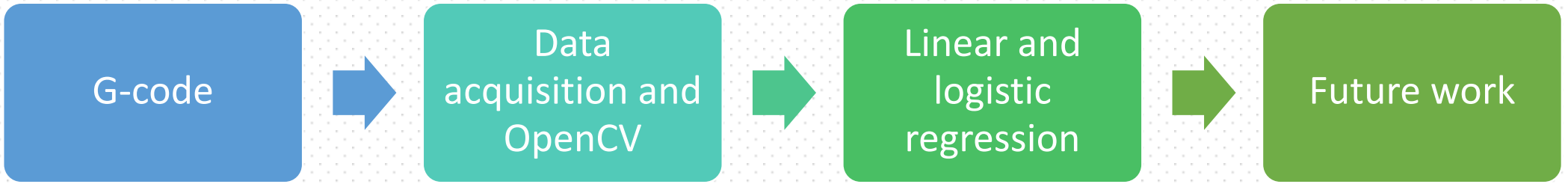
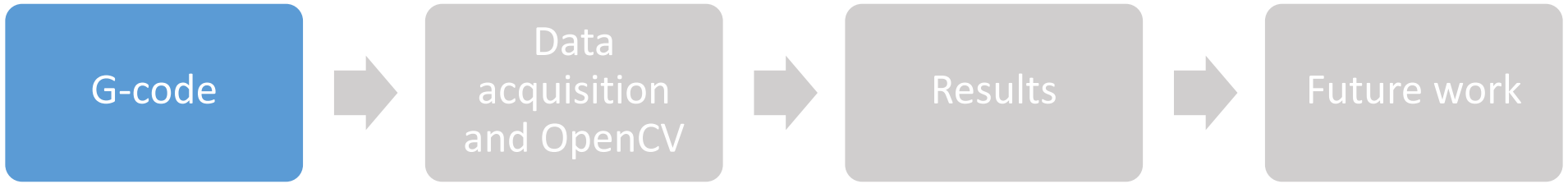
Effect of extrusion speed on extruded PETG filament dimensionality




G-code
Data acquisition and OpenCV
Results
Future work

Printer	Ender 5 pro
Camera	Optical 12MP
Material	PETG
Filament rod diameter	1.75 mm

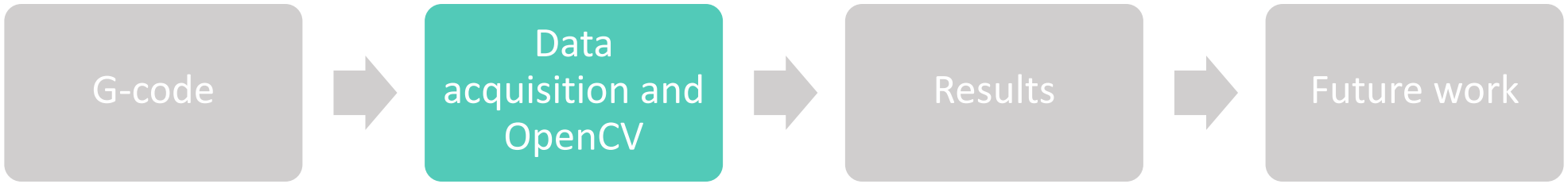
Nozzle diameter	0.4 mm
Hot end temperature	230 deg. C
The only variable is :	
Print speed (Extrusion speed)	100-1100 mm/min

```
1
2  G90 ; absolute positioning
3  M82 ; release tool
4  M106 S0 ; fan speed
5  M104 S230 T0 ; start heating extruder
6  M109 S230 T0 ; wait till extruder is heated
7
8  G28 ; home all axes
9  G1 X5 Y10 Z0.2 F3000 ; get ready to prime
10 G92 E0 ; reset extrusion
11
12 G1 X160 E15 F600 ; prime nozzle
13 G1 Z10 F3000
14 G1 X100 Y160 ; go near camera
15
16 ; layer 1, at Z=100, extrude at speed F100
17 G1 Z100 F500
18 G1 E0.0000 F2400 ; move E axis
19 G92 E0 ; reset E
20 G1 E50 F100
21 G92 E0 ; reset E
22 G1 E-20 F100 ; pulling filament back to prevent drol
23 G04 S20 ; dwell for 20 sec
24
```

- Simplify3D does not allow to set the extruder feed rate explicitly, but is calculated internally,
  1. Extrusion width
  2. Extrusion multiplier
  3. Layer height
  4. Printing speed

✓ **Assumption** - Increasing any of above will increase extruder feed rate*.

*https://forum.simplify3d.com/viewtopic.php?t=4877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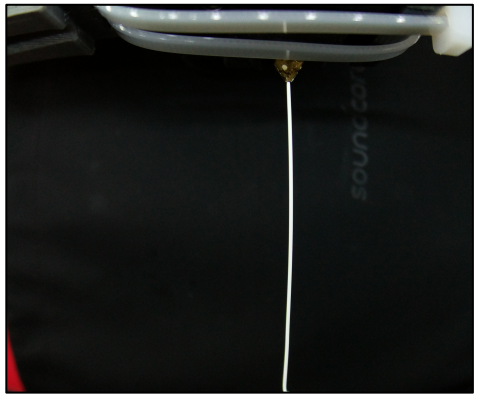
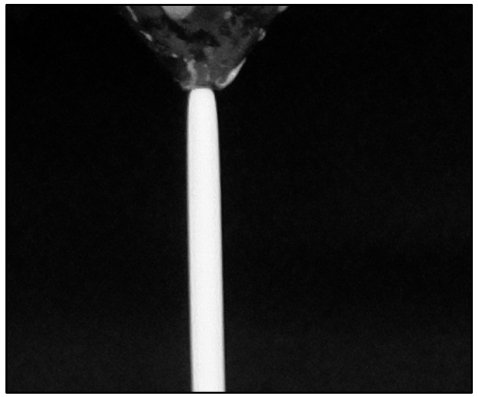
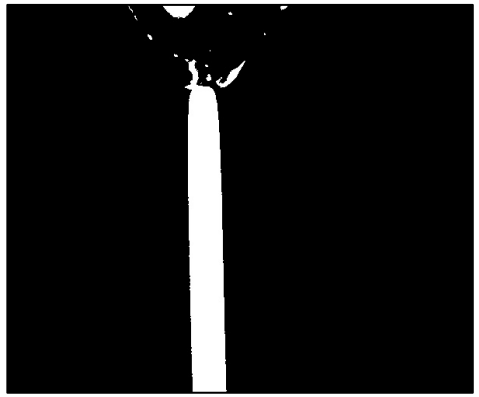


Original Image
4056 x 3040

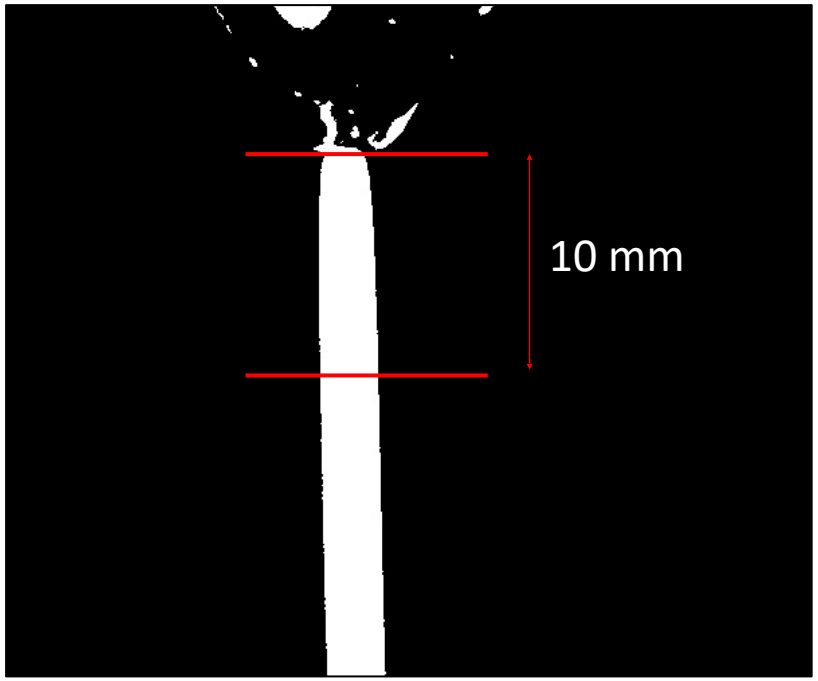
Cropped Image
500 x 600



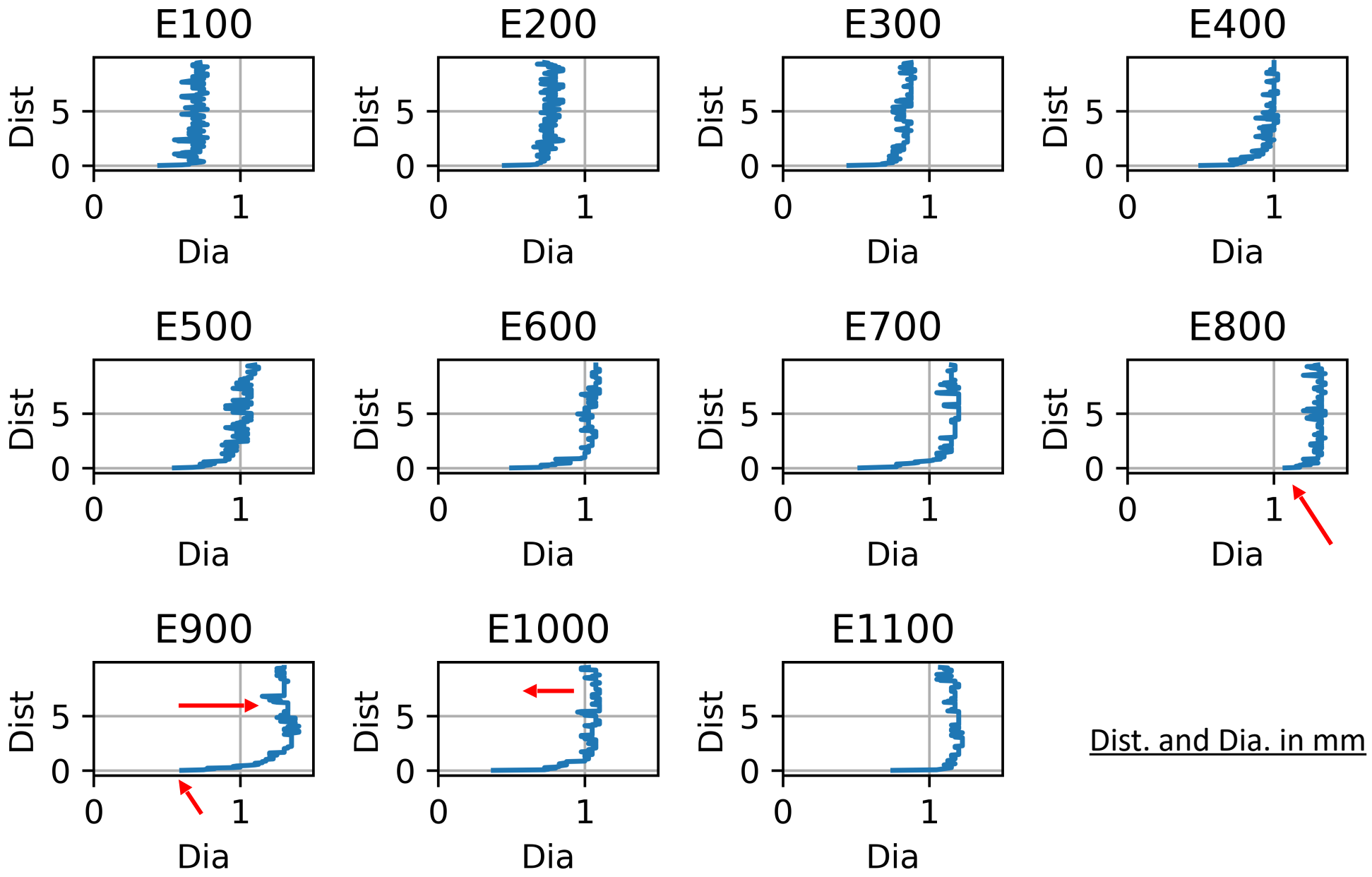
Gray Scale Image
500 x 600



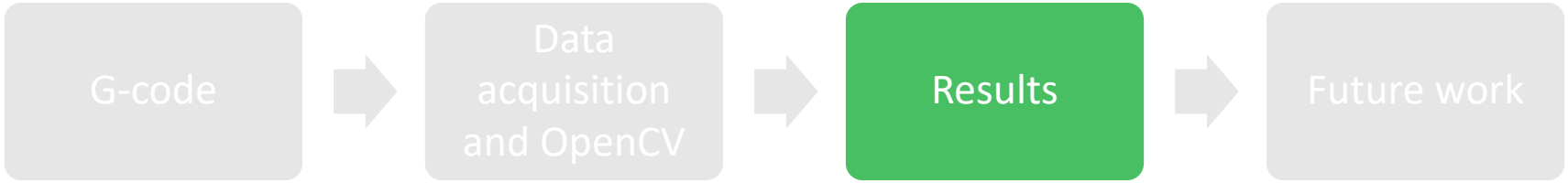
Binary Image
500 x 600



- Diameter of the extruded filament calculated based on length of ’bright’ (255) pixels across the red line.
- Measurements taken from the tip of the nozzle to about 10 mm down to study filament morphology and ‘die swelling’ effect as it exits the nozzle.
- The calculation is performed for different values of extrusion speed E



Dist. and Dia. in mm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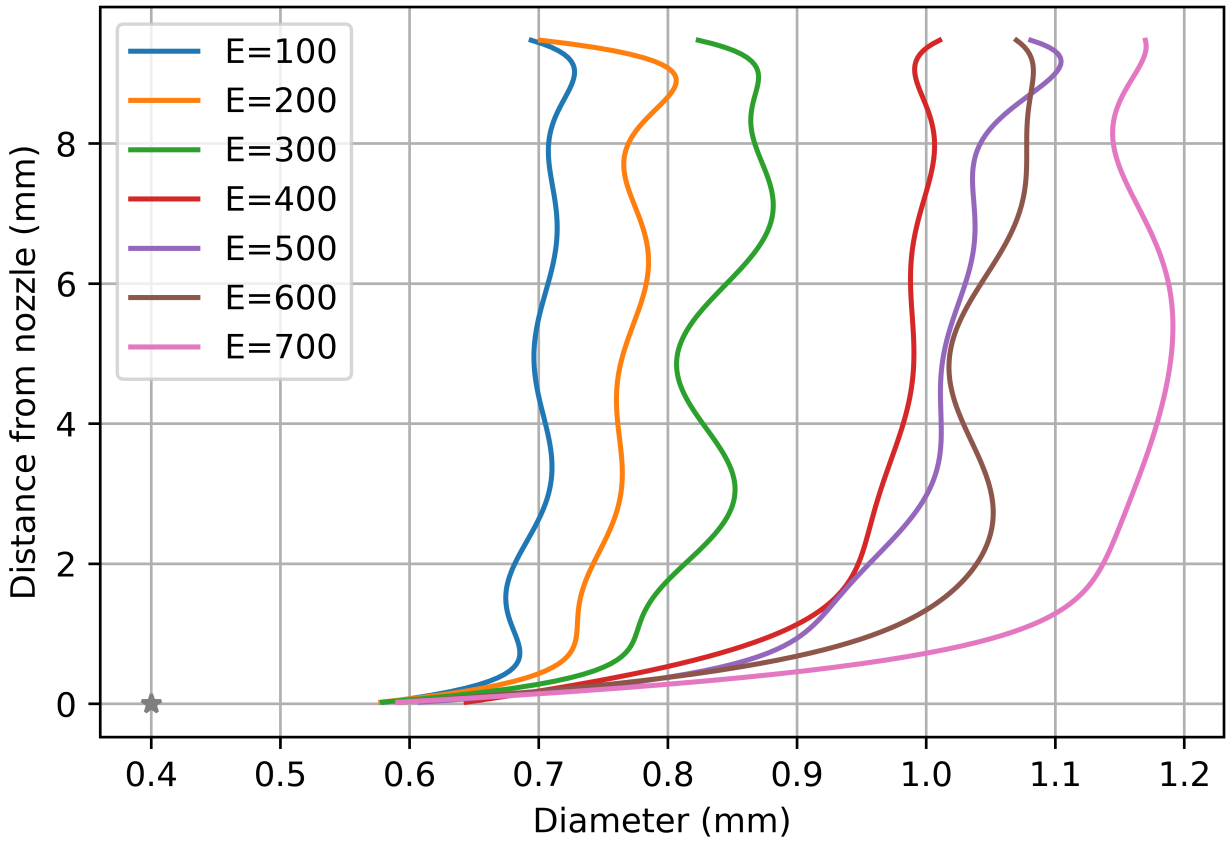
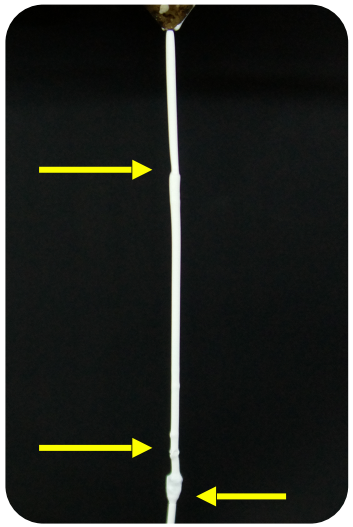


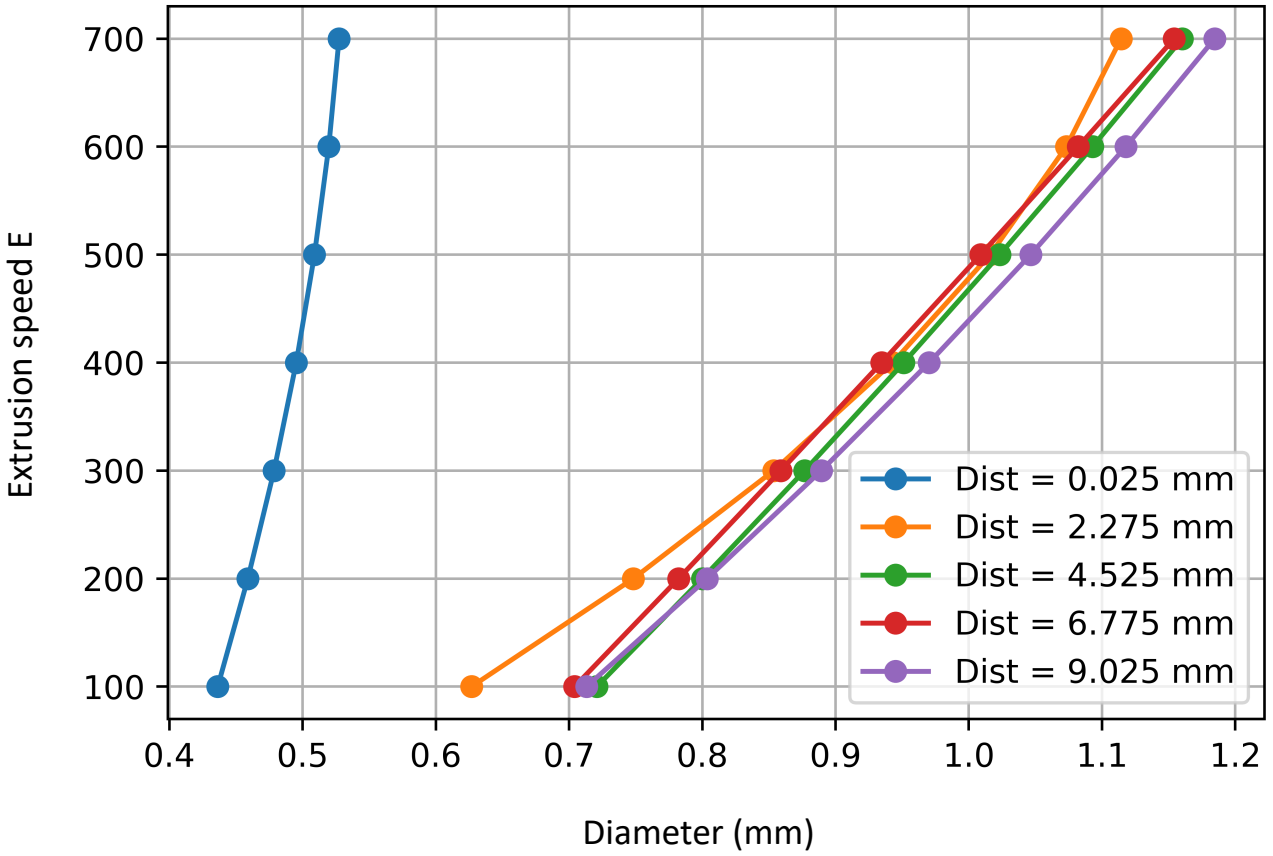
Diameter evolution as function of extrusion speed E and distance from nozzle

- Rapid expansion of filament near nozzle is seen as extrusion speed E is increased.
- Evident from the graph and optical images, the filament tends to become unstable with increase in E



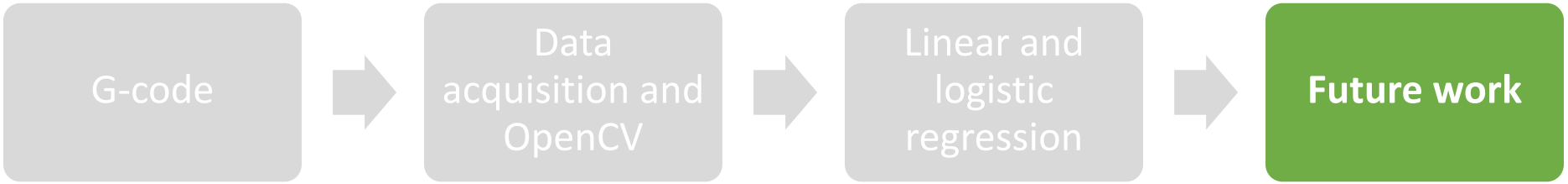
E = 900

✓ Good linear relationship between filament diameter and extrusion speeds



Measurement of diameter at intervals of 2.5 mm for extrusion speeds E

- ✓ Given an extrusion speed E, final expanded diameter of filament can be estimated
- ✓ Filament expansion occurs within 2-3 mm from the tip of nozzle


G-code
Data acquisition and OpenCV
Linear and logistic regression
Future work

Improvements

- Mounting of camera as close to nozzle as possible to avoid loss of resolution
- Verification of filament diameter using optical microscopy for variation of filament diameter
- Include more features such as material, extruder temperature, pressure, nozzle profile, etc. to be used for classification using logistic regression algorithms