원예산업 가치사슬의 디지털화

한국과학기술연구원 강릉분원
천연물연구소
김형석

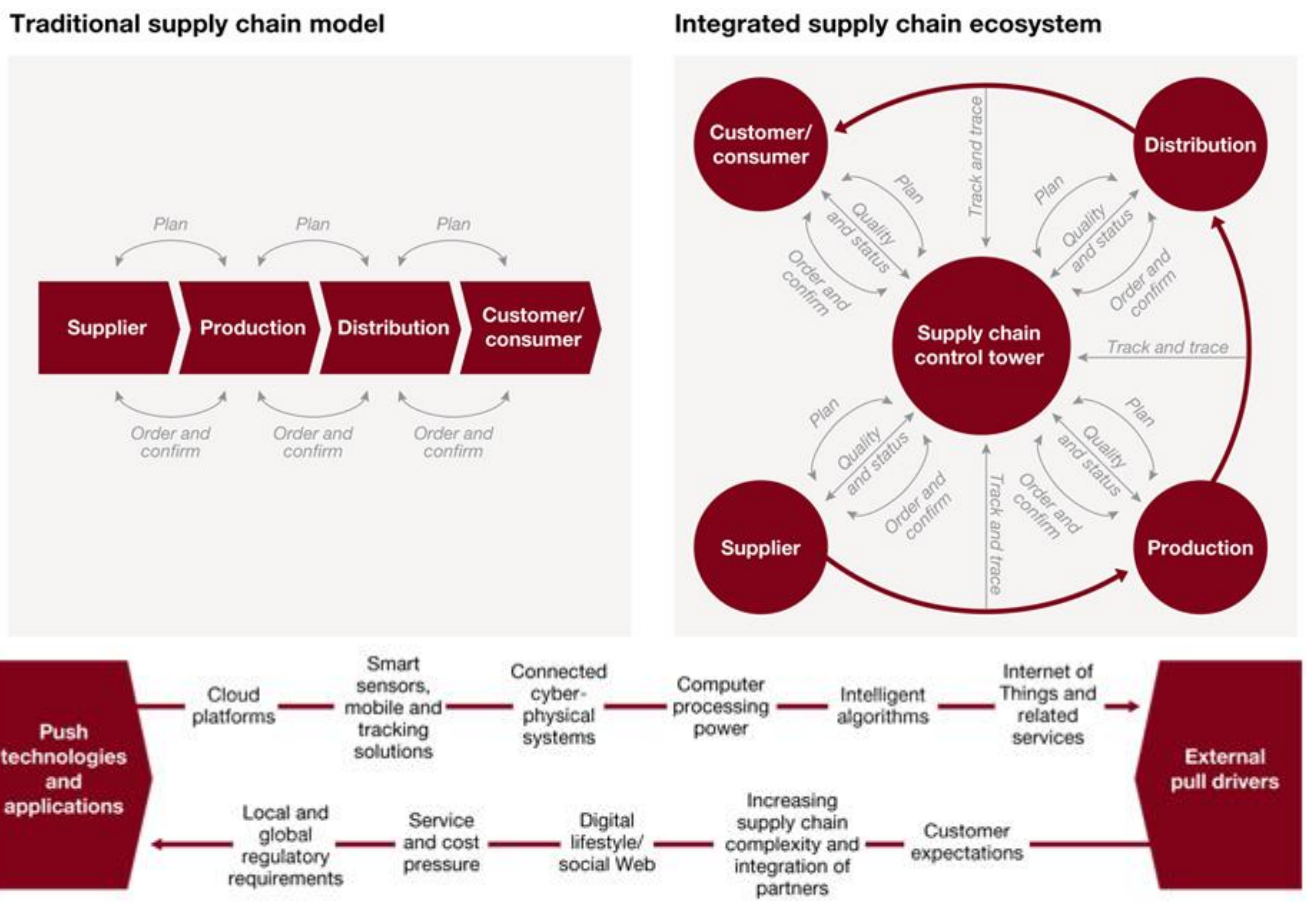
2018. 10. 19.

KIST Korea Institute of Science and Technology
한국과학기술연구원 강릉분원
천 연 물 연 구 소

농산업 value chain의 **변화**

▮ 초연결, 지능화, 고효율 방식으로의 전환을 위해서는 **모든 요소 정보의 Digitalization 필요**

Exhibit 3
The digitally enabled supply ecosystem vs. traditional linear supply chain

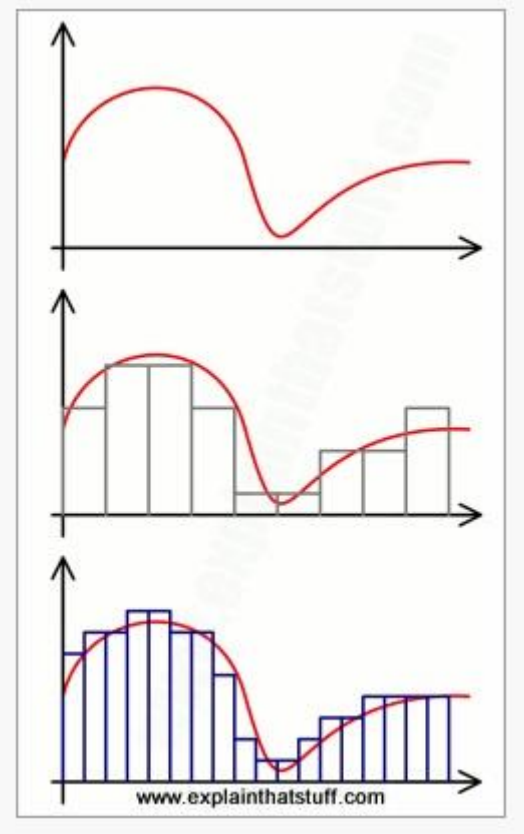


Source: Strategy& analysis

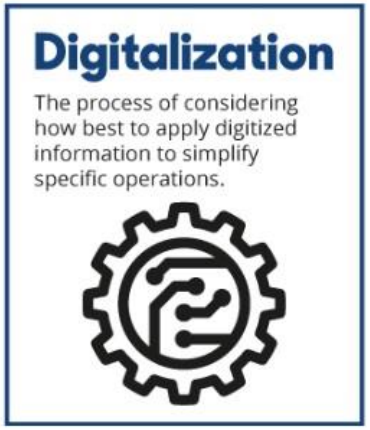
http://image.slideserve.com/694340/slide4-l.jpg

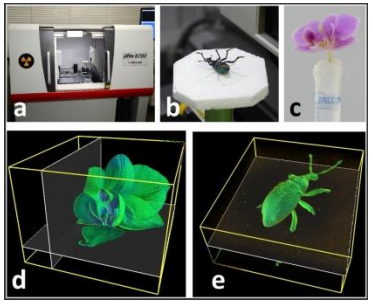
Digitalization의 개념

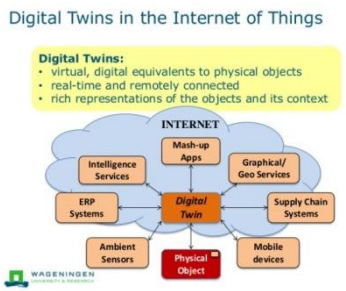
Analog vs Digital

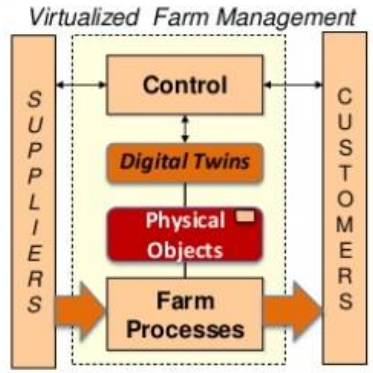


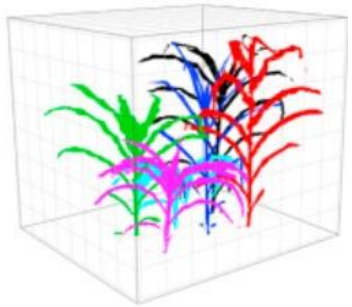
Digitalization: Digital-Physical 현상의 결합





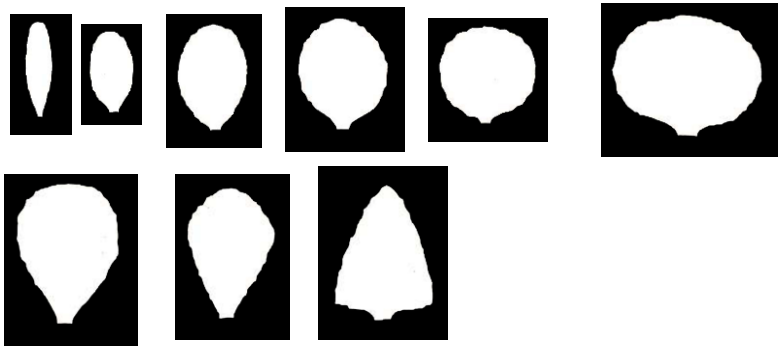




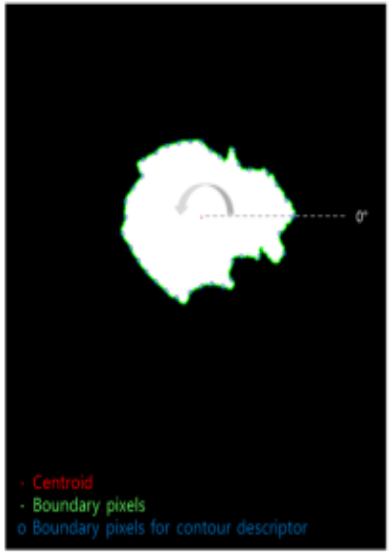


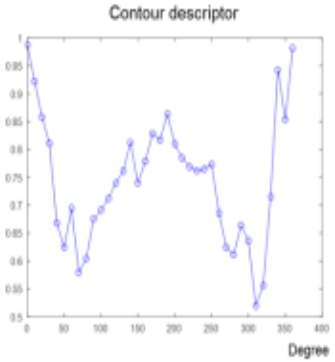
Digitization vs digitalization

Legacy approach

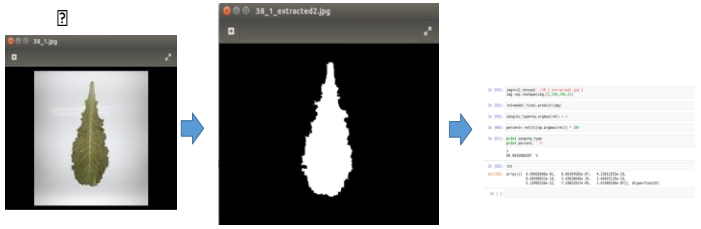


- Contour Descriptor





Deep learning model



Paradigm shift in agriculture

Digital agriculture - opportunities

- Agfunder (online investment market place) invested 230 millions dollars* for agtech startups
  *more than 70 % increase over 2015 - Nature Biotechnology (2017) 35:397
- Bayer + Monsanto => Bayer / Digital 종자 기업
  Pioneer + Dow AgroScience => Corteva Agriscience / Digital Agriculture divisions
  ChemChina + Syngenta => Syngenta / AgriEdgeExcelsior (S)

United Nations Global Compact

Source: http://breakthrough.unglobalcompact.org/site/assets/files/1332/hhw-16-0025-d_n_digital_agriculture.pdf

Paradigm shift in agriculture

Digital farming – definition &

7 Factors That Could Make or Break Digital Farming

By: **Michael R. Collins**

April 13, 2018

Email Print Facebook 54 LinkedIn Google Twitter

Digital farming is the new technology genie – a genie that is now out of the bottle and cannot be put back. It is the overarching concept that embraces the precision afforded by global positioning, integrates the resolution and fidelity of new sensors and controls, and unleashes the economics, computer horsepower, and storage capabilities of the digital revolution — the now-emergent fourth Industrial Revolution, an Agricultural Revolution. Digital farming is the digital modeling of the entire cultivation – i.e., "a digital twin," a digital replica of physical assets, processes, and systems. And its integration with a farm management system in a digital ecosystem enables all stakeholders to investigate alternatives and generate decision-quality information when it is most critical, before the need arises.

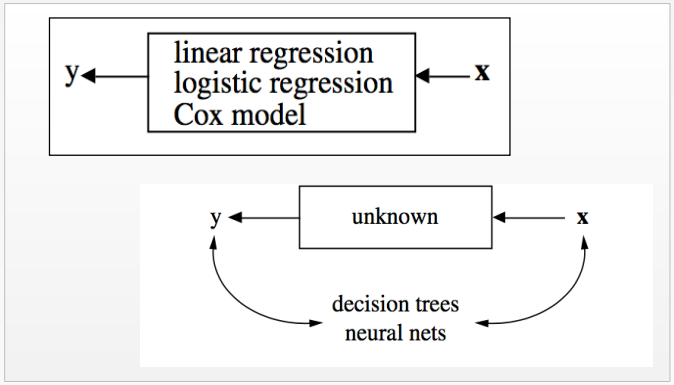
- "**Digital description of the seed or crop.** Fifth, the seed or the crop to be grown needs to be digitally described and a body of growth metrics develo ped that characterize the cultivation of that crop and variety."

Source: http://www.precisionag.com/author/michael-r-collins/

Data analysis– Deep learning vs. Machine learning

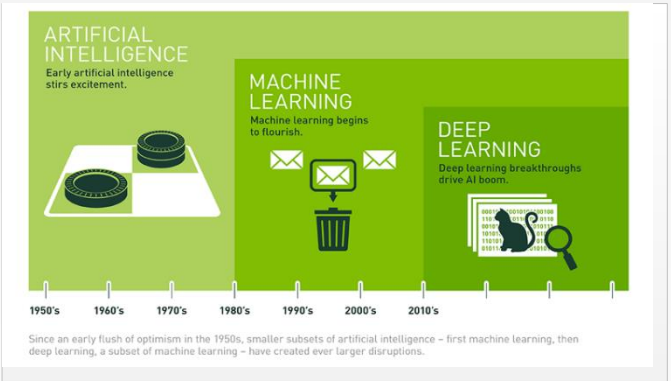
Concept

Statics VS. ML



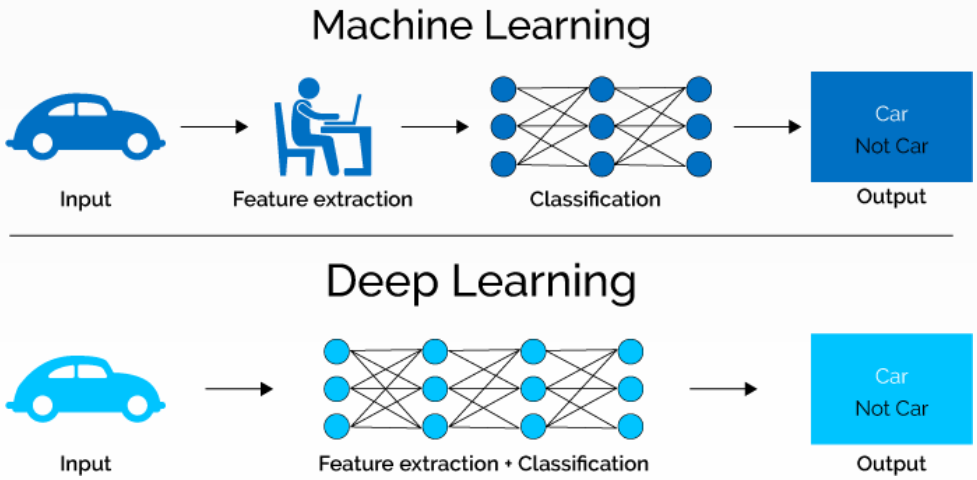
Sources: *Statistical Science* (2001) **16**, 199-215

Brief history



Sources: https://blogs.nvidia.com/blog/2016/07/29/whats-difference-artificial-intelligence-machine-learning-deep-learning-ai/

ML VS. DL



Sources: https://medium.com/swlh/ill-tell-you-why-deep-learning-is-so-popular-and-in-demand-5aca72628780

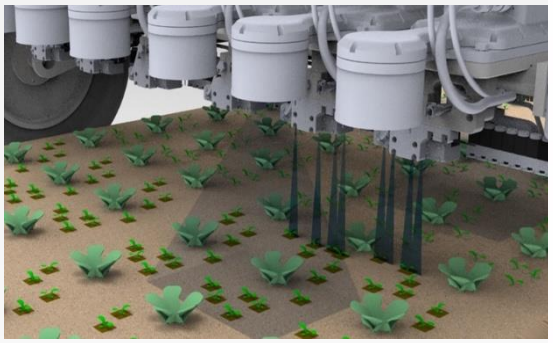
Digital Phenotyping

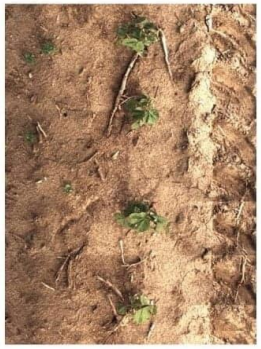
Digital phenotyping

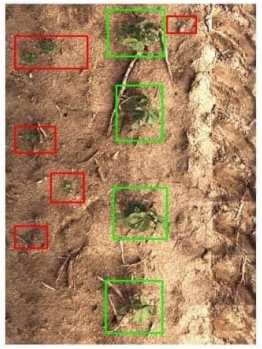
TOM SIMONITE BUSINESS 09.06.17 08:23 PM

WHY JOHN DEERE JUST SPENT $305 MILLION ON A LETTUCE-FARMING ROBOT

BLUE RIVER TECHNOLOGY

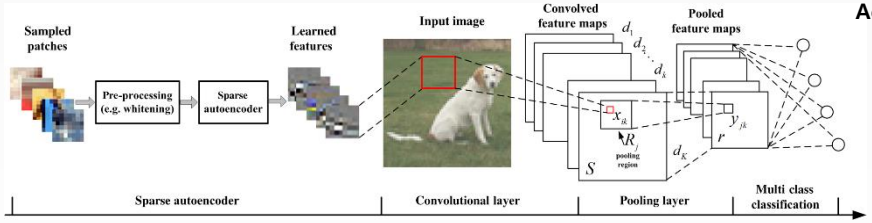






Source: http://www.bluerivertechnology.com

Suspected frame work (DL architectures)



Actuators	Spay
Off	Off
Off	Off
Off	Off
ON	O
Off	N
Off	Off
	Off

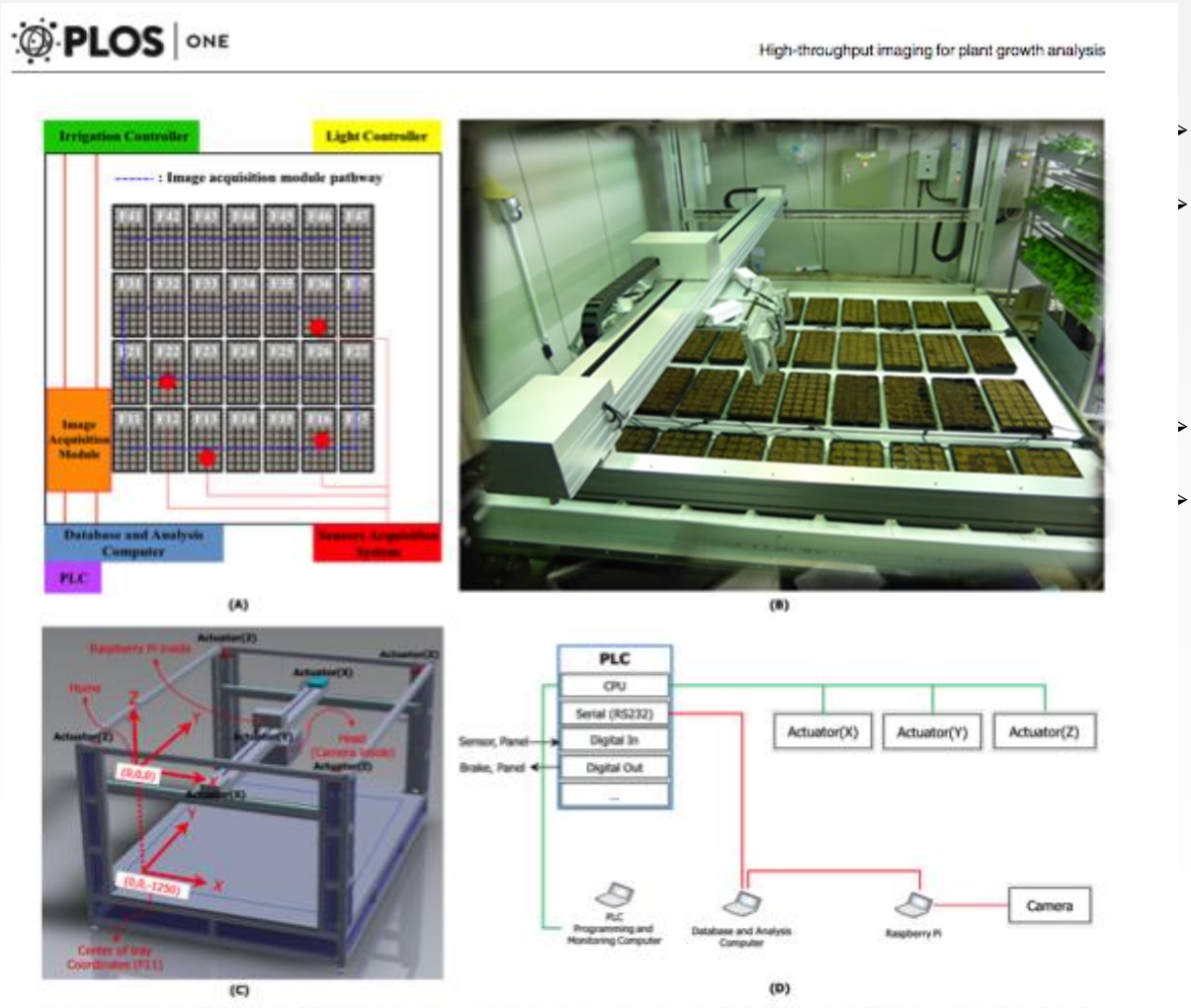
Source: J. of Electronic Imaging, 25(2),02318 (2016)

- "LOOK OUT WEEDS. Tractor giant John Deere just spent $305 million to acquire a startup that makes robots capable of identifying unwanted plants, and shooting them with deadly, high-precision squirts of herbicide".

Source: https://www.wired.com/story/why-john-deere-just-spent-dollar305-million-on-a-lettuce-farming-robot/

KIST digital phenotyping experiment I

Sensor to plant type (XYZ)



- Designed in 2012
- Equipped with cutting-edge motors and sensors
- Construct platform in 2013
- Major upgrade platform
  I. 2015 (Top camera)
  II. 2017 (LED lighting)
  III. 2018 (New sensors)

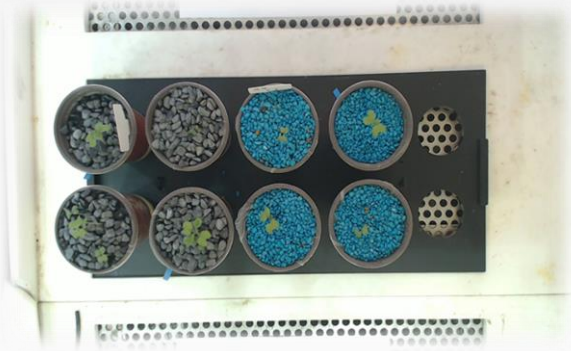
Source: *PLOS ONE* (2018) **13**, e0196615

KIST digital phenotyping experiment I

Sensor to plant type (XYZ)

Lighting problem

Background problem

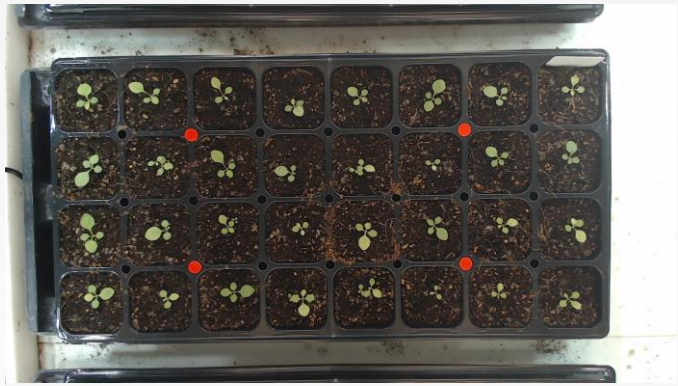


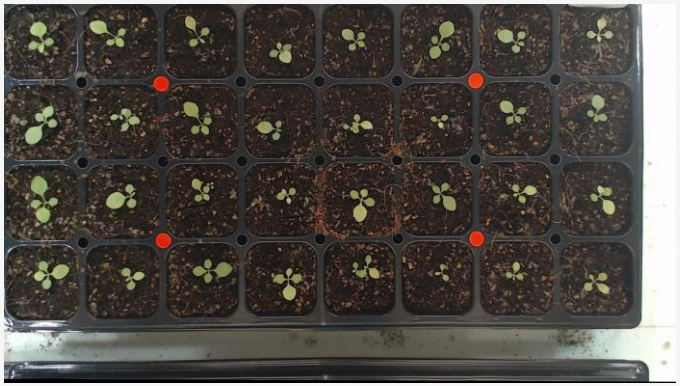
Positioning problem

KIST digital phenotyping experiment I

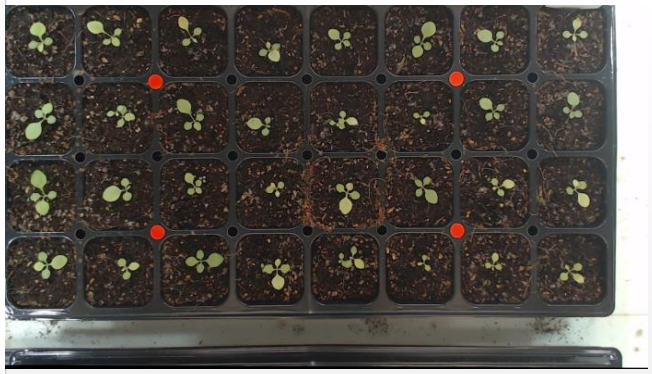
Pre-processing

Image warping - python





Cropping - python



Source: *PLOS ONE* (2018) **13**, e0196615

KIST digital phenotyping experiment I

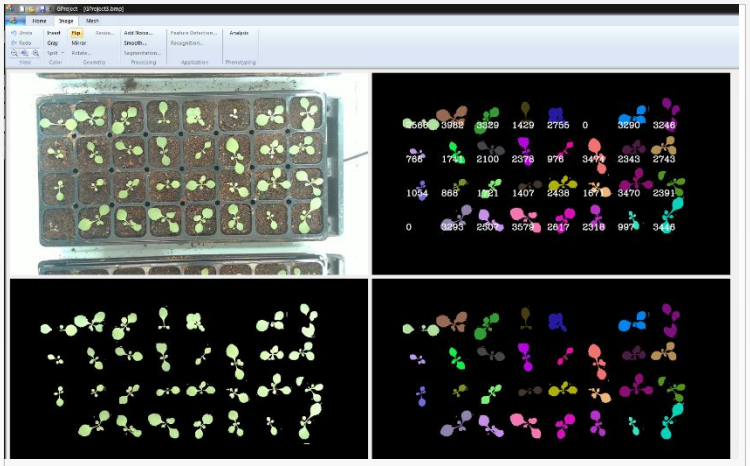
Sensor to plant type (XYZ)

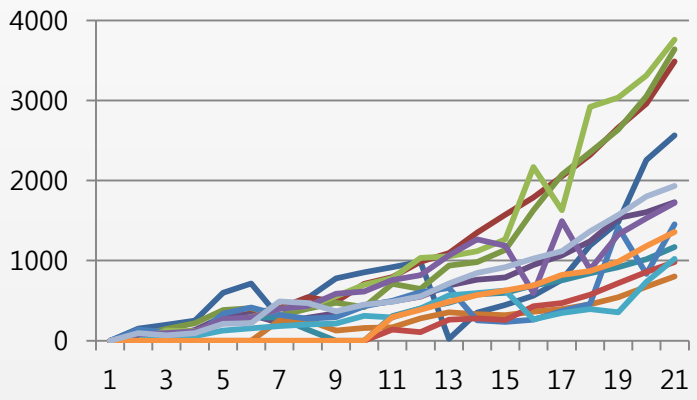
	Camera type (2015)	Lighting (2017)	Sensors (2018)
OLD	 3D depth camera	 Metal	 Single top view camera
NEW	 Top view HD camera	 LED	 Adjustable head Multiple cameras Load cells

KIST digital phenotyping experiment I

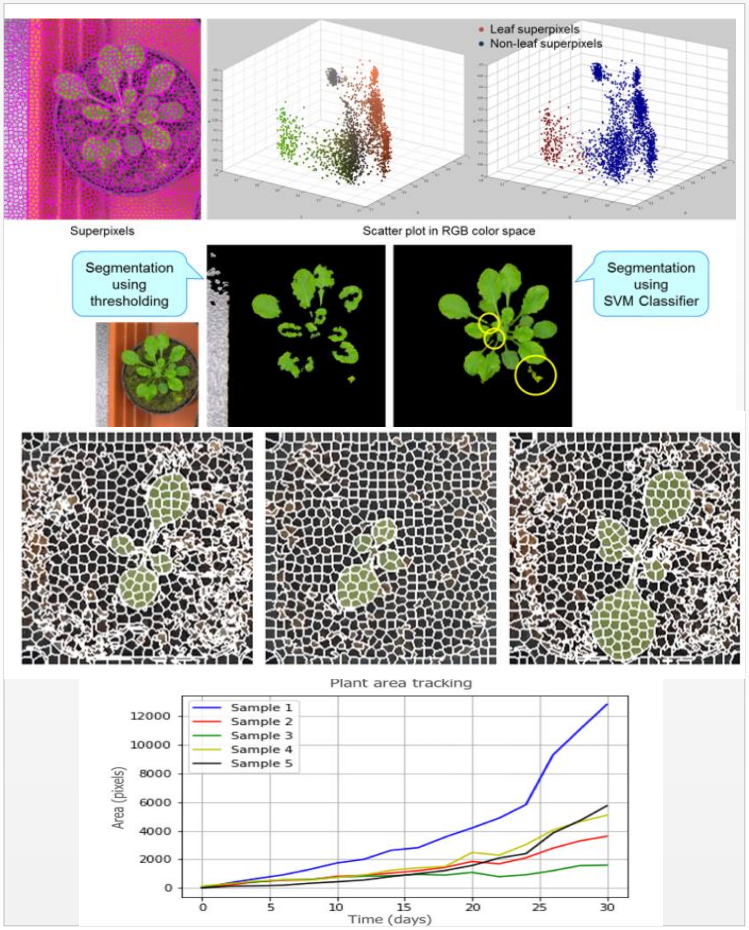
Legacy & Superpixel method

Legacy method – visual studio





Superpixel

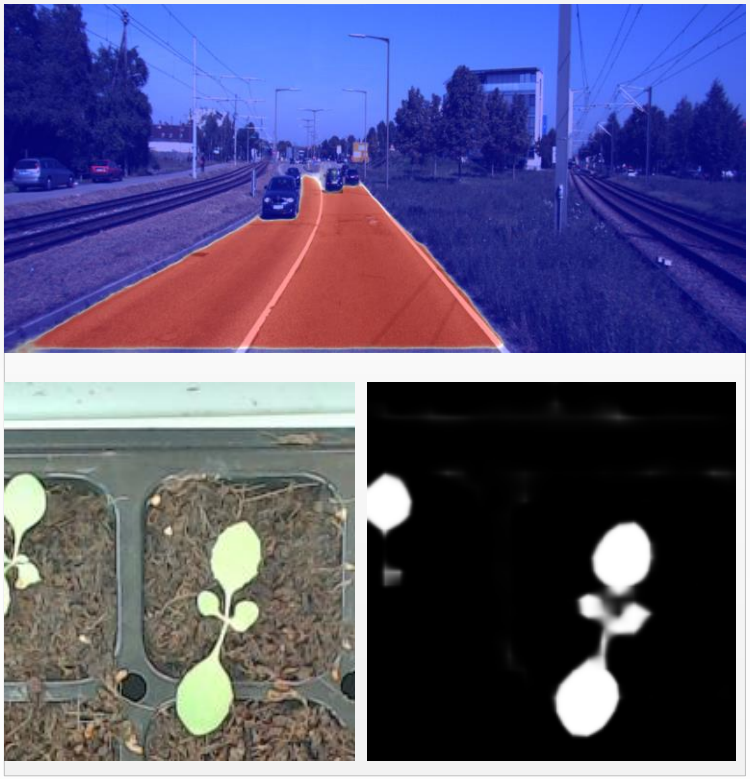


Source: *PLOS ONE* (2018) **13**, e0196615

KIST digital phenotyping experiment I

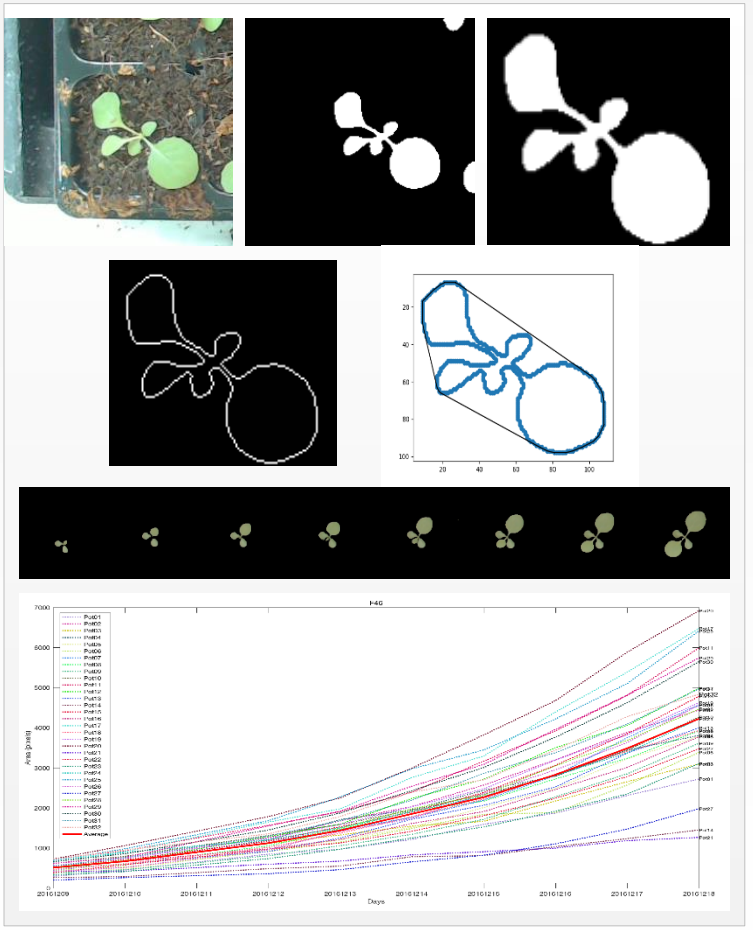
Deep learning (DL) - kittiseg & xx

Kittiseg



Source: https://github.com/MarvinTeichmann/KittiSeg

XX network

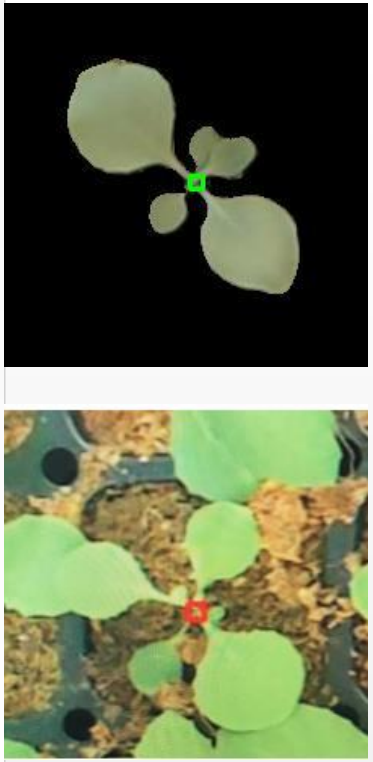


Source: Chang., et al (201X). Manuscripts preparation

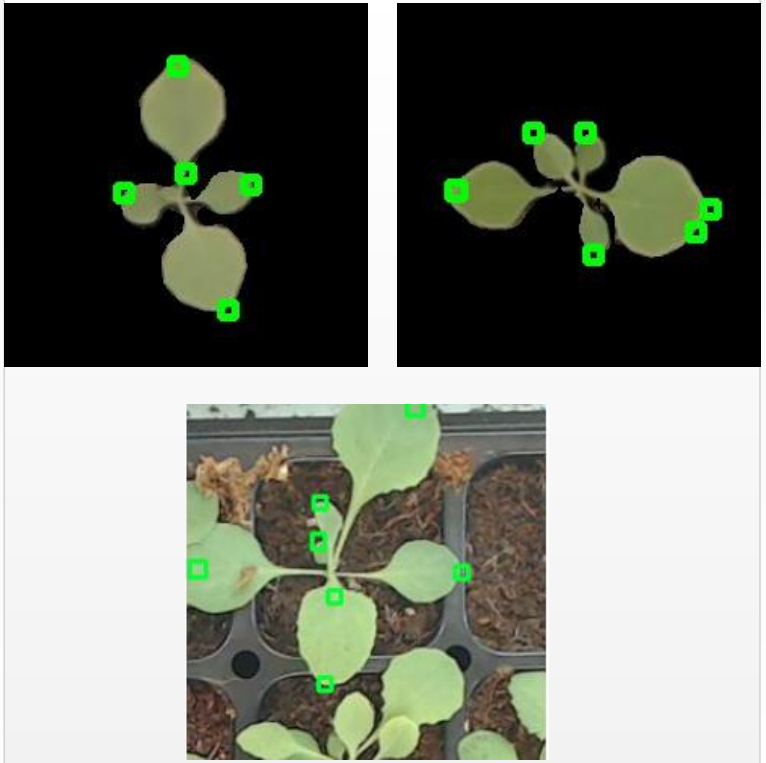
KIST digital phenotyping experiment I

Modified DL

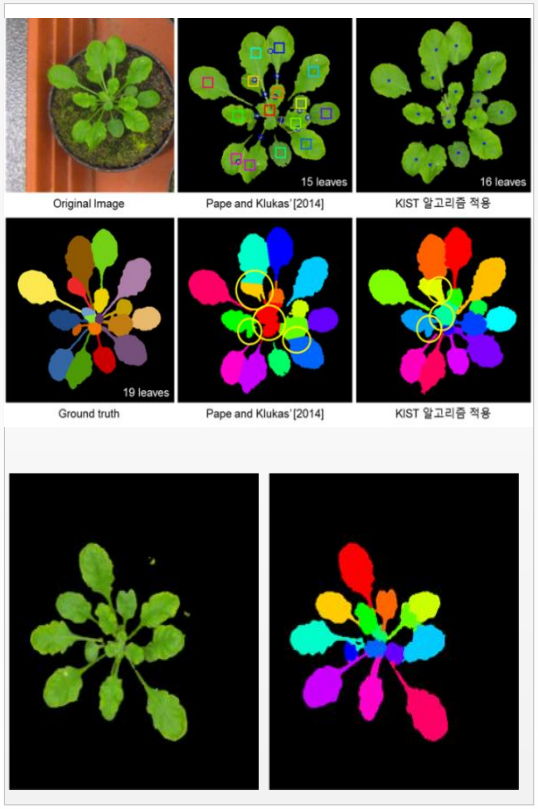
Center detection



Edge detection



Tracking

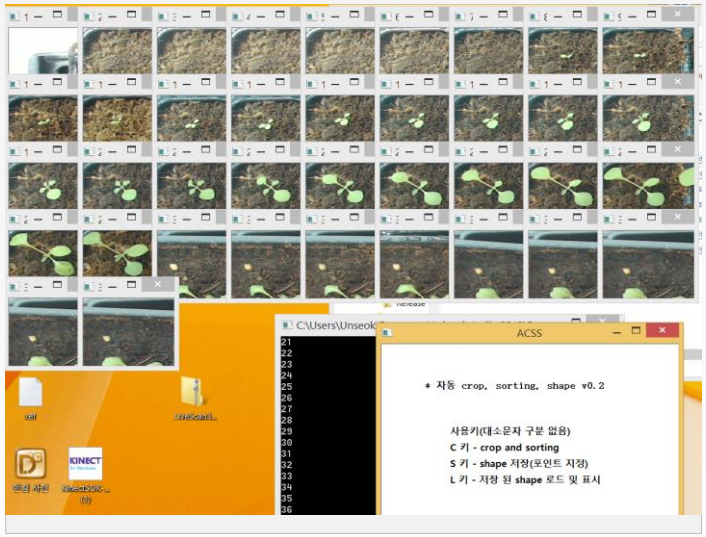


Source: Lee., et al (2018). In press

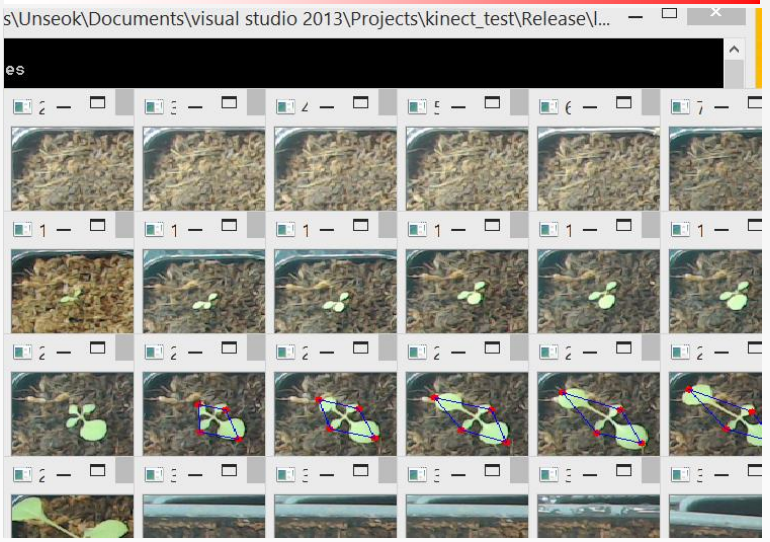
KIST digital phenotyping experiment I

Semi-automatic method

1. Load cropped data



2. Point (center & edge) selection



3. Saved point for further analysis

Point1: 79 (X), 141 (Y)
Point2: 101 (X), 131 (Y)
Point3: 111 (X), 106 (Y)
Point4: 117 (X), 138 (Y)

Point 1: 81 (X), 139 (Y)
Point 2: 105 (X), 115(Y)
Point 3: 125 (X), 83 (Y)
Point 4: 163 (X), 131 (Y)
Point 5: 42 (X), 76 (Y)
Point 6: 105 (X), 128 (Y)

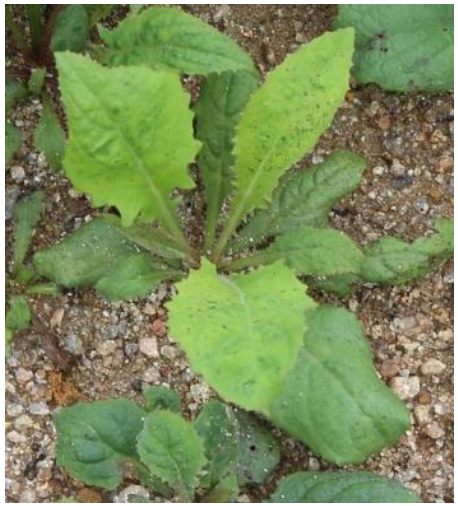
Source: Chang., et al (201X). Manuscripts preparation

KIST digital phenotyping experiment I

- **후보소재1: 이고들빼기**

  - 선행기술: 이고들빼기 추출물 함류 간 기능 개선용 건강 기능식품 소재
  - 제품화 진행: 임상시험 진행 중 (2019년 상반기 출시 예정)
  - 유전자원 확보 현황: 강원도 군락 형성 10개 ecotype에 대한 유전자원 확보
  - 선행연구: 주요 성분 및 활성 분석법 확립
    10개 유전자원에 대한 DNA 분석, 집단 간 성분 및 생육분석 데이터 기 확보

이고들빼기 원료 노지 재배 사진 (phenotypic variation)

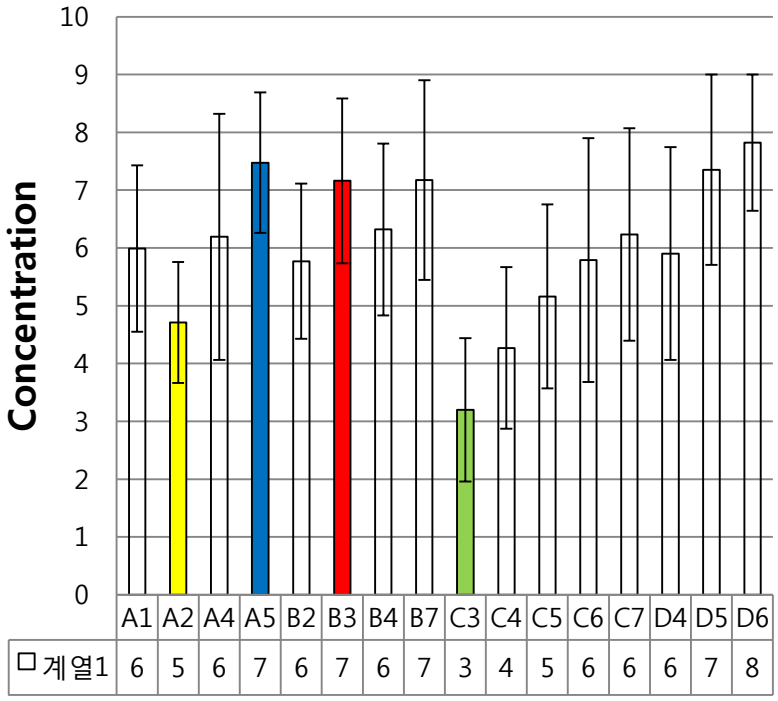




KIST digital phenotyping experiment I

- **후보소재1: 이고들빼기**

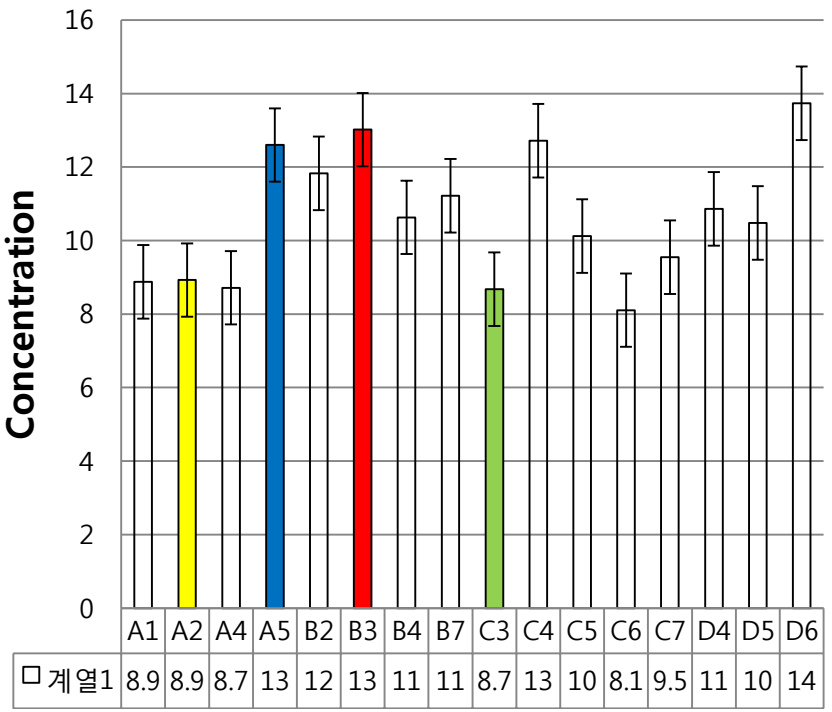
이고들빼기 유전자원 별 주요성분 함량 variation

Chlorogenic Acid



	A1	A2	A4	A5	B2	B3	B4	B7	C3	C4	C5	C6	C7	D4	D5	D6
계열1	6	5	6	7	6	7	6	7	3	4	5	6	6	6	7	8

Chicoric Acid

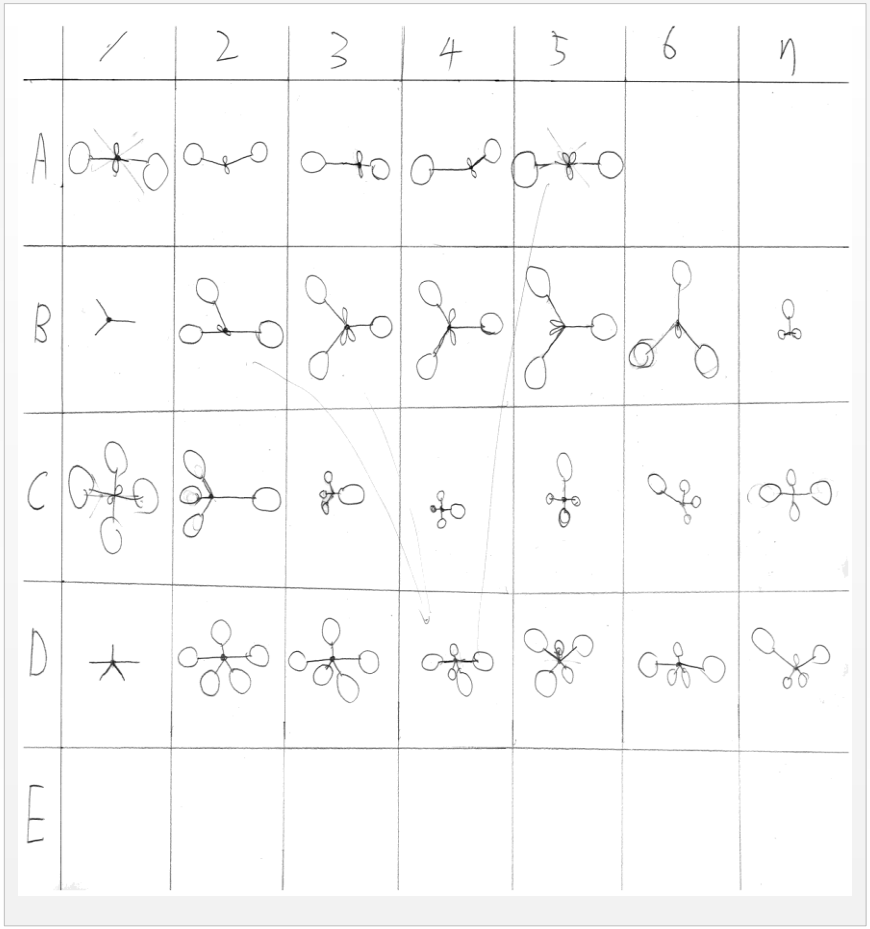


	A1	A2	A4	A5	B2	B3	B4	B7	C3	C4	C5	C6	C7	D4	D5	D6
계열1	8.9	8.9	8.7	13	12	13	11	11	8.7	13	10	8.1	9.5	11	10	14

KIST digital phenotyping experiment I

Sensor to plant type (XYZ)

Classification definitions



Classification

X = 식물없음
?? = 크기작아 판단어려움
??? = 구분이 안됨

식물두종류 = △

V002 (F12)

A1	A2	X	A1	X	C4	A4	A4
A2	??	A3	C5	A2	A4	A4	B7
???	A2	A4	C4	C6	C4	C6	X
A1	A2	A4	A2	A4	C3	C3	B7

V003 (F13)

A3	C2	X	D4	C3	D5	C5	C5
D2	C5	D2	C4	D4	D4	A2	C6
D3	D3	C2	D4	B7	A5	A5	C3
B7	A5	C5	C7	C5	??	C5	X

V004 (F14)

D5	C3	D4	B4	D6	D4	A1	B7
D3	D6	C5	D6	D4	D4	C3	X
D4	D6	132	D5	D4	D6	A4	C3
A2	A2	???	D4	D4	B4	C5	C5

V005

△	B2	△	D4	D4	B3	A2	B7
△	△	△	△	D6	X	X	A3
△	??	D4	X	A3	△		C7
B7	△	D4	X	??	??	C7	A1

V006

D6	C5	D6	B4	B4	D4	B2	B2
D5	D4	C7	B4	D4	B3	???	D4
C7	A2	D6	B4	C7	D5	D6	D6
D7	C7	B3	B4	B3	C5	D5	B2

V00n

C7	B3	C7	C7	B4	C4	D4	???
C7	D4	B7	B7	D4	B3	C7	???
B6	△	D4	△	C7	B3	B6	B4
D4	C7	B3	D4	D4	???	D6	B4

KIST digital phenotyping experiment I

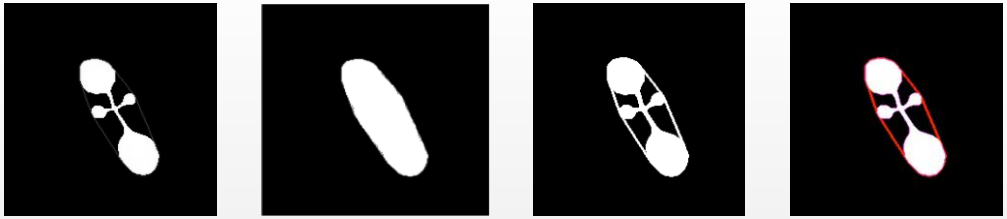
Sensor to plant type (XYZ)

Dimension

One Scalar

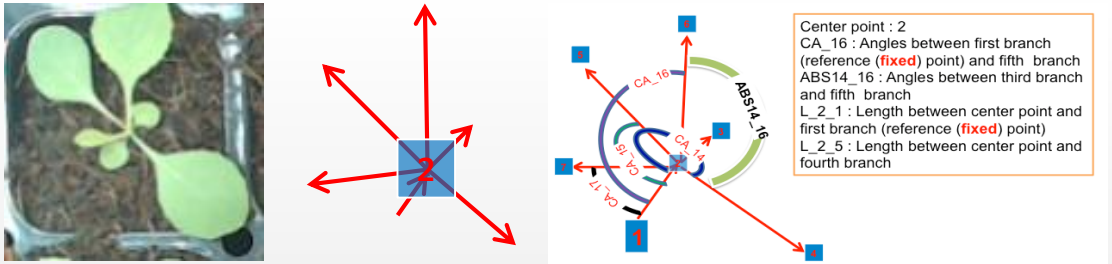
Basic features

Projected Area | Convexhull Area | Compactness | Convexhull_perimeter



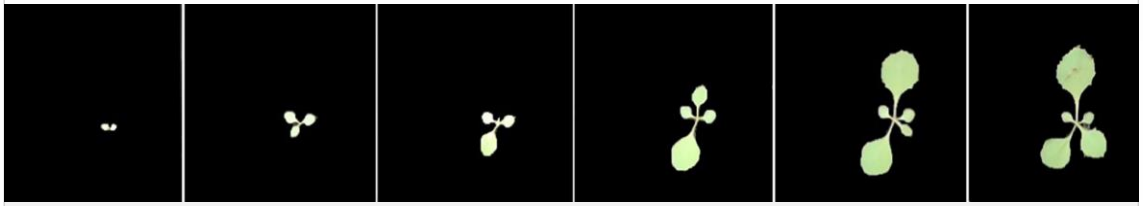
Principal features

Two Vector



Dynamics features

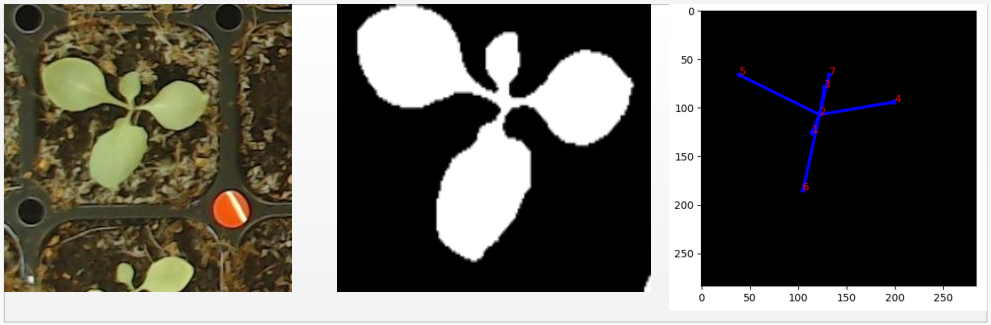
Three Tensor



KIST digital phenotyping experiment I

Visual studio / C++

Re-construction



All feature file (CSV)

TrayID	PotID	Year	Date	Time	L_2_1(cm)	L_2_3(cm)	L_2_4(cm)	L_2_5(cm)	L_2_6(cm)	L_2_7(cm)	A_13(degree)	A_14(degree)	A_15(degree)	A_16(degree)	A_17(degree)	ectedArea(c	rexHullA	rea(mpactness(cr	kHullP	erimetbur	Perimete	ABS_13_14	ABS_13_15	ABS_14_15	ABS_14_16	ABS_15_16	ABS_14_17	ABS_15_17	ABS_16_17
F24	Pot23	2015	1119	11	0.61032778	0.91787799	2.66270539	3.04138127	3.48209707	0.6	185.634267	90.7051432	277.584445	140.824407	34.9920202	10.695	14.83875	0.72074804	15.323544	21.7287841	94.9291235	91.9501781	186.879302	50.1192636	136.760038	55.713123	242.592425	105.832387
F24	Pot23	2015	1120	11	0.6726812	0.8845903	2.86006993	2.99666481	4.10030487	0.98234414	179.277823	95.5179781	286.277259	147.548723	27.2436497	12.2525	17.10375	0.71636337	16.5340052	23.9894442	83.7598444	106.999436	190.759281	52.0307447	138.728536	68.2743285	259.033609	120.305073
F24	Pot23	2015	1121	11	0.81394103	0.95524866	2.77353565	3.17529526	4.49944441	1.38654246	179.631544	98.533903	286.348881	147.318824	16.8694413	14.1925	19.64375	0.72249443	17.6690543	26.4036578	81.0976405	106.717337	187.814978	48.7849211	139.030057	81.6644618	269.479439	130.449383
F24	Pot23	2015	1122	11	0.78262379	0.90138782	2.66270539	3.26534837	4.82700735	1.95576072	172.874984	82.2781742	271.177145	129.737605	354.093859	16.145	22.04	0.73253176	18.8097133	28.8521859	90.5968095	98.3021612	188.898971	47.4594304	141.43954	271.815685	82.916714	224.356254
F24	Pot23	2015	1118	13	0.68007353	0.9617692	2.61007663	2.77353565	2.91204396	0.38078866	188.130102	89.5965153	278.076404	141.972769	12.8287829	9.39	12.94875	0.72516652	14.2127238	20.5338094	98.5335871	89.946302	188.479889	52.376254	136.103635	76.7677324	265.247622	129.143986
F24	Pot23	2015	1119	13	0.75	0.9617692	2.66270539	2.99708191	3.51069794	0.52201533	188.972627	92.5830207	279.022319	144.272602	20.1706534	10.8	15.04875	0.71766758	15.4580253	22.0116268	96.3896059	90.0496928	186.439299	51.6895811	134.749718	72.4123673	258.851666	124.101948
F24	Pot23	2015	1120	13	0.71063352	0.93941471	2.54017716	3.19765539	4.01808412	1.0511898	205.50947	104.517386	293.744879	157.341547	25.3644172	12.465	17.39125	0.71673974	16.6668164	24.1601549	100.992084	88.2354092	189.227493	52.824161	136.403332	79.1529686	268.380462	131.97713
F24	Pot23	2015	1121	13	0.90138782	1	2.70416346	3.15317301	4.47493017	1.36565003	176.82017	90	276.312365	137.260502	9.94057303	14.2725	19.74625	0.72279547	17.7530154	26.5208151	86.8201699	99.4921949	186.312365	47.2605019	139.051863	80.059427	266.371792	127.319929
F24	Pot23	2015	1122	13	0.79056942	0.93005376	2.78028776	3.26534837	4.80520551	2.06700266	178.441316	87.0009131	279.307247	136.706632	2.54285839	16.3025	22.60375	0.72122988	18.8517271	29.200714	91.4404027	100.865931	192.306334	49.7057188	142.600615	84.4580547	276.764389	134.163774
F24	Pot23	2015	1118	19	0.76321688	0.93941471	2.68001866	2.70601183	3.16741219	0.40311289	186.406379	84.9513938	274.0955	133.449578	24.4824859	9.645	13.22	0.7295764	14.4617444	20.6459414	101.454985	87.689121	189.144106	48.4981846	140.645921	60.4689079	249.613014	108.967093
F24	Pot23	2015	1119	19	0.71063352	1.01242284	2.69118933	3.06471858	3.82001309	0.45	186.384164	94.1229708	281.051961	143.689428	39.2894069	11.27	15.70875	0.71743455	15.9121024	22.5116268	92.2611931	94.6677974	186.928991	49.5664574	137.362533	54.833564	241.762554	104.400021
F24	Pot23	2015	1120	19	0.68007353	0.96046864	2.65047166	3.15356941	4.29330875	0.86313383	177.367565	90.2383999	280.681197	140.872826	26.0193936	12.975	17.9225	0.72395034	17.0697894	24.6551297	87.1291652	103.313632	190.442798	50.6344256	139.808372	64.2190064	254.661804	114.853432
F24	Pot23	2015	1121	19	0.76157731	0.89022469	2.68001866	3.17529526	4.56097577	1.18532696	165.041364	76.5424821	267.037024	125.863654	355.552615	14.3975	19.62625	0.73358385	17.8940446	26.3208151	88.4988818	101.99566	190.494542	49.3211722	141.17337	279.010133	88.515591	229.688961

ID Time Principal features Basic features Combined features

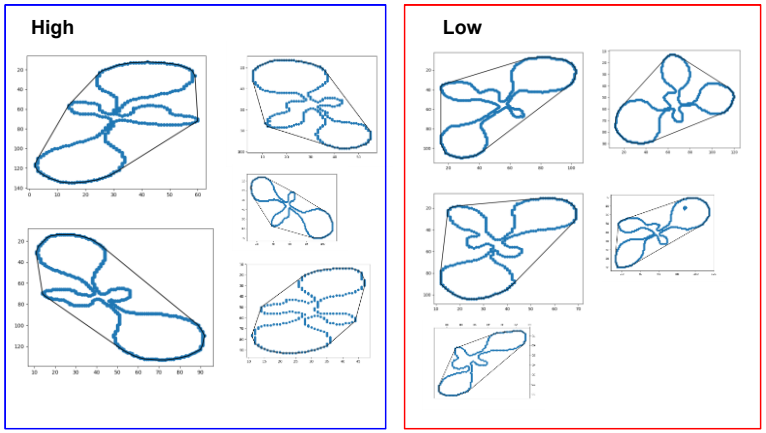
Source: Chang., et al (201X). Manuscripts preparation

KIST digital phenotyping experiment I

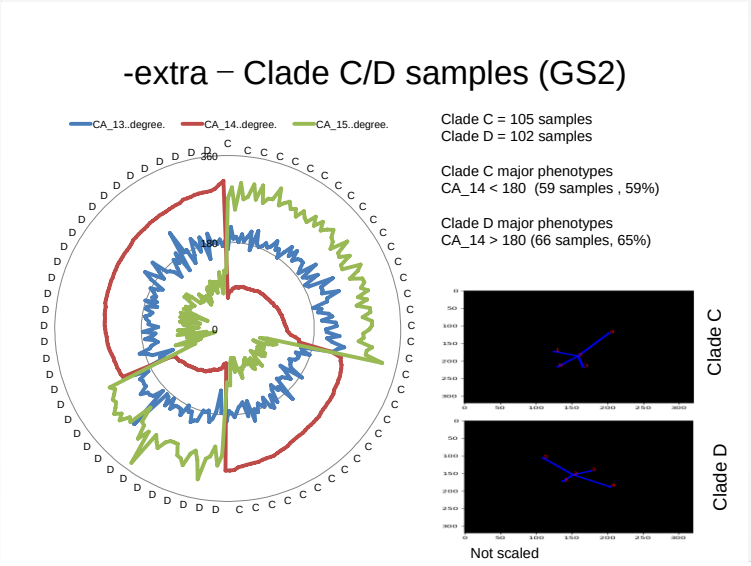
Sensor to plant type (XYZ)

Chemotype characteristics

Supplementary Fig. F3. Visualized low and high three major metabolites by geometry shape of a plant



Population characteristics



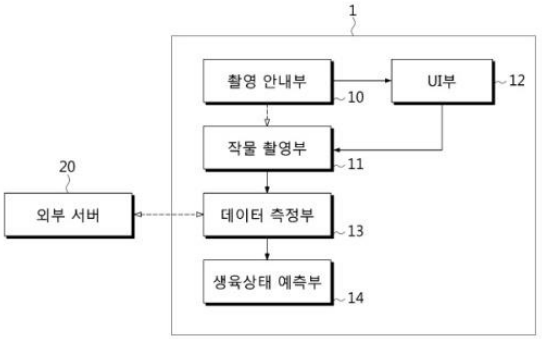
Source: Chang., et al (201X). Manuscripts preparation

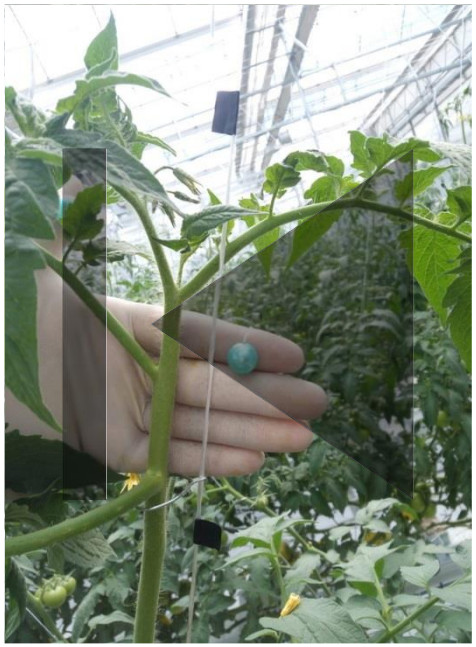
디지털 작물 정보의 활용: 스마트팜 작물 생육측정

영상기반 작물 생육데이터 측정

▮ 스마트팜 작물 생육측정을 위한 가이드 및 체계 제공

- 생육단계를 거치는 모든 작물의 생육측정에 있어 보편적으로 적용되는 체계
- 개화, 착과 등의 측정이 요구되는 과채류 작물에 적용되는 보편적 가이드
- 토마토, 딸기 , 파프리카 생육정보 및 병해/장애 영상 취득 어플리케이션 보급 중
- 아이디 로그인을 통한 농장기본정보, 사용자 정보 DB화





KIST 확보 기술

측정지표/매주 측정

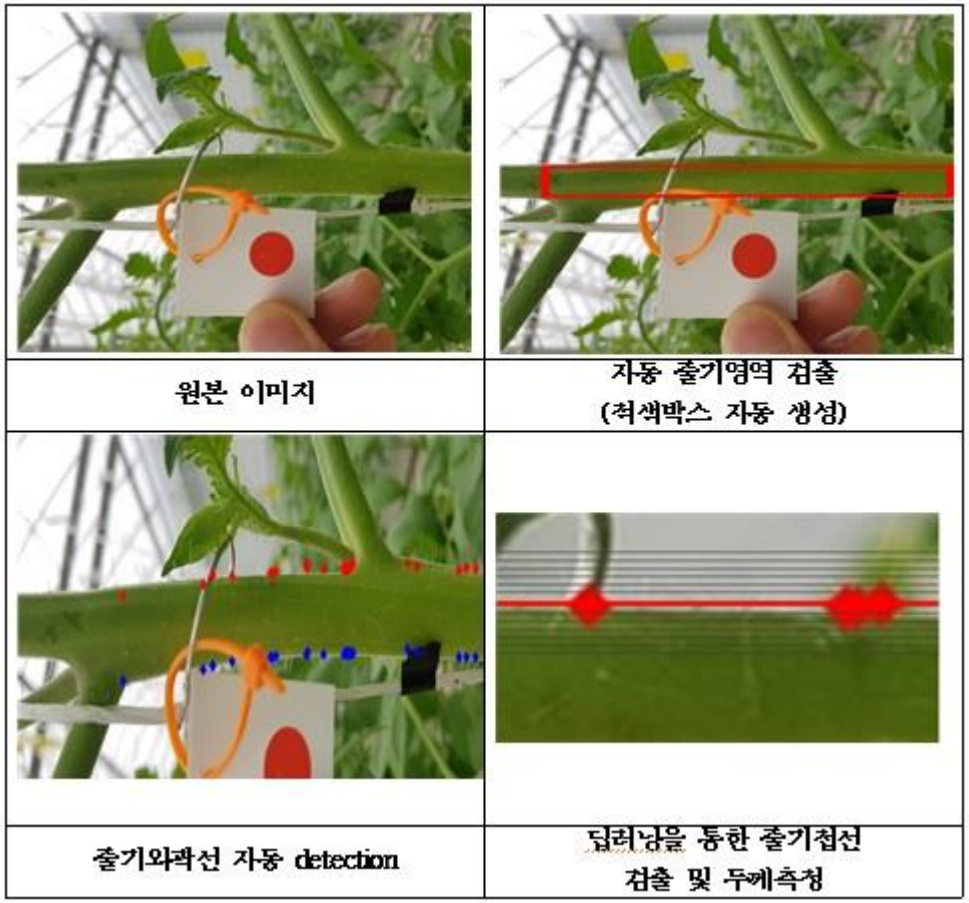
데이터 종류	토마토	파프리카	딸기
영양생장 지표	생장길이 초장 줄기직경 (전 주 생장점 위치) 화방높이 (생장점에서 개화화방) 엽장 (생장점 하위 3엽) 엽폭 (생장점 하위 3엽)	생장길이 초장 줄기직경 기부직경 화방높이 마디길이/마디수 엽장/엽폭	엽수 엽면적 엽색 관부직경(현재 실측)
생식생장 지표	꽃 개수 꽃 개화여부 과실 개수 과실 과장 과실 과폭 화방 간 거리 적화/적과 수 수확과실 무게	꽃 개수 화뢰 형태 과실 개수 과실 과장 과실 과폭 화방 간 거리 적화/적과 수 수확과실무게	화뢰 수 꽃 수 착과 수 과실 과장 과실 과폭 수확과실 무게
병해충/생리장해 증상	증상 발생 엽/생장점	증상 발생 엽/생장점	증상 발생 엽/생장점
해충정보	끈끈이 (해충 종류, 발생밀도)	끈끈이 (해충 종류, 발생밀도)	끈끈이 (해충 종류, 발생밀도)

KIST 확보 기술

딥러닝 기반 생육지표 영상 분석 기술 개발

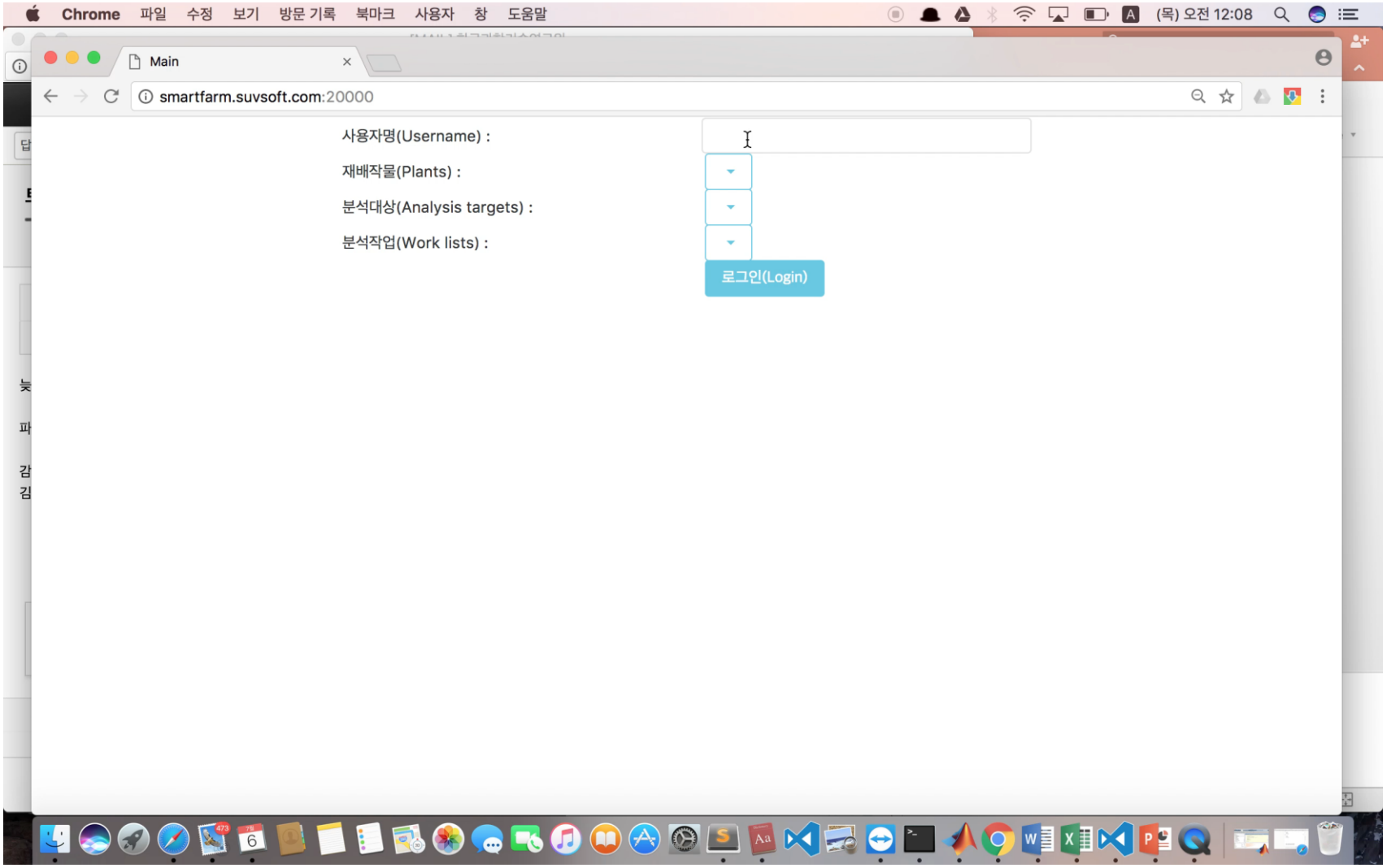
▮ 생육지표 별 딥러닝 기반 3차 학습 모델 SW 개발

- 구분이 힘든 영상 데이터 분석을 위한 강력한 인공지능 모델을 생성하여 측정치 정확도 향상
- 생육지표 별 공통의 인공지능 학습 모델 tool을 적용하여 범용성 확보



KIST 확보 기술

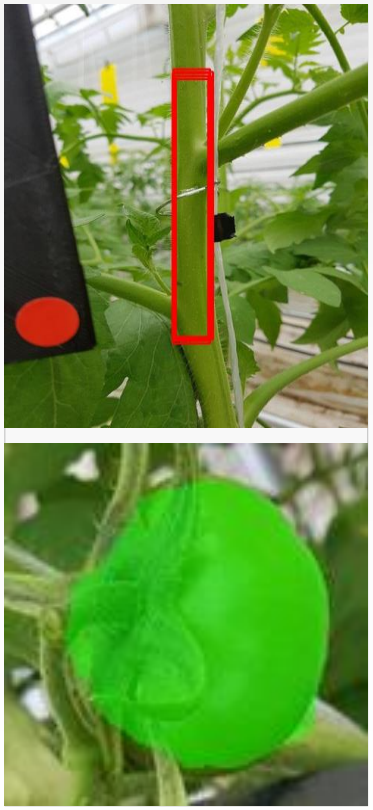
딥러닝 기반 생육지표 영상 분석 기술 개발



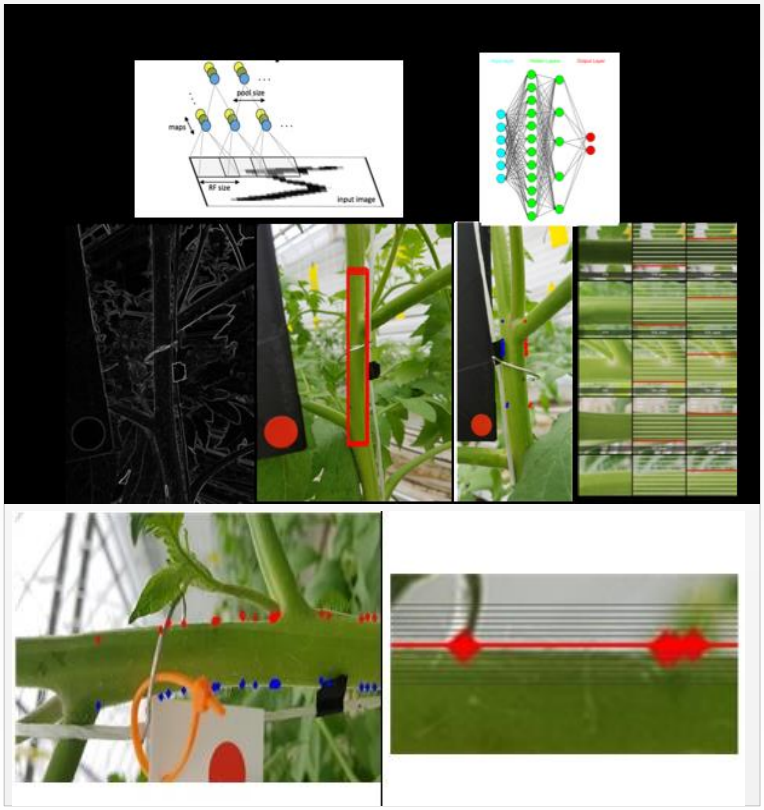
KIST portable device data – detection & measurement

Modified DL

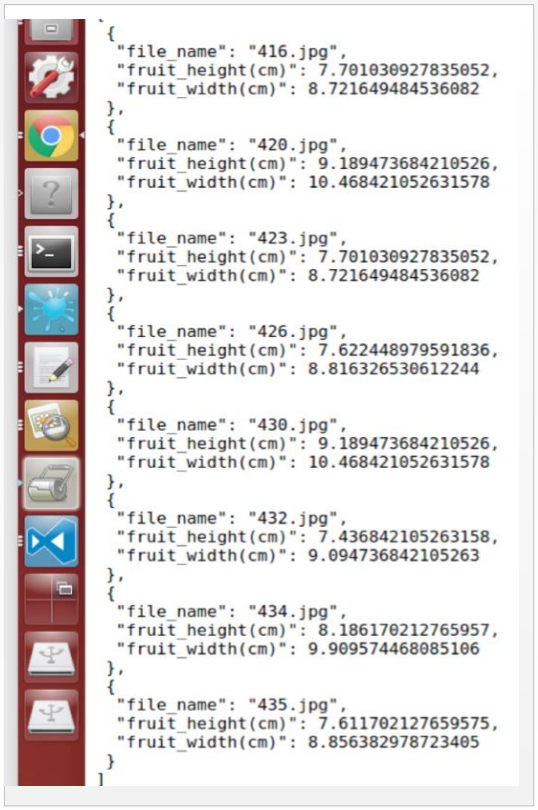
Object detection



Detection process



Measurement




```
{
 "file_name": "416.jpg",
 "fruit_height(cm)": 7.701030927835052,
 "fruit_width(cm)": 8.721649484536082
},
{
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 "fruit_width(cm)": 10.468421052631578
},
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}
]
```


Source: Lee., et al (201X). Manuscripts preparation

디지털 작물 정보의 활용: 스마트팜 작물 생육측정

생육정보 가시화 – (생식생장) 꽃수, 개화수준, 과실개수, 과실수준, 총화방수 등

◁ 농장 관리 페이지로
기본 정보
생육 정보
생장 갤러리
과실 체적량 예측
생산량 예측
센서 모니터링
센서 데이타 Export

생육 정보

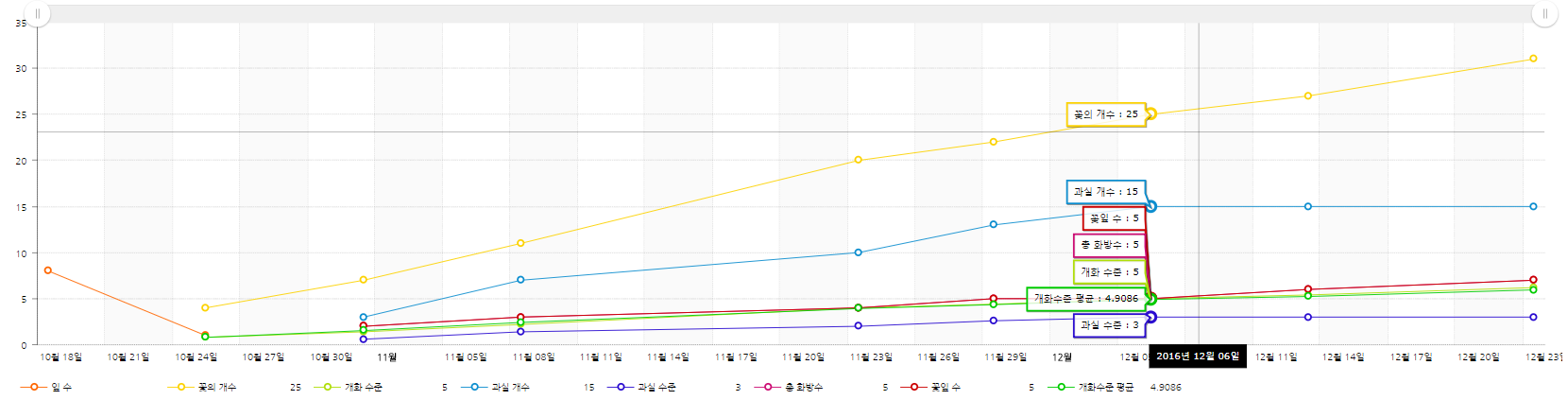
생육 정보 페이지 입니다. 업로드 된 생육정보 데이터를 그래프를 통해 시각화 합니다.

조회 설정

생장 타입	생식생장
조회 날짜	2016-06-01 ~ 2016-12-31
플랜트 ID	150

조회완료

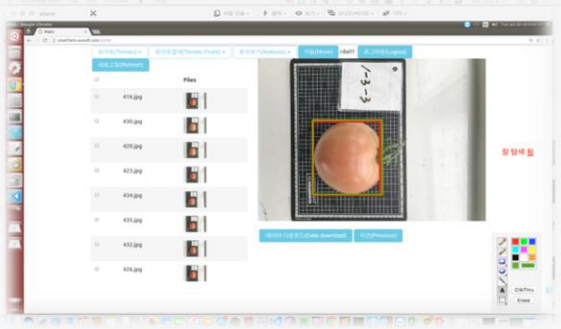
생장 그래프



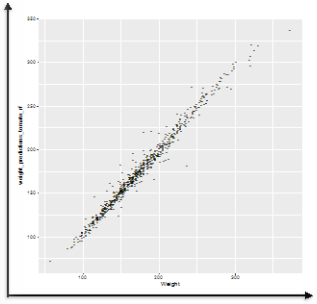
토마토 과실 영상정보를 통한 과실무게 예측

과실 무게예측 ML 모델

토마토 샘플 영상을 통한 ML모델 생성 및 검증



- Prediction with Random Forest (RF)
- Features (Height, Width, Volume), Target (y=weight)
- Result

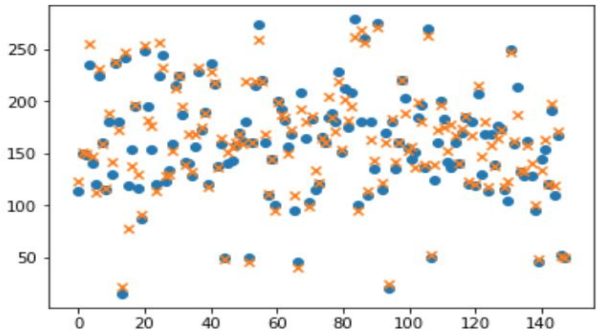



```
> tomato_predictions_rf
     RMSE      Rsquared
6.9906699   0.9785511

> varImp(tomato_weight.rf)
       Overall
Width  36.03414
Height 27.50649
Volume 31.71681
```

실제 생장 토마토 영상정보를 통한 무게 예측 검증

```
<matplotlib.collections.PathCollection at 0x116260ad0>
```

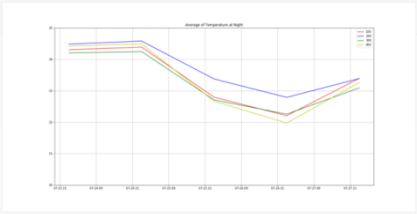



```
###### Cross Valdiation ######
score :  0.9330566528437283
score :  0.9157352112863907
score :  0.9683187405078538
score :  0.9571017011807285
score :  0.95662599762411
score :  0.969441216201044
score :  0.8307263872028888
score :  0.9506948652558285
score :  0.9237733597774429
score :  0.9696349369530012
mean score(r square) : 0.9375109068833017
```

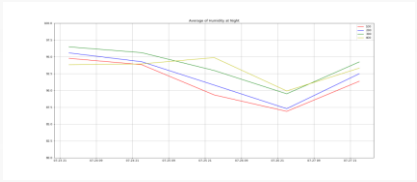
토마토 생육정보 분석을 통한 생장 예측 및 분석

환경에 따른 생장 예측

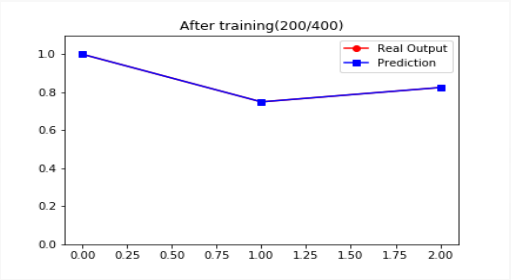
생육-환경정보 기반 생장 예측



<각 동별 온도변화>

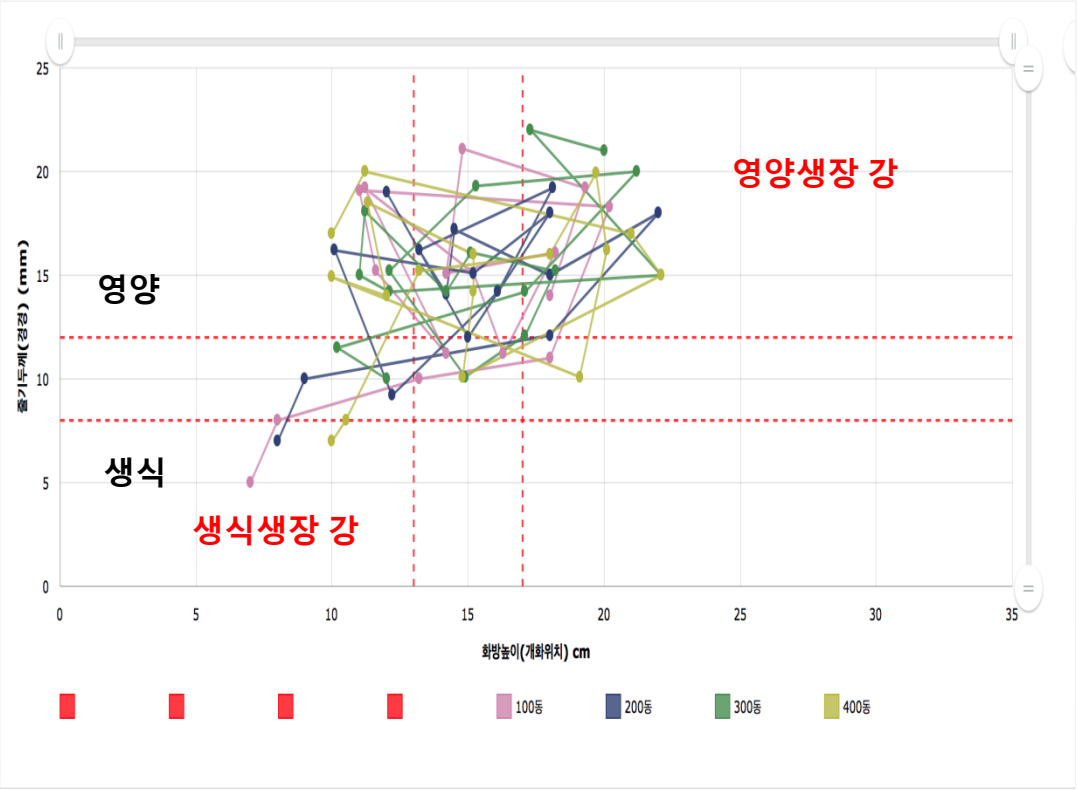


<각 동별 습도변화>



환경정보(온도/습도/EC 값)에 따른 줄기두께 변화 예측 (2일후)

생육정보 분석을 통한 토마토 영양-생식 생장 분석



감사합니다