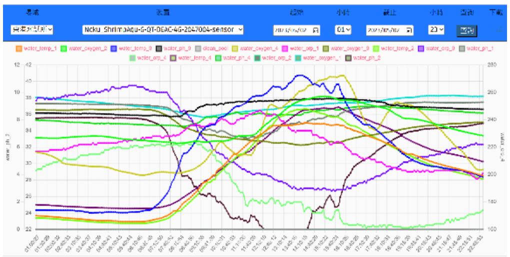
In particular, the backend program automatically calculates and stores the received image recognition data and water quality data in the database on a regular basis, which helps to establish the basic elements of the data query function. The developed culture management website mainly contains image information, water quality information, and statistical information, which can also be queried by users. The management interface (center console) provides menus, real-time underwater images, graphs of identification data, identification data and field information, etc., so that farming information can be viewed at a glance by users:

A. **Real-time Images:** The underwater images obtained from the underwater camera are categorized by the image server according to the user's field, and the corresponding underwater real-time images are displayed in the system dashboard (as shown in the red box), so that users can browse and master the image information in the pool as quickly as possible.

B. **Recognition Images:** The various recognition images processed by the server are displayed in the interface in real time. Users only need to click on the Icon (arrow in the red box) next to the camera's real-time image to view the recognition images of different items, and can grasp the approximate accuracy of the current recognition function.

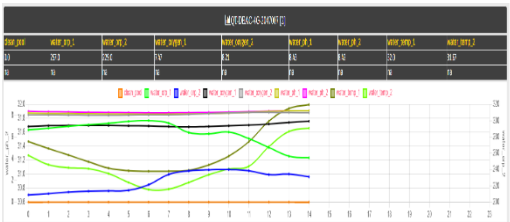


C. **AI Recognition Chart:** The data generated by each recognition function is displayed in the interface as a long bar graph and a line graph. For example, in the blue box attached to the real-time image, the recently obtained recognition data will be displayed next to the real-time image of the corresponding camera, so that users can grasp the recent feed residue and shrimp length. In addition, the system interface also provides users with the ability to check past identification data records. By selecting the corresponding camera and date, users can trace the historical information obtained by the camera and track past feed consumption and shrimp size growth records.



D. **AI Recognition Data :** In addition to the graph, users can additionally view the latest recognition data in the dashboard and set the feed alert value. When the feed quantity recognition result exceeds this value, the data will be displayed in the dashboard (such as the green box in the attached image) to remind users that the current feed quantity has exceeded the limit and they should pay attention to managing the residue quantity and water quality.

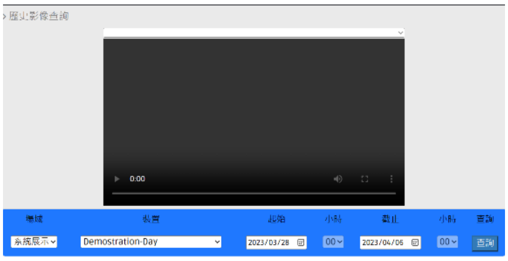
E. **Water Quality Data Chart :** The system can integrate the water quality sensor data of different brands, even if the farmers use sensors of different manufacturers, the underwater images can be presented in the interface at the same time, so that the farmers do not need to open other software pages of the sensors, which is beneficial to the unified management of underwater images and water quality data. The picture on the top right shows the



water quality data of the day, so that farmers can observe the changes of water quality on the day.

Users can also download the water quality data report for that period and compare it with the weather and farming operations during the corresponding period to understand the impact on water quality.

F. Historical Video Search : In addition to real-time image information, the system interface can query and download historical video (every 15 minutes), and farmers can analyze the past images and their corresponding water quality and identification data to understand whether abnormal conditions occur during the culture process (e.g., through the change in image clarity to know the change in pool water turbidity, and to predict whether the phenomenon of inverted algae occurs), and can use this as a reference for the next culture period. We can use this as a reference for the next culturing period to develop culturing strategies to know the past and the future.



3.3 Key Features and Innovations in Hardware Technology

3.3.1 Underwater Camera

Type	IP camera
Waterproof level	IP68，Continuous normal operation in seawater environment for more than three months
Resolution	Master code flow：1080P、720P Subcode flow：704*576、640*480、320*240 1/2.8" SONY CMOS sensor Color 0.001Lux F1.2 black/white 0.0001Lux F1.2
Lighting	Infrared, white light
Focusing Method	Motorized Zoom (0.05~4m)
Recording mode	General mode, night mode (infrared or white light); light-sensitive switching, timer switching, manual switching
Image Color	White light: full color; infrared light: automatically switch to black and white
Communication Protocols	RTSP、RTMP、HTTP
Image Code	H.264、MJPEG
Depth of Pressure Resistance	50 meter

FPS	1~30(Adjustable)
FOV	Approximately 105° laterally

The waterproof and dustproof specifications will be higher than those of commercially available underwater cameras:

3.3.2 Multi-lens Underwater Camera

In order to improve the vision of underwater camera in turbid water and to provide distance information of target observation, we expect to develop a multi-lens underwater camera, whose structure is multiple underwater lens modules connected to a control computing module, and the lens modules are arranged side by side or in an array, through which multiple underwater images can be obtained at the same point in time, and then the control module will create a stitched image or stereo vision, which can provide a larger range of underwater images and distance information of object observation.

3.4 Commodity Value and Marketability

3.4.1 Productivity: Effective Yield Improvement of 26%

Indoor Circulation Pool	Control pool (B1)	AI Test Pool (B2)
Density (Unit/㎡)	300	300
Primary Weight (g)	0.06	0.06
End Weight (g)	22.3	20.6
Survival rate (%)	62.6	84.7(+22.1%)
Production (kg/㎡)	4.2	5.3(+26%)

After the installation of the team's intelligent aquaculture management system at the East Harbor Biotechnology Research Center of the Institute of Aquaculture Research from 2021 to 2022, it was confirmed that the introduction of the AI underwater monitoring and management system could actually improve the ecology and quality of aquaculture, and the system was proven to be effective in increasing aquaculture production by 26%. (See table on the right)

3.4.2 Breeding Income : 15% Increase in Revenue

The results of this innovation will be demonstrated in 2022 at the East Harbor Biotechnology Research Center of the Institute of Water Research, where the breeding rate will be increased by 20%, the meat exchange rate will be improved by 6%, and the yield will be increased by 26%.

The model is based on the model of 12 ponds (each pond is about 0.8 dun), and the benefit of breeding is calculated at least 15% of new income in one year. **Costs**

3.4.3 Breeding : 3% Increase in Cost

In terms of cost, the cost of a single farming operation at $80 per catty is about NT$240,000. As shown in the table below, due to the intelligent baiting and management, we can avoid over-baiting and save electricity, so we can reduce feed and electricity expenses, although the cost is slightly increased by 3% due to the increase of equipment.

Item	Traditional Farming		Smart Farming		Difference
	Amount	Proportions	Amount	Proportions	
Feeds (1kg of feed is about NT$55)	148,500 (FCR 1.5)	62%	118,800 (FCR 1.2)	50%	29,700
Electricity Charges	56,000	23%	43,200	18%	12,800
Wages	19,000	8%	19,000	8%	0
Shrimp Seedling	9,500	4%	9,500	4%	0
Others	7,000	3%	7,000	3%	0
Depreciation of Smart Farming Equipment ($0.2 million amortized over 2 years and 4 times)	--	--	50,000	21%	+50,000
Total	240,000	100%	247,500	103%	+7,500

3.4.4 The Value That Smart Farming Can Create for all of Taiwan

According to the above, it can effectively increase the output by 26%, which in turn increases the revenue by 15% and cost by 3%.

The actual profit analysis of raising white shrimp for 1 year and 2 times in a pond, the profit increased by 40%. According to the above income and costs of white shrimp farming, the following table was calculated:

	Traditional Farming	Smart Farming
Income	NT$360,000*2 times=$720,000	NT$417,000*2 times=$834,000
Costs	NT$240,000*2 times=$480,000	NT$248,000*2 times = $496,000
Net Profit	NT$72,000 - NT$48,000 = NT$240,000	NT$834,000 - NT$496,000 = NT$338,000 (NT$338,000 - NT$240,000 = NT$98,000) 40% increase in profit (NT$98,000/NT$240,000)

Based on the total area of 725 hectares (about 7,479 hectares) of white shrimp stocked in Taiwan, the general farming earns NT$1.79 billion in a year (NT$240,000 per year for 1 hectare*7,479 hectares of stocked area in Taiwan), while the smart farming earns NT$2.53 billion (NT$338,000 per year for 1 hectare*7,479 hectares of stocked area in Taiwan), with an estimated increase in production value of NT$740 million. The estimated increase in production value is NT$740 million.

3.5 Marketability

The SOFIA (The State of World Fisheries and Aquaculture, SOFIA) report provides global fish supply trends by species, region, and wild-caught or cultured. 2018 global fish production reached 179 million metric tons, with sales valued at approximately US$401 billion, of which Aquaculture products accounted for 46% of the total production. Mainland China is the world's No. 1 producer of fish products and has produced more aquaculture products than all other countries combined since 1991.

Global aquaculture will continue to expand, and the proportion of global consumption and trade is expected to continue to grow over the next 10 years, with African aquaculture production estimated to grow by about 48%. Fish consumption accounts for 1/6 of global protein intake, and in some countries even more than 1/2, such as Bangladesh, Cambodia, Gambia, Ghana, Indonesia, Lion Mountain, Sri Lanka and some developing island countries.

In addition, according to SOFIA's global statistical issues and the following data: the sales value of fishery products reached USD 401 billion, of which USD 250 billion was aquaculture fishery products. The total value of fishery products exported to the international trade accounted for 38% of the global fishery production and US$164 billion. Looking at the global market, there is no limit to the future as a smart solution for aquaculture.

4 Green Design Concept and Aspiration

4.1 Origin of Green Concept : The Rise of International and Taiwan Carbon Trading Market, Taiwan is Committed to Cultivating Carbon Footprint Tracking

The global greenhouse effect has caused the melting of glaciers in high latitudes, the flooding of land in low latitudes, and drastic climate change, resulting in global economic and life losses. Everyone in the global village cannot stay away from it and cannot shirk their responsibilities. The team wants to respond to the global trend and the government's carbon emission policy by labeling the carbon footprint of shrimp farming so that consumers can consciously consume green food and serve as a venue for education on the carbon emission farming industry. We hope that through green design practices, we can contribute to 2050 net zero emissions and create a low carbon emission green production and consumption ecology for Taiwan.

Low carbon economy has become a global trend and carbon trading is flourishing in the international market. In April 2023, the President of Taiwan officially announced that Taiwan will establish its own carbon trading platform to trade carbon rights domestically in order to achieve the goal of net zero carbon emissions by 2050. According to media reports, the Taiwan Stock Exchange and the National Development Fund will jointly fund the establishment of the "Taiwan Carbon Rights Exchange" and complete the registration process this year (2023). The services include "domestic carbon rights trading", "foreign carbon rights services", and "carbon consulting services".

In the past decade, according to the research report of the Fisheries Department of the Council of Agriculture of the Executive Yuan, our country's agriculture and fisheries industry has gradually paid attention to the carbon footprint labeling of products, and has taken an inventory of carbon emission information for shrimp and shellfish farming. According to the *Agriculture Policy and Review* issued by the Council of Agriculture of the Executive Yuan in 2022, it is further stated that our country's fishery administration unit wants to establish "a marine carbon exchange calculation model that meets the characteristics of Taiwan's industry", through the above we can know that our country wants to invest in carbon emission and reduce greenhouse gas in aquaculture and fishery.

In order to participate in the global low-carbon emission campaign, the team will practice low-carbon emission in two ways. First, in terms of production technology, the team will invest in innovative underwater smart farming equipment that allows farmers to monitor the health and feeding conditions of shrimp through underwater cameras, so as to effectively feed and avoid wasting feed and polluting water. In addition, by mastering the carbon emission path, we can mark the low carbon emission data and carbon emission path under the farming technology in the product packaging of our partner shrimp farmers, which will become a sales tool to "educate consumers" through creative and marketing methods, spreading the concept of green aquatic products and creating the habit of consumers to purchase green aquatic products. This green design plan will create green aquatic products consumption and production by upgrading technology, consumer purchasing habits, and penetrating the upstream industry chain. The next paragraph will explain how the green concept will be implemented.

4.2 Green Design Concept

4.2.1 Low Carbon Emission Production : Optimize Shrimp Farming and Reduce Feeding Consumption

Shrimp farmers' farming practices play a key factor in whether carbon emissions are high or low. With the shrimp farmers in what way will determine whether the farming "effectively reduce" carbon emissions, or because of non-environmentally friendly farming methods, causing more environmental damage. In addition, according to a report published by the Environmental Information Center also pointed out that the key to the carbon footprint of aquaculture is in the way the industry operates, aquaculture industry can save a lot of carbon emissions generated by fishing boats out at sea, as opposed to pumping devices, temperature control equipment, carbon emissions from feed, will vary greatly according to the farming method.

According to a study conducted by the Institute of Marine Environment and Ecology, National Taiwan Ocean University, the carbon emissions from the production of white shrimp, for example, are ranked in descending order: electricity, feed, indirect raw materials, waste treatment, transportation, and refrigerant. The team is committed to creating an environmentally friendly shrimp farming industry chain by improving shrimp farming efficiency and reducing feed waste through technological farming with "underwater smart farming technology". The team uses underwater aquaculture equipment and technology to reduce carbon emissions from aquaculture.

4.2.2 Low Carbon Aquaculture Brand Certification : Promote Low Carbon Production and Green Farming

The shrimp farming industry in Taiwan is currently actively promoting technology and green farming in the farming industry, but there is a lack of systematic certification and market labeling for technology and green farming in the farming industry. The current shrimp aquaculture industry includes: shrimp fry breeding without specific disease sources, feed formulation, probiotics, automatic control equipment (water truck, automatic baiting machine, automatic inlet and outlet), water quality sensing equipment, etc. The team wants to promote the use of underwater smart farming equipment to encourage partner shrimp farmers to display their carbon footprints on shrimp farms and to label the climate benefits of purchasing AI-farmed shrimp on the product packaging. The benefits of technology farmed aquatic products and green farmed shrimp to the environment, through commodity marketing, so that consumers choose to buy technology farmed, green farmed shrimp, influencing consumer buying habits, which in turn upward influence the shrimp supply source of farmed shrimp farmers.

For those who cooperate with our team, we will have our aquaculture experts provide industrial counseling to the aquaculture industry and give regular health checks and farming advice for shrimp. Manufacturers who wish to cooperate with us will agree to provide a healthy and non-toxic environment for shrimp farming with green farming practices and a carbon footprint display at the site. The product will be allowed to provide a healthy and non-toxic shrimp certification label and to name the shrimp's carbon footprint, allowing consumers to understand that purchasing green farmed aquatic products will contribute to today's difficult global warming issues, which means that consumers' daily purchasing choices will have a subtle impact on global environmental issues with a handful of hands. Further, it will influence consumers' purchasing habits and stimulate the shrimp farming industry in Taiwan to switch to a "technology-based" and green farming model. In turn, the shrimp pond pollution problem in Taiwan's early industrial chain will be improved, creating a green farming culture in Taiwan.

With Taiwan as the starting point, our team is looking forward to expanding our green production technologies and concepts to shrimp farming countries around the world. The team is looking forward to extending the smart farming technology and green farming certification concept to the shrimp farming industry worldwide. At present, the global aquaculture industry has already cooperated with Vietnam, India, and Indonesia to learn about green farming and smart farming solutions, and even have the opportunity to further negotiate cooperation.