**Health-Smart Secure Farming (HSSF)**

Updated: 2017/11/25

* Application: **Health-Smart Secure Farming (HSSF)**
  + Target Problem
    - How to achieve “**health-smart secure farming**” such that the following 3 conditions can be satisfied
      * **Precise monitoring** of the **crop** growing conditions, **weather** (temperature, humidity, etc.) and **soil** (moisture, pH, etc.) so that we can learn new “integrated crop growth models”
      * **Detecting** specific problems related to productive farming, including input/output wastage, pests and diseases, and **controlling farming activities** such that crops grow healthily.
      * **Scalable control and distributed security** must be ensured for food safety.

The 3 problems that can solved by Health-Smart Secure Farm Management:

1. Precise Farm Monitoring via IoT: The benefits that farmers get from IoT application in agriculture are twofold. First, these systems help farmers decrease production costs and waste by optimizing the use of inputs. In addition, IoT can increase yields by improving their decision-making with more and accurate data. (<http://blogs.worldbank.org/ic4d/agriculture-20-how-internet-things-can-revolutionize-farming-sector>)
   * + **Integrated Crop Growth Model Learning**: Learning new crop growth models by monitoring climate, soil, farming activities (irrigation, adding fertilizers, and applying pesticides) and crop growing conditions. Heterogeneous data fusion among the above data types is performed in LPWAN gateways to learn new integrated crop growth models. For example, for grapes, spring frost frequently damages opening buds and young shoots, and in some regions early fall frost can defoliate vines before harvest. Thus, frost detection for grape growers is required to avoid crop wastage (ref. Quora).
2. Model-Predictive Plant Health Control:
   1. Plant pathology level identification (NTTU levels: 1-5)
   2. Health-conscious farming:
      * Precise watering: underwatering/overwatering exacerbate disease (root exudation: roots exposed to water-saturated soil for 18 hours, underwatering results in more susceptible to cankers)
      * Precise fertilizing: high levels of nitrogen fertilizers results in ammonia toxicity and exacerbate disease via pathogens such as Rhizoctonia, Pythium, Phytophthora, Fusarium, Armillaria, Sclerotium, Pseudomonas, Corynebacterium, powdery mildews, rusts, cyst nematodes and many others.
      * Use of biomedical pesticides (Taitung University)
3. Food safety and distributed supply-chain security: HSSF Blockchain design.

Other important links:

* Can IoT solve our biggest agriculture problems? <https://news.elementum.com/can-the-internet-of-things-solve-our-biggest-agriculture-problems>, April 25, 2017 (Elementum News).
* Digital Transformation in Agriculture: <https://www.extentia.com/single-post/2017/07/06/Digital-Transformation-in-Agriculture>, July 6, 2017 (The Extentia Blog)
* Cybersecurity Threat in Agriculture: <https://agfundernews.com/what-is-the-cybersecurity-threat-in-agriculture.html>
* Pest and Disease Identification using Deep Learning (CNN, etc.)
  + <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5032846/>
  + PlantVillage Database: <https://plantvillage.org/>
  + 10 Principles of Plant Pathology: <http://ceventura.ucanr.edu/Environmental_Horticulture/Landscape/Problems/Pathology/>

**Role of DNN in the Project**

1. To collectively learn a new integrated crop growth model:

The *Integrated Crop Growth Model* (ICGM) is a DNN model that is trained using the following data (**input**):

* *Farm information*: Location, crop, soil, farming equipment, automation level, etc.
* *Weather conditions*: temperature, 24-hour temperature difference, pressure, irradiation, etc.
* *Soil conditions*: moisture, pH, etc.
* *Crop growth and health conditions*: images (height, leaf pattern, etc.) and pathology level (local status data of sensors will be collected)
* *Farming activities*: irrigation, adding fertilizers, applying pesticides, harvesting, etc. (same or a superset of the transactions in the agri-blockchain)

The ICGM model outputs the future farm global status (**output**) including:

* *Normal* state: There is no problem with the farm currently.
* *Problematic* state:
  + Pathological state: Crop will be infected with some pests/diseases, output gives possible pathology level.
  + Bad environment state: Soil moisture will be saturated for more than 8 hours, 24-hour temperature difference will be larger than the threshold, soil will be contaminated with too much nitrogen fertilizer, etc.
* *Control* state: Will need farming control and might initiate smart contracts. For example, add fertilizer, apply pesticide, harvest, etc.

1. DNN model reduction/optimization techniques:

* Crop-specific pathology engineering: pathogens, pesticides, etc.
* Leveraging existing crop growth models: including fertilizers, etc.
* Periodic/Event-based co-relation analysis among 3 sets of factors:   
  (a) weather/soil conditions vs. (b) crop growth/health conditions vs. (c) farming activities
* Heterogeneous data fusion among the above 3 sets of factors.

1. Main method: Model-Predictive Control (MPC) for HSSF

* Reference Target: Long-term normal state (very few problematic states)
* Prediction Model: The ICGM model learnt by HSSF
* Control Actions: Farming activities

**Proposed Health-Smart Agriculture Blockchain (HSAB)**

Cloud-Level

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Buy seeds

Send to processing plant

Apply Pesticide

Add Fertilizer

Harvest Crop

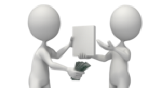
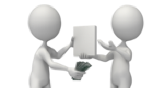
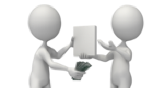
Irrigate

Sow/drill seeds

④

③

**HyperLedger Fabric**



Node-Level

②

③

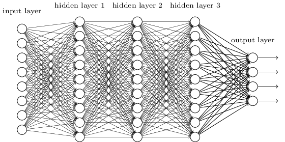
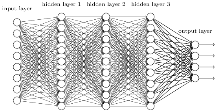
**IEC 61499 with data fusion**

**Pathology Model**

②

①

Kubernetes



**Crop Model**

①

Pesticide Node

Irrigation Node

Fertilizer Node

**LoRaWAN**



Device-Level

soil sensors weather sensors crop image sensors

Two Use Cases for Health-Smart Agriculture Blockchain:

* *HSAB Transaction*: Pathology in crop is detected by the 1-bit DNN models at some sensor devices. After a gateway collects a number of similar detections, it uses a 16-bit Pathology DNN model to predict if the current condition of pathology, as detected by sensors, requires pesticides to be applied. If yes, an “Apply Pesticide” transaction is created and committed to HSAB. This scenario is depicted by blue-numbered steps as follows:

1. Pest/Disease Predicted by Pathology DNN model at Gateway 🡺

② An “Apply Pesticide” transaction is created 🡺

③ An “Apply Pesticide” block is added into HSAB

* *HSAB Smart Contract*: Issues in crop growth are detected by the crop DNN model in S3G sensors. After a gateway collects a number of similar detections, it uses a 16-bit Crop DNN Model to predict if the current condition of crop growth, as detected by sensors, requires fertilizers to be added. If yes, a Smart Contract is initiated and executed as follows. An “Add Fertilizer” transaction is created automatically by the smart contract and committed to HSAB. This scenario is depicted by black-numbered steps as follows:

① Crop growth delay predicted by Crop DNN Model at Gateway 🡺

② A Smart Contract to Add Fertilizer is executed 🡺

③ An “Add Fertilizer” transaction is created 🡺

④ An “Add Fertilizer” block added into HSAB.

**Explanation on the Agri-Block Design:**

* Our S3G LoRa sensors for soil, weather, and crops will be used for collecting related data.
* A smart network management system will be developed for managing farms using nodes that correspond to farming activities, including irrigation, adding fertilizers, and applying pesticides.
  + Each node is capable of creating new transactions, either using function blocks (FB) in IEC 61499 or automatically via the execution of smart contracts.
  + A FB will implement data fusion in each node.
  + Kubernetes will be used to design and implement all the nodes that conform to the IEC 61499 industrial distributed control standard. Each node will be in a Docker container.
  + Deep neural network models will be used to trigger a node. For example, a plant pathology model will be used to trigger the Pesticide Node and a crop model will be used to trigger the Fertilizer Node.
  + Smart contracts can be configured specifically for each farm.
* Hyperledger fabric will be used to design and implement the HSAB. Each block will consist of one or more HSAB transactions, where each transaction corresponds to one agricultural activity such as irrigating, adding fertilizer, applying pesticide, harvesting, etc.. The HSAB will be implemented across two or more S3G LoRaWAN-based gateways such that *food safety* can be ensured. For parties that do not possess an S3G LoRaWAN-based gateway, a PC server installed with HSAB can also be used to interact with the HSAB blockchain.