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# IoT solutions for precision farming and food manufacturing

## Artificial Intelligence applications in Digital Food

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***Abstract*— In many respects, farming and food processing have lagged other industries when it comes to adoption of innovative technology. Whilst bioengineering has brought about seeds with much higher yield and less need for water and nutrients, it is only now with IoT that farmers can work on the intensive use of natural resources to increase the sustainability of their operations.**

**In the last ten years, high-end machinery has evolved primarily to the benefit of larger corporations, with the introduction of satellite driven machines, sensors and all components of precision farming. The most recent IoT advances bring about a level of simplification and cost reduction that enable all farmers to benefit and a true adoption of prescription agriculture.**

**In this conference presentation, we will examine a practical case of a Malthouse, where careful modeling of how CO2, Temperature, Humidity and PH vary in the three steps of the malting process, enabled an artificial intelligence system to prescribe different setting and schedules. The end result is malt with higher content of starch and proteins, which in turn means higher alcohol in the downstream process.**

**A second example on the cultivation of Medical Marijuana, where similarly but in a more complex fashion (138 variables) the artificial intelligence supported the tuning of many settings and schedules, is presented only in the conference**

***Keywords—IoT, Precision Farming, Prescriptive Farming***

## I. Introduction

The past ten years witnessed the growth of several technologies aimed at increasing the yield, safety and productivity of most crops. From bio-engineering, to OGM, to precision farming and track and trace of produce, the entire production chain from the field to the final distribution. One could argue that most of this progress has benefited larger and more financially robust corporations, whilst small farmers and transformation companies have lagged less sophistication. With the advent of Internet of Things (IoT), the market has seen the development of low cost sensors, open source applications and more generally the ability to increase the level of farming sophistication without the need to invest large sums in capital investment. One specific area of attention is Artificial Intelligence (AI), where self-learning algorithms can contribute to develop new insight in the settings and schedules that optimize yield and quality of a given process. In this Workshop paper we provide a description of one case studies where IoT and AI proved instrumental in improving malt quality and efficiency in production. A second case is presented only at the conference.

## II. IoT Sustainability

### *A. Asset rich, cash poor*

Farmers and generally small businesses involved with harvest and transformation of vegetables work on very thin margins as they compete with larger corporations whose clout in supply chain and marketing is a definite competitive advantage. This means investments in capital equipment are difficult and as a result small companies have generally lagged larger players.

Public opinion has picked up on the issues of sustainability as key feature of good quality produce, opening a door for small farmers. According to a 2015 survey [1], there was almost a 20% jump in the number of food and beverage companies with product sustainability goals compared to 2013. When you think about sustainable farming, waste reduction, and keeping up with feeding the world's population, one does not think about technology and IoT. However, the potential for smart connected products, systems, and operations when it comes to the food and beverage industry is mindboggling. As an example, AB Inbev's Smart Barley Program allows barley farmers to benchmark their progress by comparing their crop yields to those of other growers both in their regions and beyond. With AgriMet farmers have real-time access to vital data concerning water usage.

At a more basic level, IoT can also help individual farmers in the monitoring of those physical variables (relative humidity, PH of the soil, CO2 and temperature in storage and transformation facilities, which help reduce the frequency and amount of treatments, optimize irrigation and seeding patterns. Data is useful from the basic representation to the farmer, but more importantly makes up the set from which real insight can be gained on how to improve processes.

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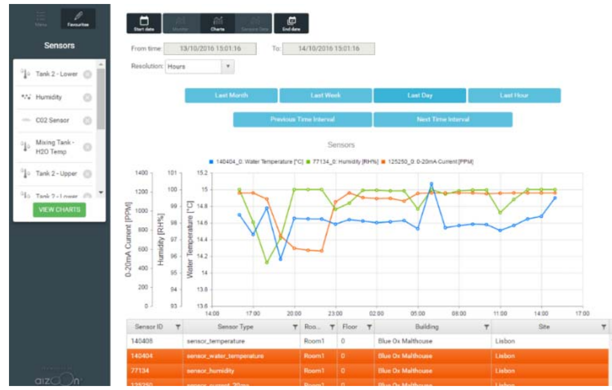
The most recent IoT advances bring about a level of simplification and cost reduction that enable all farmers to benefit and a true adoption of prescription agriculture. When physical sensors drop to less than $100, and virtual sensors based on complex correlation algorithms allow for a 60% reduction of sensing technology, the small and cash stripped farmers can start competing with the larger corporations.

## III. Case in point: Malthouse

The Malthouse key process is centered on the ability to receive and store correctly several types of grains, and then go through a process of steeping in cold water for several hours, slowly reducing humidity to specific set points, and finally dry the seeds in a kiln to stop the germination process started in the water. In essence, the optimal Malthouse operation transforms the grains of barley and other crops by starting and stopping the germination process so that the seed increases the count of several starches and proteins. This in turn will mean higher alcohol content in the downstream process of brewing.

It may be intuitively evident how several variables enable the correct monitoring of this process. Temperature is key at all stages, air flow is critical in the ability to evenly bring all produce to a set humidity, PH is a definite indicator of metabolic reactions, CO2 is the environmental measurer of progress in germination. This picture shows the problems faced by the company: uneven distribution of airflow, therefore humidity, therefore homogeneity of germination.

After proper engineering of the system dynamics, sensors were placed in different parts of the building to continuously monitor the values of all physical variables. With circa a month worth of historic data, we built a model to create a production process simulator. This Digital Twin goes through several interactions to ensure correct matching with the real conditions of the plant. Once this is proven, the reliability of what-if scenarios increases and the operator is then capable of trying different settings and schedules to improve key output variables such as starch and protein content.




A Bayesian Network Analysis [2] and Multi-Variate analysis [3] are the base for the intelligence work, where we study the correlation of the different input and output variables over time. This enables the Digital Twin to increase accuracy in prediction of the effect of several changes of settings and schedules.

In conclusion, the parameters of malt before and after the development of this IoT and AI project showed an important growth in starch, protein and other indicators in a company with 150 years history of producing malt.

| Date | Moisture | Friability | Extract | Color | Target A | Target B | Target C | Target D | Filtration | Clarity |
|---|---|---|---|---|---|---|---|---|---|---|
| | % | % | % | °SRM | UM | UM | UM | UM | Time | |
| before | 5,1 | 91,4 | 81,8 | 2,16 | 92 | 170 | 95 | 49,3 | slow | hazy |
| before | 4,6 | 88,6 | 82,2 | 2,11 | 95 | 164 | 89 | 50,1 | normal | hazy |
| before | 5,1 | 94,7 | 82,7 | 2,32 | 27 | 186 | 112 | 57,3 | normal | clear |
| before | 5,0 | 97,6 | 82,8 | 2,37 | 20 | 192 | 109 | 60,8 | normal | clear |
| before | 5,7 | n/a | 83,3 | 2,16 | 63 | 81 | 103 | 22,9 | normal | clear |
| before | 5,8 | 38,0 | 83,1 | 2,92 | 47 | 95 | 114 | 21,5 | normal | clear |
| before | 5,5 | 84,3 | 82 | 2,24 | 366 | 145 | 75 | 15,2 | slow | hazy |
| before | 5,2 | 88,3 | 81,6 | 2,32 | 235 | 156 | 88 | 29,9 | normal | clear |
| before | 7,3 | 86,1 | 82,4 | 2,77 | 167 | 180 | 119 | 62,9 | normal | clear |
| before | 6,6 | 79,1 | 80,7 | 1,98 | 429 | 145 | 98 | 34,7 | slow | clear |
| after | 5,1 | 89,3 | 80,9 | 2,79 | 180 | 201 | 126 | 50,4 | normal | clear |
| after | 5 | 92,4 | 81,6 | 3,09 | 134 | 172 | 110 | 40 | normal | clear |
| after | 4,8 | 90,1 | 83,3 | 2,4 | 134 | 105 | 118 | 29,1 | normal | clear |
| after | 5,1 | 96,6 | 83,4 | 1,61 | 117 | 150 | 101 | 54,4 | normal | clear |
| after | 5,2 | 92,0 | 81,3 | 3,53 | 126 | 217 | 128 | 60,1 | normal | clear |
| after | 4,9 | 88,8 | 80,6 | 2,86 | 301 | 187 | 116 | 54,1 | normal | clear |
| after | 5 | 89,8 | 80,1 | 5,96 | 247 | 197 | 126 | 50,1 | normal | clear |
| after | 5,1 | 91,3 | 82,1 | 4,94 | 292 | 137 | 117 | 39,8 | normal | clear |
| after | 5,1 | 90,3 | 82,1 | 1,97 | 250 | 153 | 119 | 31,7 | normal | clear |
| after | 5,2 | 88,6 | 82,8 | 3,16 | 400 | 168 | 99 | 38,2 | normal | clear |

## References

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