Machine Learning Approach to Remove Ion Interference Effect in Agricultural Nutrient Solutions

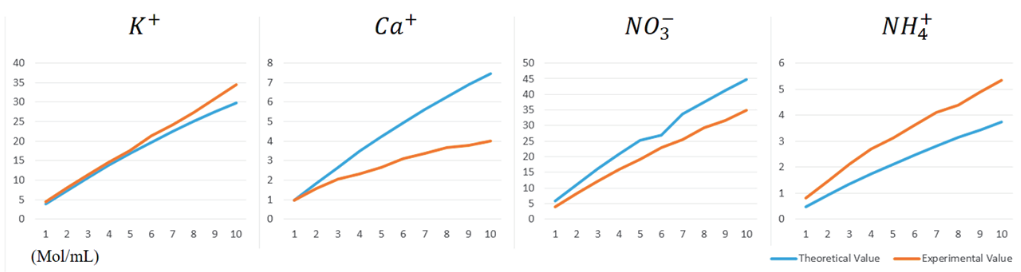
Byunghyun Ban[1]*, Donghun Ryu[2] & Minwoo Lee[2]

[1] Ministry of Employment and Labors, [2] Imagination Garden Inc.
{halfbottle, dhryu, hydrominus}@sangsang.farm

Abstract

High concentration agricultural facilities such as vertical farms or plant factories consider hydroponic techniques as optimal solutions. Although closed-system dramatically reduces water consumption and pollution issues, it has ion-ratio related problem. As the root absorbs individual ions with different rate, ion rate in a nutrient solution should be adjusted periodically. But traditional method only considers pH and electrical conductivity to adjust the nutrient solution, leading to ion imbalance and accumulation of excessive salts. To avoid those problems, some researchers have proposed ion-balancing methods which measure and control each ion concentration. However, those approaches do not overcome the innate limitations of ISEs, especially ion interference effect. An anion sensor is affected by other anions, and the error grows larger in higher concentration solution. A machine learning approach to modify ISE data distorted by ion interference effect is proposed in this paper. As measurement of TDS value is relatively robust than any other signals, we applied TDS as key parameter to build a readjustment function to remove the artifact. Once a readjustment model is established, application on ISE data can be done in real time. Readjusted data with proposed model showed about 91.6 ~ 98.3% accuracies. This method will enable the fields to apply recent methods in feasible status.

Ion Interference Effect



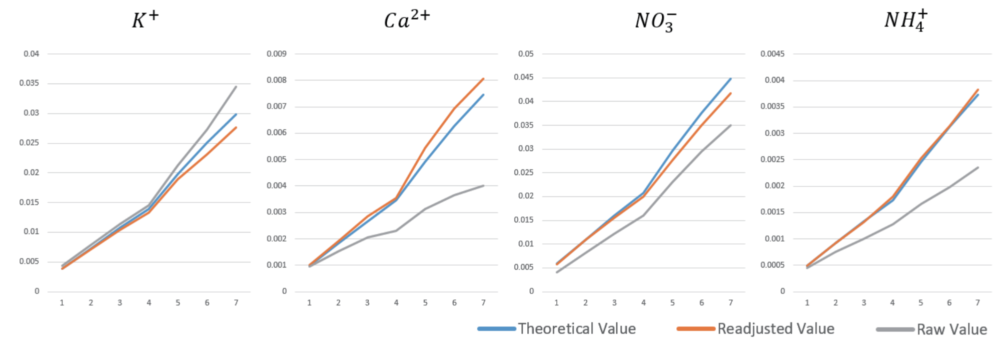
Ion selective electrodes(ISEs) acquires Nernst potential across the glass membrane induced by the gradient of ion concentration. But flow of undesired ion across the poles induce artifacts. It is called ion interference effect. The graph above shows the scale of artifacts. Orange lines are experimental values, which are far from the blue-colored theoretical value. Predicting the exact scale of this artifact requires a lot of experimental coefficients.

Readjustive Method

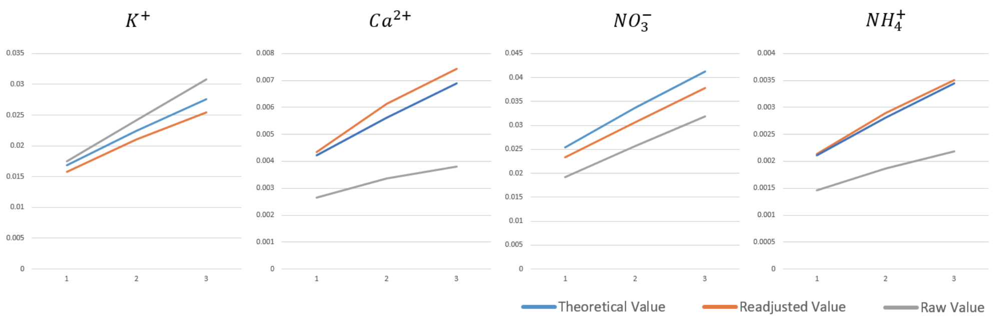
Regression on equation (1) enables readjustment of raw values, by multiplying predicted value with measured value as equation (2). Quadratic regression is appied because its inference step requires O(1) time. Real-time readjustment on embedded device is feasible.

$$\mu(\mathrm{TDS}) \approx \frac{C_t}{C_{ISE}} \quad (1) \qquad C_r = \mu(TDS) \times C_{ISE} \quad (2)$$

Experiment & Results



Results on training data. Blue lines are theoretical values, orange lines are readjusted values and gray lines are raw values.



Results on test data. Applycation on NH4+ showed dramatic effects.

	K^+		Ca^{2+}		NO_3^-		NH_4^+	
	Training	Test	Training	Test	Training	Test	Training	Test
Raw data	91.0985	92.3161	71.499	59.331	75.9049	76.3167	73.6818	66.1971
Proposed method	**95.6468**	**93.1957**	**93.5715**	**93.2089**	**95.8048**	**91.5922**	**98.3132**	**97.8293**

Accuracies of raw and readjusted signals. Readjusted value showed 93.6~98.3% accuracies on the training data, and 91.6~97.8% accuracies on the test data. Especially, trial on the test data of Ca++ and NH4+ showed dramatic results.

Conclusion

Although the time complexity of application of the proposed method is O(1), it showed great result on removal of ion interference effects. Compared to prior art from CRC which required both deep learning and genetic algorithm at the same time, the proposed method is more feasible and realistic to apply on real-world smart farms.

My Little Farm on the Table
상상텃밭