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Prospects of Using Neural Networks for Recognition of Certain Stages in Plant Growth

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Abstract. The article contains results of research of using neural networks to determine the leafy lettuce's stages of growth. Lettuce has been grown using hydroponic facility. It was found that neural networks can determine certain stages of growth with high precision.

1. Introduction

Indoor growing technologies are becoming increasingly popular [6]. The main goal of greenhouse growing technologies is replacing human labor for automatic system of maintenance [8] [9]. The most urgent task is to create systems capable of visual evaluation of crops phenological stages especially the stage of commercial presentation [7]. In this area neural networks have proved to be very effective in analyzing videos and images [10] [12].

Life cycle of the crop plant consists of several stage of development, named phenological phases, each of which has its own distinguishing features, for example: emergence of first true leaves, emergence of buds etc. There is a significant amount of information in literature about phonological phases of crop and wild plants [11] [13] [14] [15]. Among phenological phases the most interesting are the ones, that indicate readiness of the plant as a product. Those phases also should have noticeable distinguishing features. Precise identification of phenological is essential to develop a technological map on the cultivation process. Application of theoretical knowledge allows to promptly and precisely identify stages of plant growth.

Goal of research – evaluate the prospects of using images of certain phenological phases for training a neural network [3]

2. Objects and methods

2.1. Objects of research

Objects of research: 20 plants of leaf lettuce, class «Skomorokh» (class C), and 40 plants of leaf lettuce, class «Geizer» (class G). To work with neural network was used a database of digital images of lettuce's different phenological phases recorded during continued observation (1 image of each plant once a day for 25 days), total amount of digital images– 1500.

The problem in integrating the neural network approach is the complexity of the interpretation of the results, in cases of deep neural networks it becomes almost impossible to understand the reasons for determining a particular class, various quality metrics are used to understand the quality of the model, in our case the "accuracy" metric was used, and to determine the robustness method of checking on test and validation samples. Dividing the dataset into validation and test sets was carried out by dividing the main dataset into 70% of the training set and 30% of the validation set, then 30% was chosen for the test data set from the validation set.

The basis of the neural network is a pre-trained set of convolutional layers and fully connected linear layers for classification, pre-trained on the ImageNet dataset, which includes 1000 categories and a large number of images. The reason for the workability of this approach is that the early layers cover only primitive features (points, edges, corners, etc.). For checking hypotheses about the possibility of classifying growth stages and analyzing existing architectures, promising approaches to solving the classification problem were selected and the last linear layers were trained without changing the weight of convolutional layers [2].

The convolutional neural network was chosen because the underlying mechanism of neural network data works well with data that has a mesh structure with strong spatial dependencies. A feature of image data is spatial invariance, which allows you to apply augmentation to data change the location of objects since for convolutional layers it does not matter where the object is [1].

Figure 1 shows the accuracy of predicting the stage of plant growth from the test sample in the form of a graph [5].

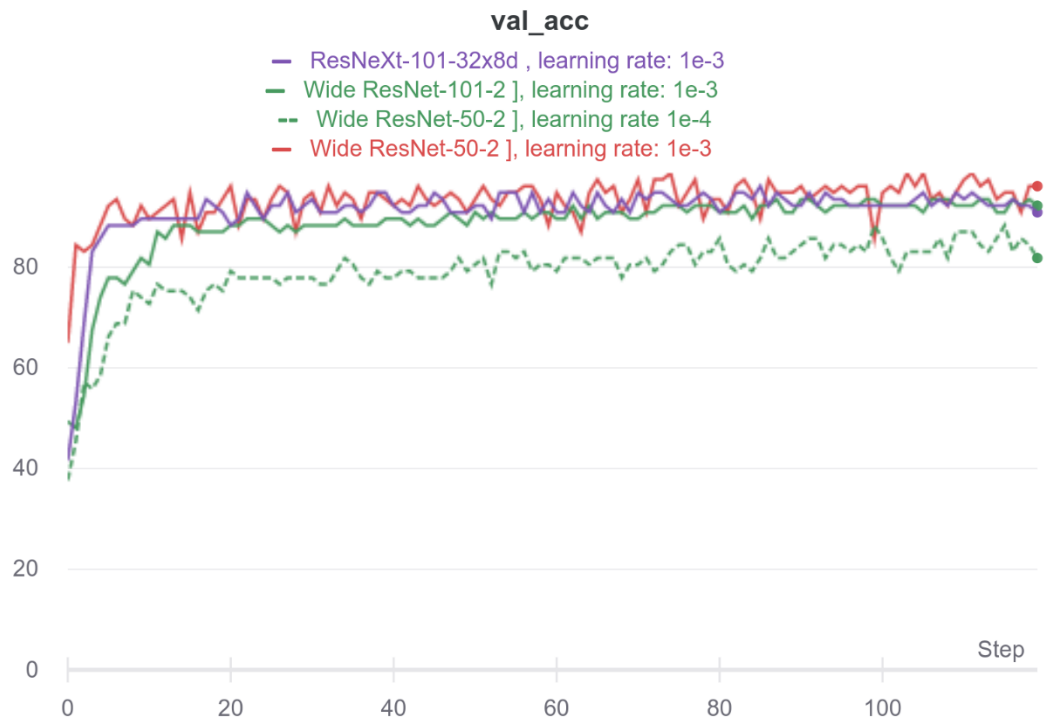

Figure 1. Graph of the accuracy of forecasting the stage of plant growth from the test sample.

For further research, the ResNeXt-101-32x8d model was chosen, since, on average, it has a better result in comparison with Wide ResNet-101-2 and a lower accuracy variance on the test sample compared to Wide ResNet-50-2. The model is a set of blocks with a split-transform-join approach [4].

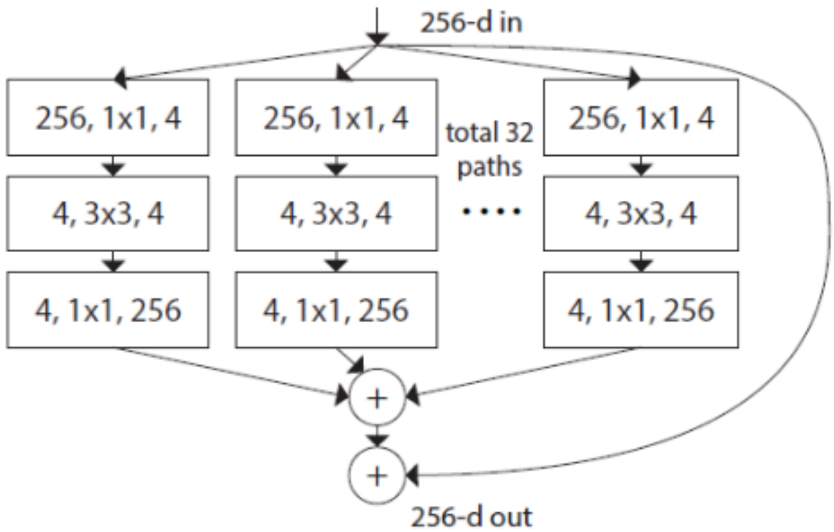

Figure 2. Block of convolutional layers of the ResNeXt-101-32x8d architecture with a split-transform-join approach.

The architecture has 5 convolutional blocks, each with its own convolutional duties.

2.2. Methods

Lettuce was cultivated in hydroponic unit. Nutrient solution was used as a substrate for plants. Nutrient solution included bottled drinking water under a trademark «Slavda» («Slavda» - artesian drinking water from 2 wells: well 14517 (Dneprovskoe deposit, Vladivostok) and well 37084 (Nadezhdinski district, basin of Tigrovaya Pad river)), pH – 7.7, Ca^{2+} - 10 - 60 mg/l, HCO_3^- - 50 - 250 mg/l, Mg^{2+} - 2,5 - 20 mg/l. Mg^{2+} - 2,5 - 20 mg/l and liquid complex fertilizers with micronutrients Flora Micro (N in compounds – 5%, K soluble – 1,3%, B – 0,01%, Ca – 7%, Cu – 0,01%, Fe – 0,12%, Mn – 0,05%, Mo – 0,04%, Zn – 0,015%), Flora Gro (N – 3%, K– 6%, P – 1%, Mg – 0,8%) и Flora Bloom (S – 5%, K– 4%, P – 5%, Mg – 3%) by General Hydroponics. Components of nutrient solution were mixed in proportion: 10 ml of each fertilizer for 19 liters of water. Monitored parameters of environment in hydroponic unit: lighting, pH, salinity, temperature.

3. Discussion

Shoots of lettuce with 2 first leaves each were placed in hydroponic unit. Cultivation in unit lasted for 25 days. After 25 days lettuce reached the stage of marketable condition, stage of fully developed plant with 9 and more large true leaves. Main phenological phases which were detected for work with neural network: emergence of 1 new leaf (1); emergence of 3 leaves (2); emergence of 9 leaves (marketable condition).

If we look at correlation between number of days required for plants to reach the marketable condition and number of leaves, it is noticeable, that each plant may stick to its own schedule of growth. And if this technology is extended to a large-scale manufacturing, it is obvious, that targeted removal of plants, that reached marketable condition. Diagram in figure 3 shows the dynamic of changing the number of leaves on plants of both classes. In 13 days of experiment plants of both classes developed equally, showing the same daily increase in number of leaves. On day 14 the average number of leaves on plants of class C increased, while number of leaves on plants of class G did not. This distinction remained for 2 days. After 2 days average number of leaves on plants of class C increased again. Stage of marketable condition was reached by plants of class C on July 21, whereas plants of class G reached that stage on July 24.

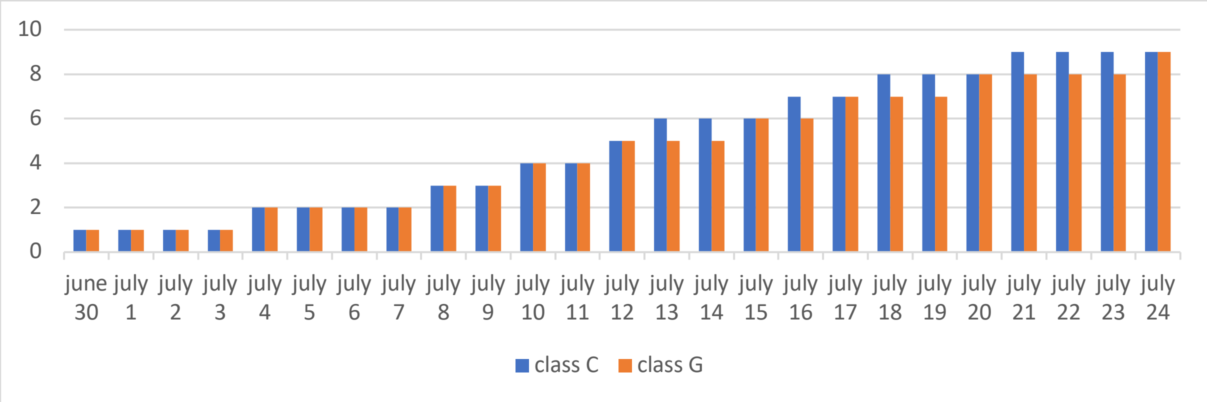

Figure 3. Dynamic of changing the number of leaves on plants of both classes.

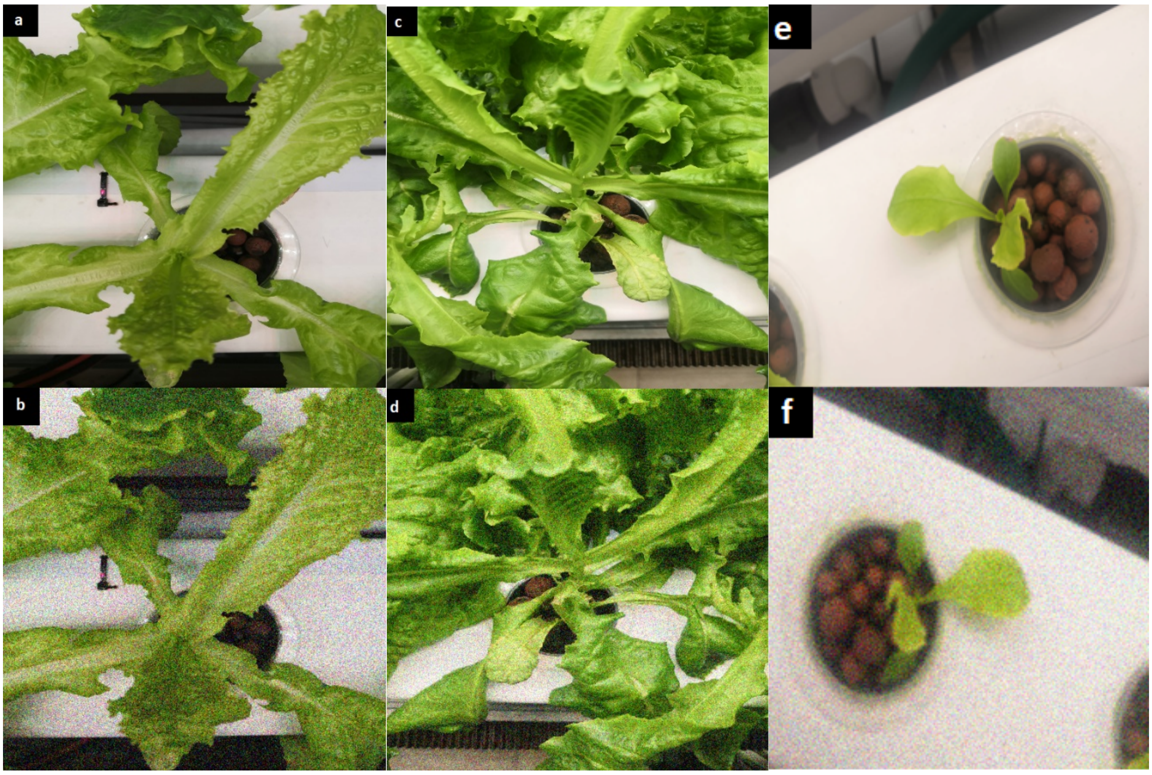

Figure 4. Images of different stages of lettuce development used to train the neural network (a - normal, stage 2; b - noisy, stage 2; c - common, stage "presentation", d - noisy, stage "marketable"; e - normal, stage 1; d - noisy, stage 1).

The result of the neural network analysis of the images shown in Figure 4: The model shows the probability of finding a plant in stage 2 - 78% in the original image and 69% in the noisy image (b); in stage 3 - 95% in the original image (c) and 98% in the noisy image (d); in stage 1 - 98% in the original image (e) and 72% in the noisy image (f).

Figure 5 shows plants of classes C (a) and G (b), respectively,

For these photographs, the following results were obtained:

Grade D, real stage 2;

Predicted:

Stage 1: 0.0029%

Stage 2: 6.1476%

Stage 3: 93.849%;
Grade C, real stage 3
Predicted:
Stage 1: 0.15%
Stage 2: 18.70%
Stage 3: 81.13%;
The final prediction for cultivar D is stage 3 with a probability of 94%, which does not correspond to the real state.

Figure 5. Images of lettuce in stage of non-marketable (a) and marketable (b) condition.

The results obtained can be explained by low quality of image a: constant focus distance is not maintained, lighting is too bright, leaves of other plants take significant part of the image.

4. Conclusion

Leaf lettuce is one if the most suitable crops for research due to its short period of vegetation and easiness of marking the phenological phases, each of which has certain number of leaves as distinguishing feature.

Each class of leaf lettuce has its own unique length of cultivation period. This fact should be considered before start of cultivation

While taking photos of plants constant distances between camera and plant should be maintained. Same amount of light and constant focus distance should be maintained as well.

Therefore, it is possible to conclude that neural networks are useful for determining of phenological phases of plants. The researched neural network determined phenological phase of plant with high precision. Discrepancy between neural network-determined and actual phenological phase could be due to low quality of photo.

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