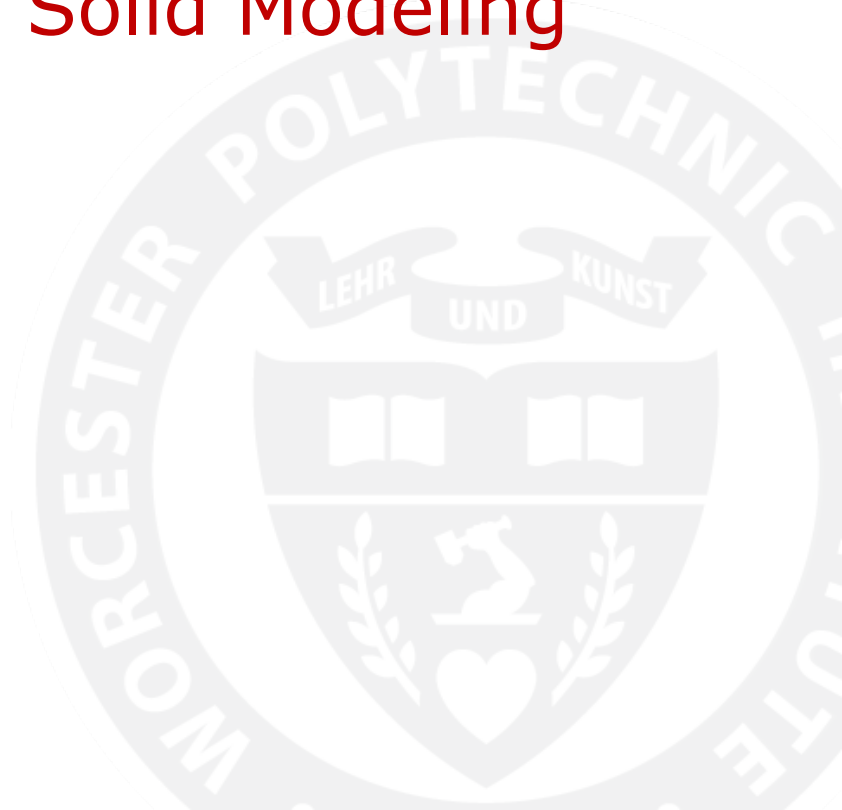# Math and Science for Sub-Saharan Africa (MS4SSA)

Project-Based Learning:
Introduction 3D Printing / Solid Modeling

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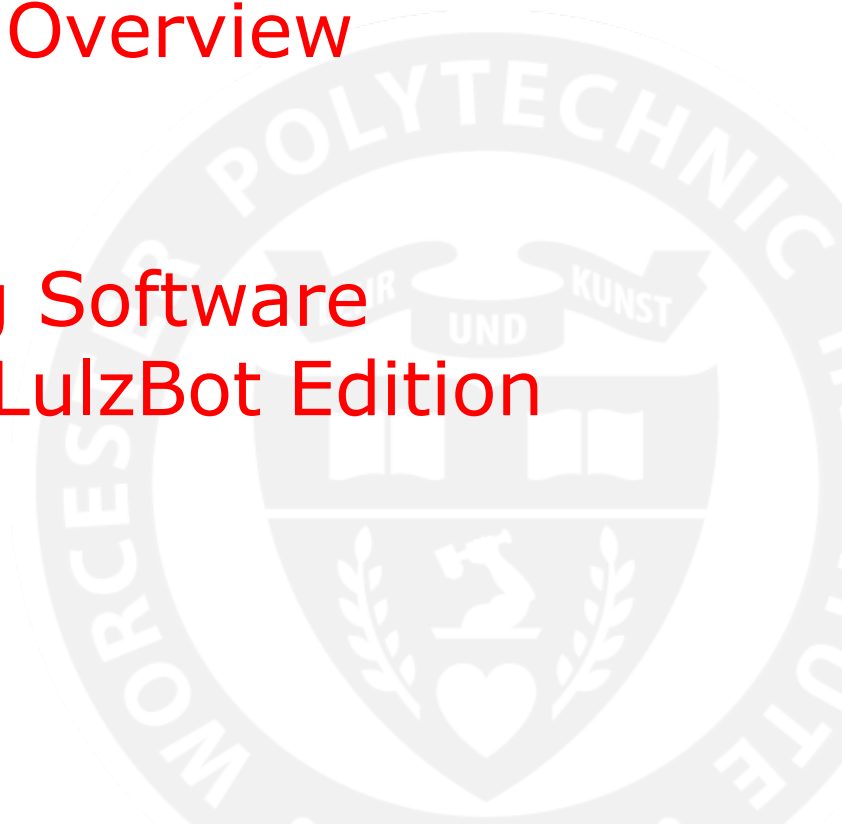*UNESCO HQ, Paris*
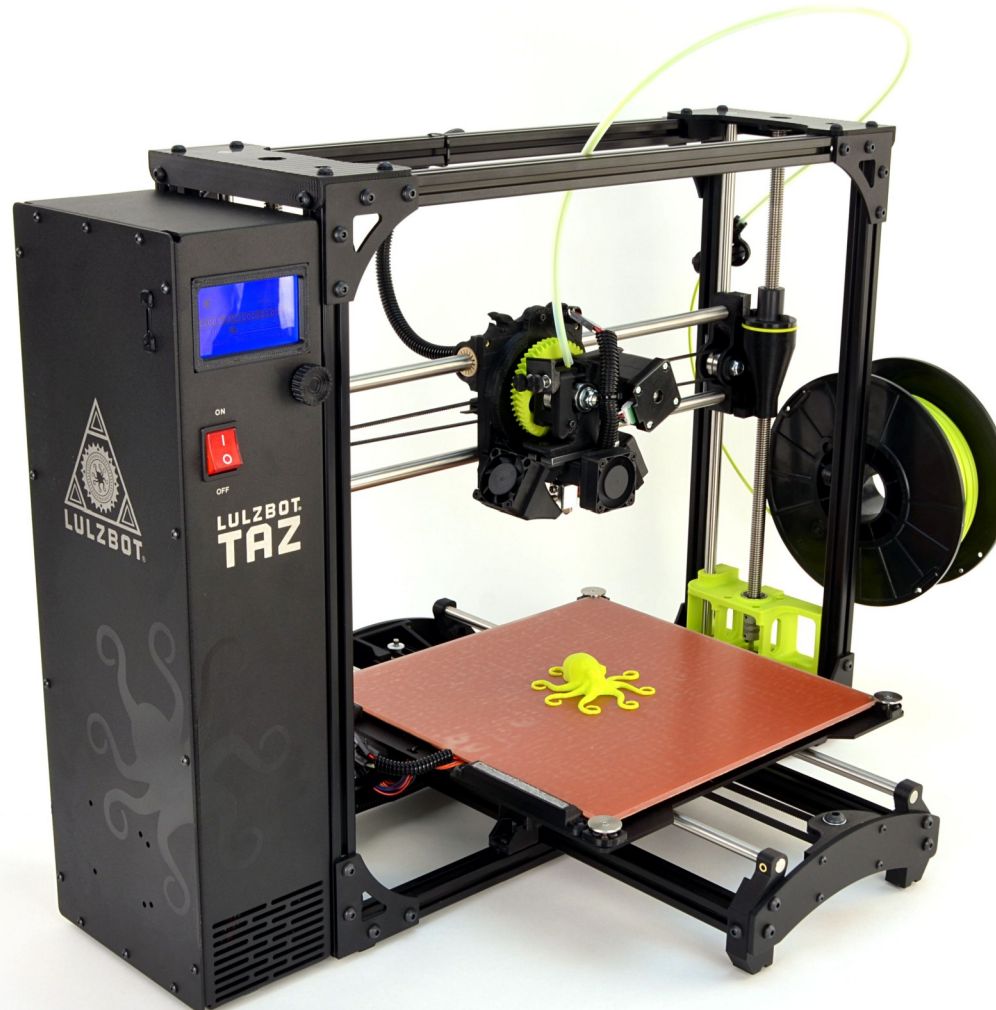
Introduction 3D Printing / Solid Modeling

1. Background and introduction
2. Overview of 3D Printing
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4. 3D   Printer Hosts
5. Slicers
6. CAD and 3D Modeling Software
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Overview of 3D Printing

- 3D Printing is an additive manufacturing process
- The solid model is sliced into several layers and the printing is done layer by layer.
- Virtually any object of any shape can be 3D printed
- Recall that in the conventional machining process, materials are removed from the workpiece

Schematics of a 3D Printer

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Extruder

Filament Spool

Hot End

Print Bed
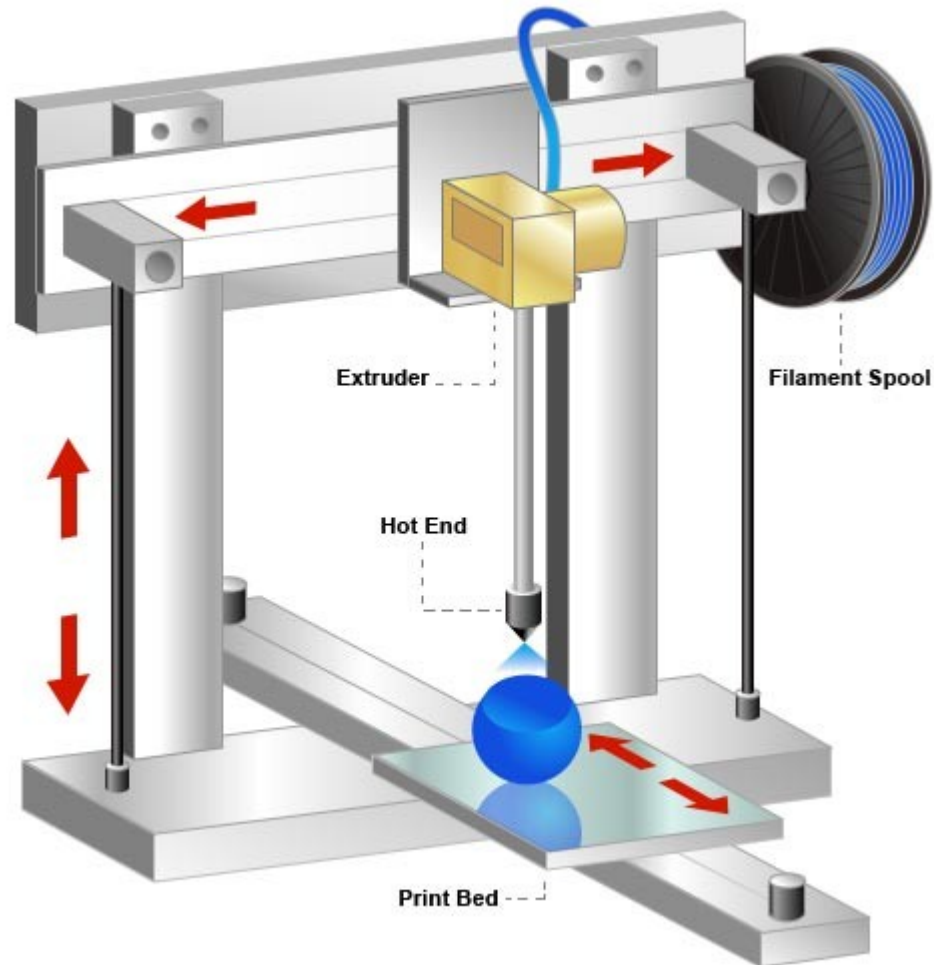
3D Printing Software Overview

- In order to operate a 3D printer, one requires few software packages:
- 3D Printer Host software
- An .STL to .GCODE generator
- CAD or 3D Modeling Software (Solid Modeling)

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3D Printer Hosts

- The 3D Printer Host software is used to control the basic operations of the 3D printer
- Manual movement of the printer (printer head) along all the axes (x, y, z, etc)
- Temperature settings (bed, extruder)
- Communication: Sends commands to printer and receives feedbak and error messages from onboard electronics

Examples of 3D Printer Hosts

- Cura LulzBot Edition
- OctoPrint
  - Http://octoprint.org
  - Uses a web-based interface to access and control the 3D printer
  - Added web-cam functionality for time-lapse videos and live stream
  - Runs on Linux, Windows, OS X based computers, RaspberryPi
- BotQueue
  - http://www.botqueue.com
  - Web-based multiple 3D operation running off a queuing system
- MatterControl
  - http://www.mattercontrol.com
  - Features 2D and 3D model viewing, print queue
  - Runs on Linux, Windows, and OS X operating systems

Slicers

- The slicer program take the 3D model (STL/OBJ/etc) and determines the 3D printer toolpath based on the option selected
- The slicing engine uses the nozzle diameter, movement speeds, layer height, and other variables to determine the coordiantes where the printhead needs to move, and the rates at which it will do so.
- This information is exported out of the program as a GCODE file
- The GCODE file is an ascii (plain-text) file containing the series of text-based codes and a list of the complete X,Y, and Z-axis coordinates used for printing the 3D model
- Cura LulzBot Edition software includes a slicer

10 most Common G-codes commands for 3D printing

- **G28** – Perform Homing Routine
  - G28 ; *home all axes (X, Y, and Z)*
  - G28 X Y ; *home X and Y axes*
  - G28 Z ; *home Z axis only*
- **G90** and **G91** – Set Positioning Mode
  - G90 ; *use absolute positioning for the XYZ axes*
  - G1 X10 F3600 ; *move to the X=10mm position on the bed*
  - G1 X20 F3600 ; *move to X=20mm*
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  - G91 ; *use relative positioning for the XYZ axes*
  - G1 X10 F3600 ; *move 10mm to the right of the current location*
  - G1 X10 F3600 ; *move another 10mm to the right*

Common G-codes

- **G1** – *Linear Movement*
  - G1 X0 Y0 F2400 ; move to the X=0 Y=0 position on the bed at a speed of 2400 mm/min
  - G1 Z10 F1200 ; move the Z-axis to Z=10mm at a slower speed of 1200 mm/min
  - G1 X30 E10 F1800 ; push 10mm of filament into the nozzle while moving to the X=30 position at the same time
- **G92** – *Set Current Position*
  - G92 E0 ; set the current filament position to E=0
  - G1 E10 F800 ; extrude 10mm of filament
- **M104** and **M109** – *Extruder Heating Commands*
  - M104 S190 T0 ; start heating T0 to 190 degrees Celsius
  - G28 X0 ; home the X axis while the extruder is still heating
  - M109 S190 T0 ; wait for T0 to reach 190 degrees before continuing with any other commands

Common G-codes

- **M140** and **M190** – Bed Heating Commands
  - M140 S50 ; start heating the bed to 50 degrees Celsius
  - G28 ; home all 3 axes while the bed is still heating
  - M190 S50 ; wait until the bed reaches 50 degrees before continuing
- **M106** – Set Fan Speed
  - M106 S255 ; set the fan to full speed
  - M106 S127 ; set the fan to roughly 50% power
  - M106 S0 ; turn off the fan completely
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CAD and 3D Modeling Software

- In our first lecture, solid modeling was introduced and examples of solid modeling software packages given. Such packages include
- **FreeCAD**
  - http://www.freecadweb.org
  - Contains a full GUI for building simple to complex CAD models
  - Capable of exporting .STL files for 3D printing
- **OpenSCAD**
  - http://openscad.org
  - Script based
- **Blender**
  - Http://blender.org
  - Free
- **Fusion 360**
- **SolidWorks**

Introduction to Cura LulzBot Edition

Quick Print Settings

- Selecting a Quick Print Profile
  - High Detail
  - Standard
  - High Speed
- Materials Selection
- Printing Support Materials
- Brim
- Load Model File
- Model Orientation
  - Rotate
  - Lay Flat
  - Reset
  - Scale

View Options

- Different modes allow the designer to view the model in a variety of ways prior to printing. These modes include:
- Normal view
  - standard view showing solid outer surface of the model
- Overhang
  - This shows where the model may need support material
- Ghost
  - Makes the model translucent to allow you to see what is behind it
- X-ray
  - Allows the designer to look inside the object
- Layers
  - To view the tool path of the print head and to ensure no skipped layers or gap use this option

Starting Your First Prints

- Once the the 3D model has been designed, and the profile / filament loaded, one can proceed to the first print.
- 3-D printing can either be done via the host computer (USB connection) or or using the SD card directly on the printer
- Printing from USB Cable
  - On proper connection, the printer will go through its automatic cleaning and wiping process before starting the print
- Pausing Mid-Print
  - When actived, this will will pause the print and move the print head away from the object
- Automatic Bed leveling
  - Before each print, for some printers, the printhead after the cleaning stage will go through a probing stage to establish the slope / tilt of the bed, including the 0 in z-axis.
- Printing from SD card
- Recommended Temperatures and Bed Preparation

Recommended Temperatures

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Filament Type	Bed Preparation	Nozzle Temp	Bed Temp	Removal Temp
ABS	Clean PEI	230-250	110	50
PLA	Clean PEI	195-215	60	45
HIPS	Clean PEI	230-250	110	50
Laywoo-D3	Clean PEI	175-195	60	45
bambooFill	Clean PEI	185-195	60	50
woodFill	Clean PEI	185-195	60	50
Laybrick	Clean PEI	175-195	60	45
bronzeFill	Clean PEI	225-235	60	50
copperFill	Clean PEI	225-235	60	50
Magnetic Iron PLA	Clean PEI	220-230	60	50
Stainless Steel PLA	Clean PEI	220-230	60	50
Conductive PLA	Clean PEI	215-230	60	50
Coffee PLA	Clean PEI	220-230	60	40
nGen	Clean PEI	220-240	85	60
t-glase	Glue stick	240-260	60	45
Flexible Filaments	Glue stick	215-230	50	35
Nylons	Glue stick	220-270	110	50
Polycarbonate	Glue stick	260-300	110	50
Polycarbonate + ABS	Glue stick	260-280	110	50
INOVA 1800	Glue stick	235-255	75	50
n-vent	Glue stick	225-245	60	50

Summary and Concluding Remarks

- This class presents an introduction 3D printing
- Basic principles of Solid Modeling were introduced
- It is our hope in our next hands-on session, we will be able to now design and 3D printconstruct simple components to take care of our respective needs