FAKULTET TEHNIČKIH NAUKA
KOSOVSKA MITROVICA

Postupci modeliranja 3D delova i 3D štampe FDM metodologijom

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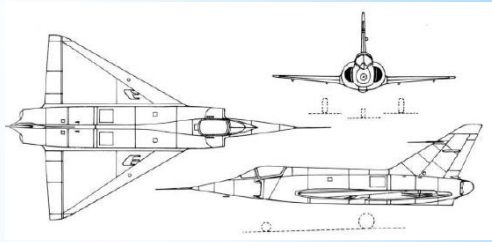
UVOD

Računarsku grafiku (Computer Graphics) - razvija američka vojska oko 1950. - napravljen prvi grafički sistem - **SAGE** - sistem protivvazdušne obrane

SAGE

MIRAGE CAD



Zatim - službeno započeo razvoj računarske grafike - 1960-ih godina - uvodi se i u vazduhoplovnu i automobilsku industriju - 3D konstrukcija spoljnih površina i NC (Numeric Control) programiranja - tadašnji status vojne tajne - dugo vremena bio skriven podatak

Prekretnicom u razvoju CAD konstruiranja - smatra sistem **SKETCHPAD**, razvijen na MIT-u (Massachusetts Institute of Technology) 1963. - omogućava grafičku interakciju s računalom

Značajni projekti - korporacije General Motors i IBM 1959. kao i Renault 1971.

SKETCHPAD

Krajem 1960-tih - francuski proizvođač letelica Avions Marcel Dassault - programira grafički programa CATIA, a Francuski borbeni avion Mirage - prvi avion razvijen pomoću njega

Kasnih 1980-tih - razvoj vrlo dostupnih CAD programa

Projektovanje prostornih elemenata

Uspešnost u projektovanju i konstruisanju – znanje, veštine, motivacija, potreba i mogućnosti sredine i sl.

Tempo koji se nameće u ovom trenutku podrazmeva - proizvode stalno usavršavati i poboljšavati - broj tehničkih informacija koje treba obraditi se stalno uvećava - vreme za uvođenje proizvoda u proizvodnju smanjuje. Savremeno projektovanje se ne može zamisliti bez upotrebe računara sa CAD sistemima.

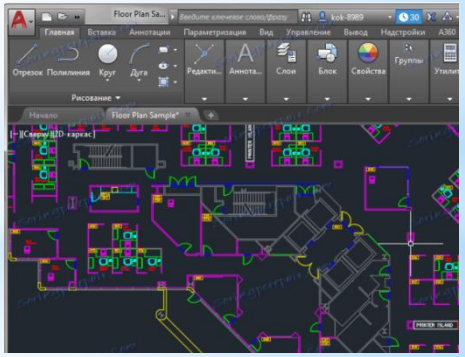
Danas postoji veliki broj realizovanih CAD (Computer Aided Design) sistema – SketchUp, AutoCAD, CATIA, SolidWorks, MeshLab,

3D modeliranje dobija sve više zamaha. Dolaskom i popularizacijom 3D štampača, potražnja za stručnjake i softvere je skočila. 3D modeli se koriste - od vojne industrije i proizvodnje proizvoda do računarske grafike u poznatim filmovima ili igricama.

CAD termin obuhvata: izradu koncepta projekta - analizu modela - konstruisanje modela – 3D modeliranje - izamenu i modifikovanje dela - izaradu projektne i tehničke dokument.

SketchUp

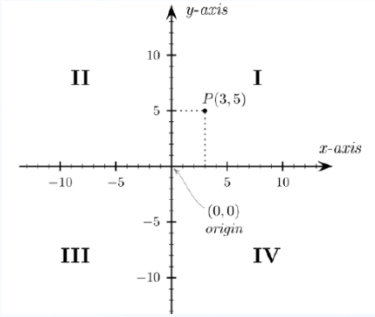
MeshLab

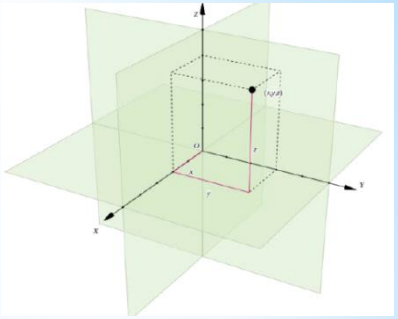


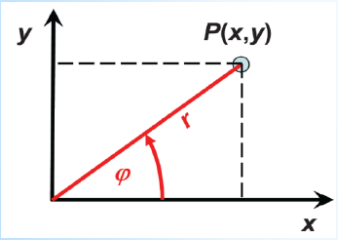
AutoCAD

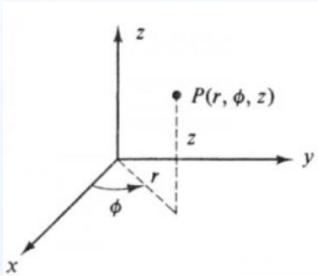
Projektovanje prostornih elemenata

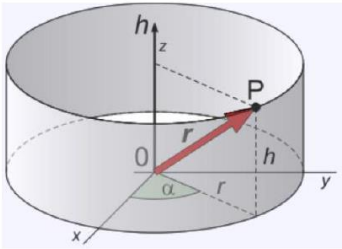
Koordinatni ravninski i prostorni elementi su sistemi u kojima se položaj (tačke) određuje pomoću koordinata
Pravougli (Kartezijev) – polarni - cilindrični - sferični

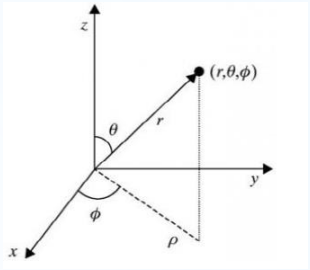


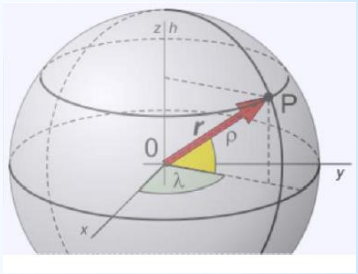






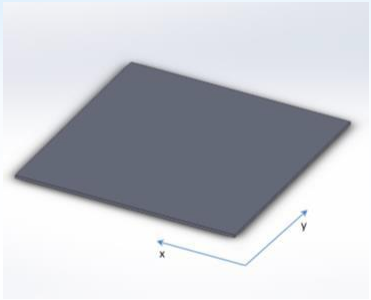


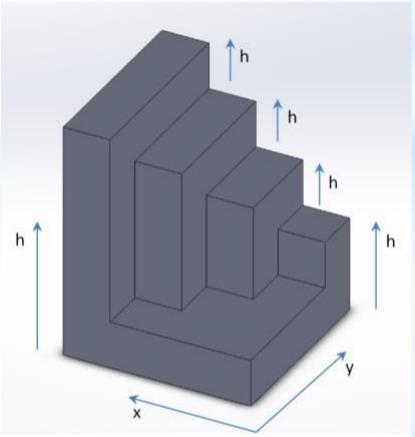


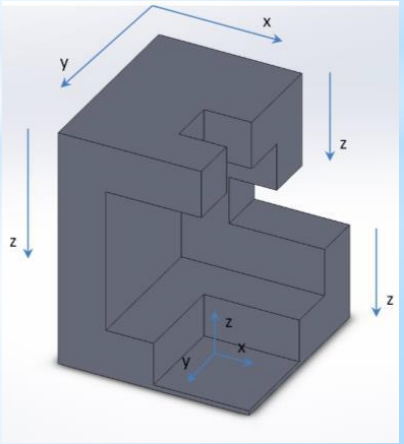


Uglavnom je 3D modeliranje slično u skoro svim sistemima.
Uradi se 2D kontura, ona se zatim koristi za kreiranje 3D elementa.
Dimenzionalnost modela:

- 2D – x,y
- 2,5D – x,y+h
- 3D – x,y,z





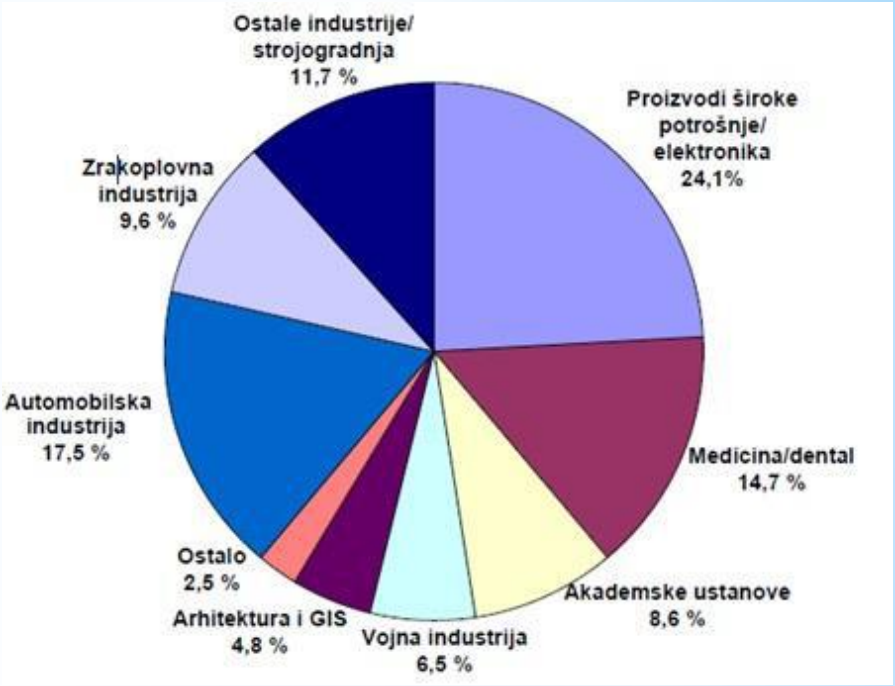


3D štampa – Aditivna proizvodnja

Brza proizvodnja prototipova (Rapid Prototyping - RP) – razvija se 1980-ih godina samo za izradu prototipova.

Uporedno se razvijala i brza proizvodnja alata (Rapid Tooling - RT), koja sa brzom proizvodnjom prototipova čini brzu proizvodnju (Rapid Manufacturing - RM).

Od 2009. prema ASTM F42, dobija naziv **aditivna proizvodnja** (Additive Manufacturing - AM).



Aditivnom proizvodnjom izrađuju se delovi komplikovane geometrije na bazi računarskog 3D modela dela u relativno kratkom vremenu.

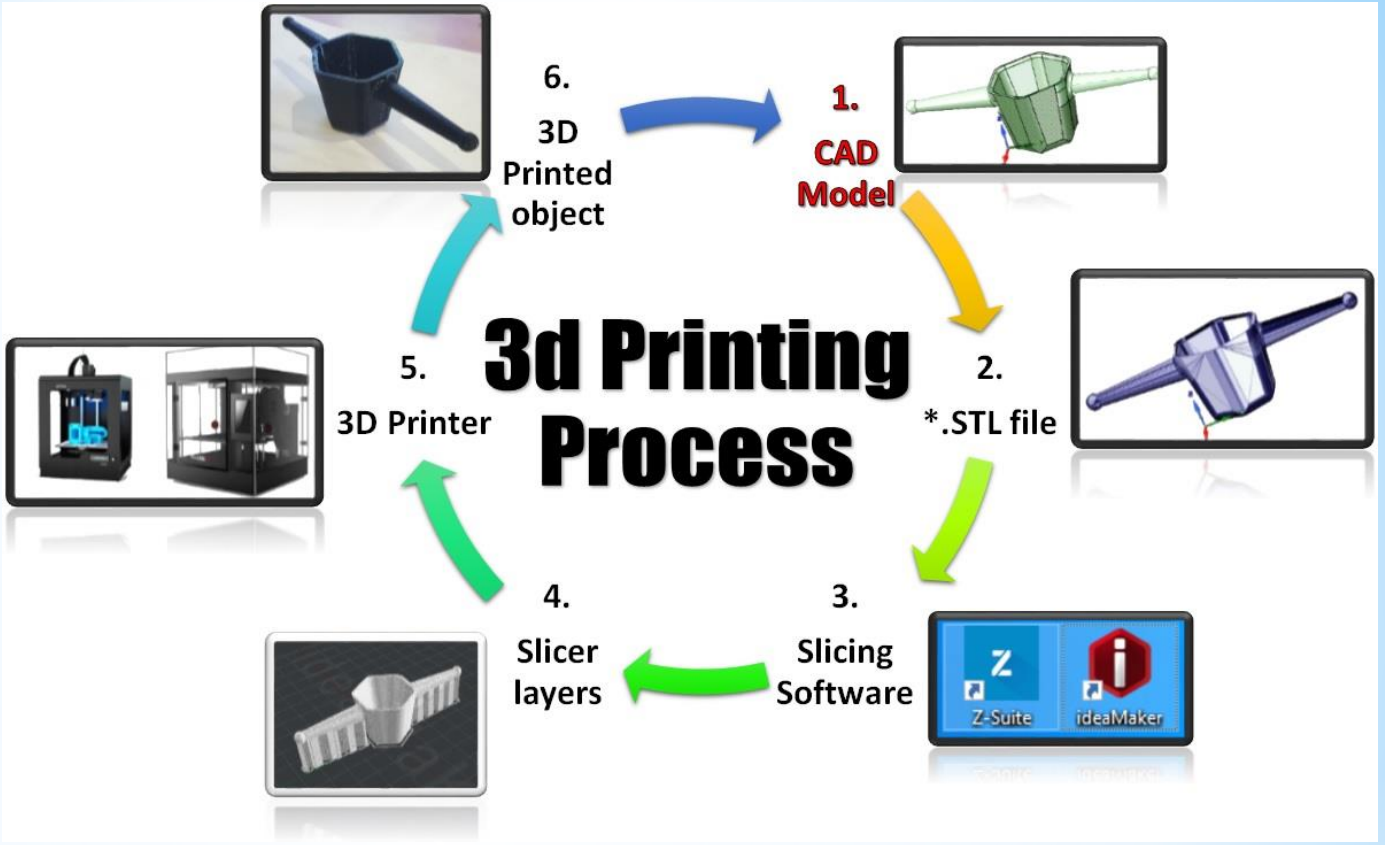
Postoje različiti načini proizvodnje, ali svi izrađuju delove - sloj po sloj.

Prednost - izrađuju delove u jednom koraku, direktno iz modela- Ne zahtevaju planiranje procesa - izradu kalupa - specifičnu opremu - transport itd.

Glavni nedostatak - ograničenje na određene materijale. Razvojem materijala – delovi se mogu upotrebiti kao funkcionalni gotovi proizvodi.

3D štampa - faze

STL fajl (Standard Tessellation Language)

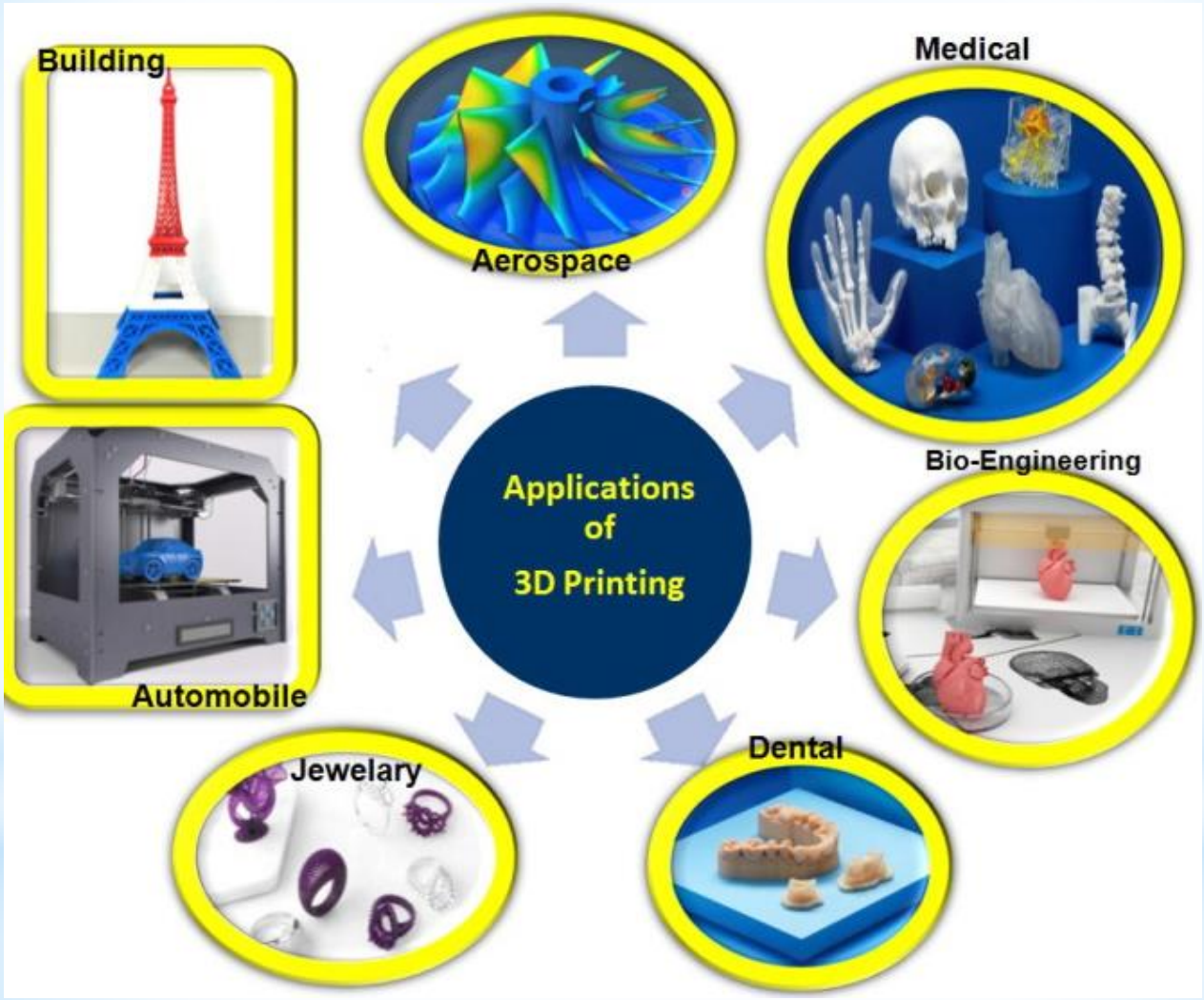


Faze3D štampe:

1. izrada CAD modela
2. export CAD modela u STL fajl
3. prebacivanja STL fajla na štampač
4. podešavanja parametara štampača
5. pravljenja prototipa - štampanje
6. skidanje prototipa
7. naknadna obrade, ako je potrebna
8. korišćenje.

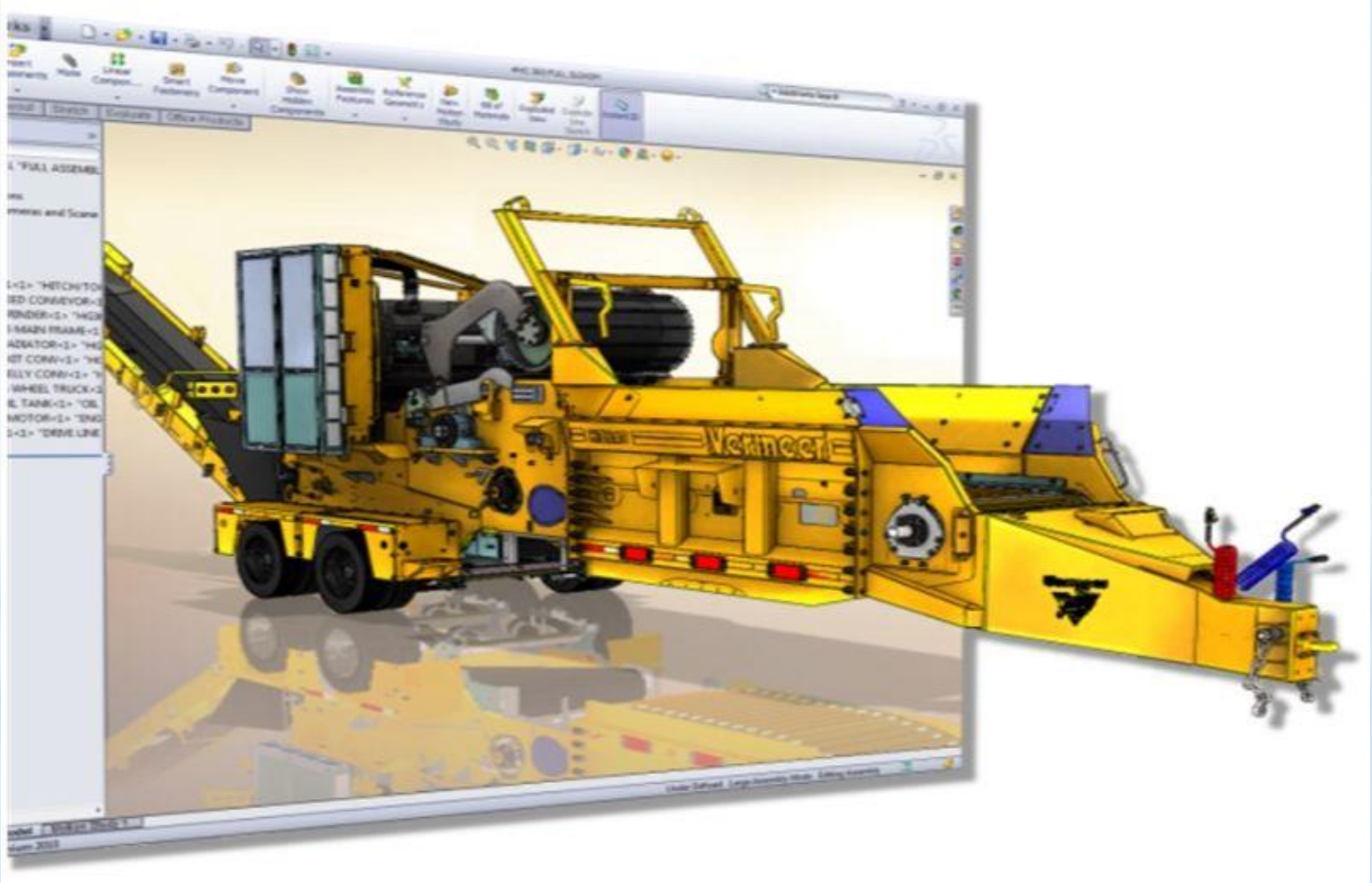
Polimerni materijali koji se najčešće upotrebljavaju su: akrilonitril/butadien/stiren (**ABS**), poliaktid (**PLA**), poliamid (PA), polikarbonat (PC), poli(metil-metakrilat) (PMMA), poli(vinil-klorid) (PVC), poliuretani, epoksidne smole, kao i čelik, aluminijum, titan i dr lake legure.

3D štampa - primena



3D MODELIRANJE

SOLIDWORKS



3D MODELIRANJE

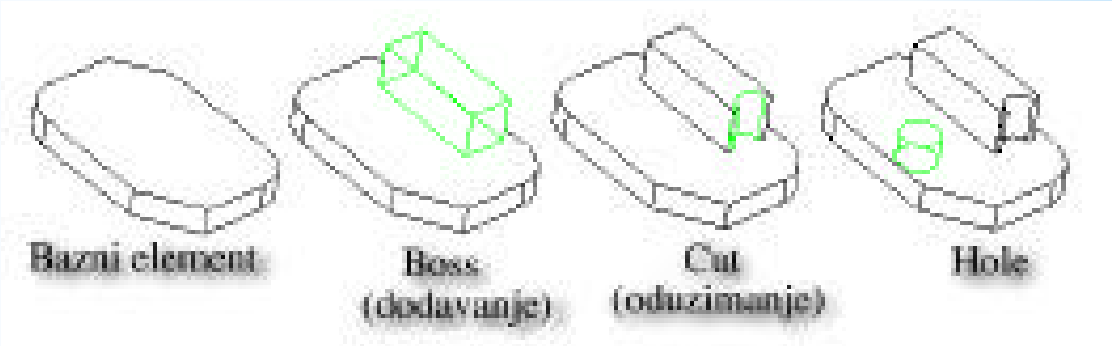
Radno okruženje SolidWorks programa

Osnovni e lementi 3D modeliranja

Deo se gradi iz takozvanih feature-ova (elemenata dela). Elementi dela su:

shapes (figure):

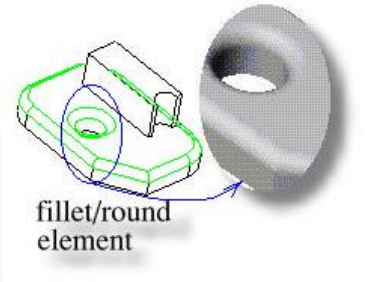
- boss (dodavanje materijala) Bool-ova opearcija dodavanja
- cut (skidanje materijala) - oduzimanja.
- hole (otvora ili rupa)

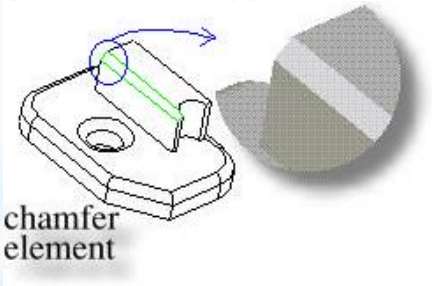


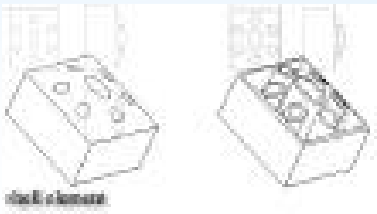
Deo se gradi iz takozvanih feature-ova (elemenata dela):

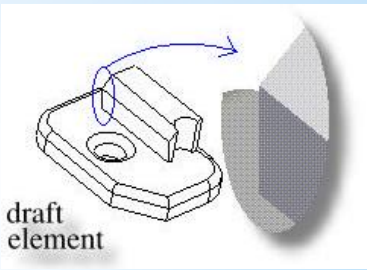
operacija (operations):

- fillet (zaobljavanje ivice)
- chamfer (obaranje ivice)
- shell (pravljenje školjke)
- draft (uklanjanje vertikalnosti)



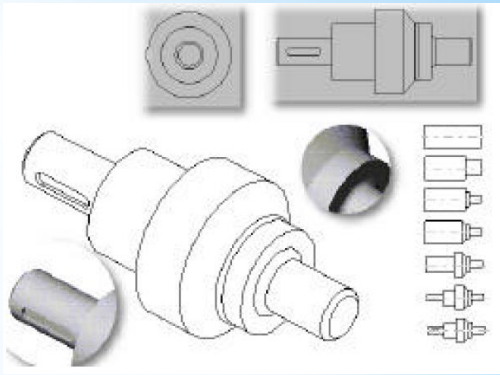




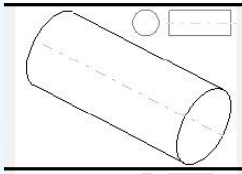
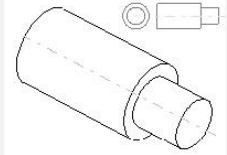
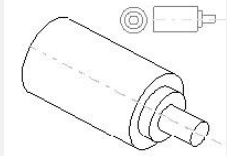
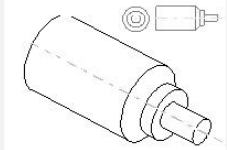


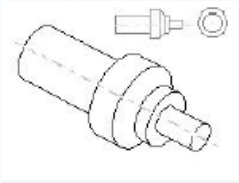
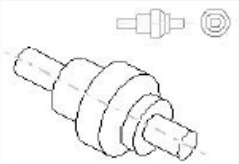
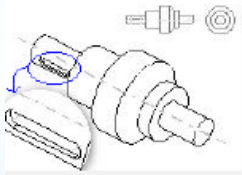
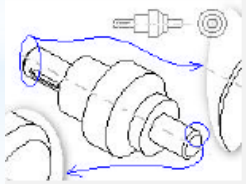
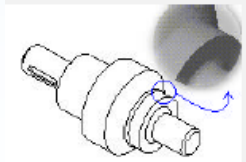
Projektovanje “filozofijom inženjera“

Pod projektovanjem “filozofijom “ inženjera podrazumevamo de je moguće kreirati deo na način na koji bi se napravio i u proizvodnji. Tako da polazimo od pripremka, pa kasnije skidamo materijal, koristeći odgovaraju}e elemente. Primer za to je dat na slici. Napravljen je deo tako što se postepeno skidao materijal koji je simulirao rad struga.



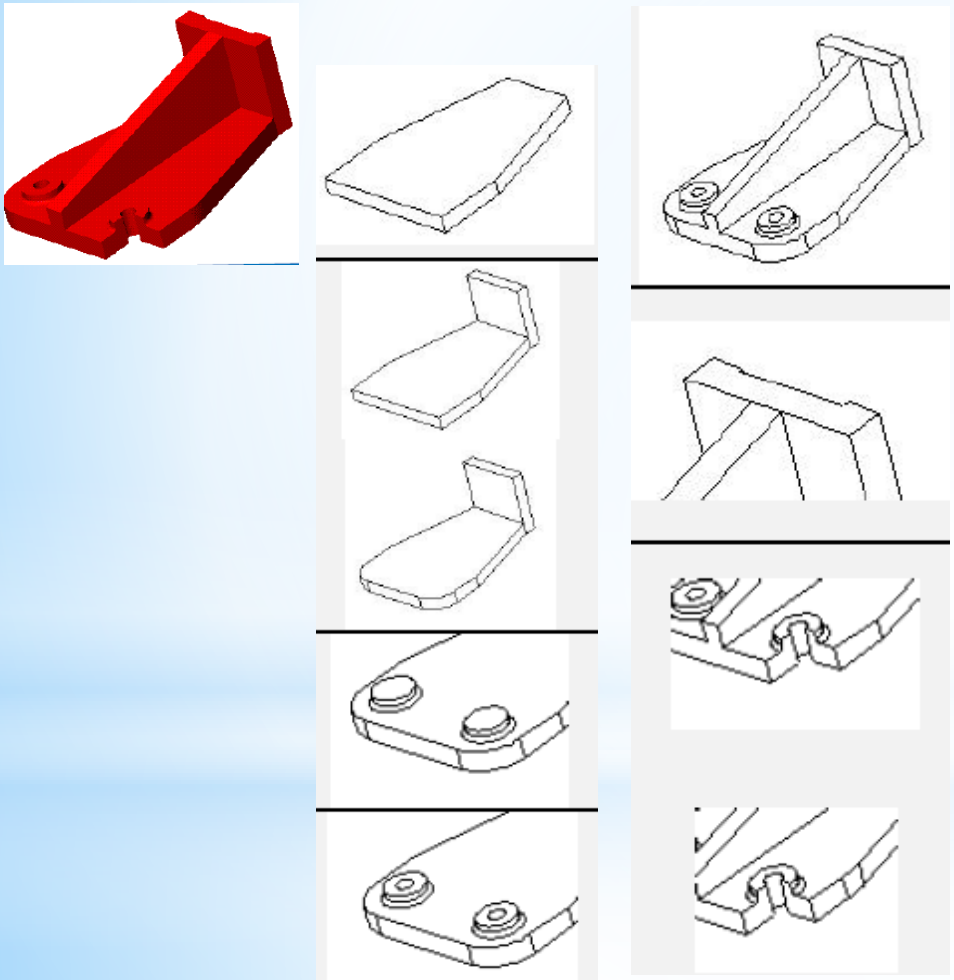
Primer 1

	• pripremak • dobijen rotacijom pravougaoni • SolidWorks model [faza1]
	• skidanje materijala • dobijen kori{}enjem tipa **cut revolve** • SolidWorks model [faza2]
	• skidanje materijala • dobijen kori{}enjem tipa **cut revolve** • SolidWorks model [faza 3]
	• skidanje materijala • dobijen kori{}enjem tipa **cut revolve** • SolidWorks model [faza 4]

	• skidanje materijala • dobijen kori{}enjem tipa **cut – revolve** • SolidWorks model [faza 5]
	• skidanje materijala • dobijen kori{}enjem tipa **cut – revolve** • SolidWorks model [faza 6]
	• udubljenje za klin, skidanje materijala • dobijen kori{}enjem tipa **cut – extrude** • SolidWorks model [faza 7]
	• obaranje ivica , skidanje materijala • kori{}ena operacija chamfer • SolidWorks model [faza 8]
	• zaobljavanje • kori{}ena operacija fillet • SolidWorks model [faza 9]

Primeri projektovanja

Primer 2



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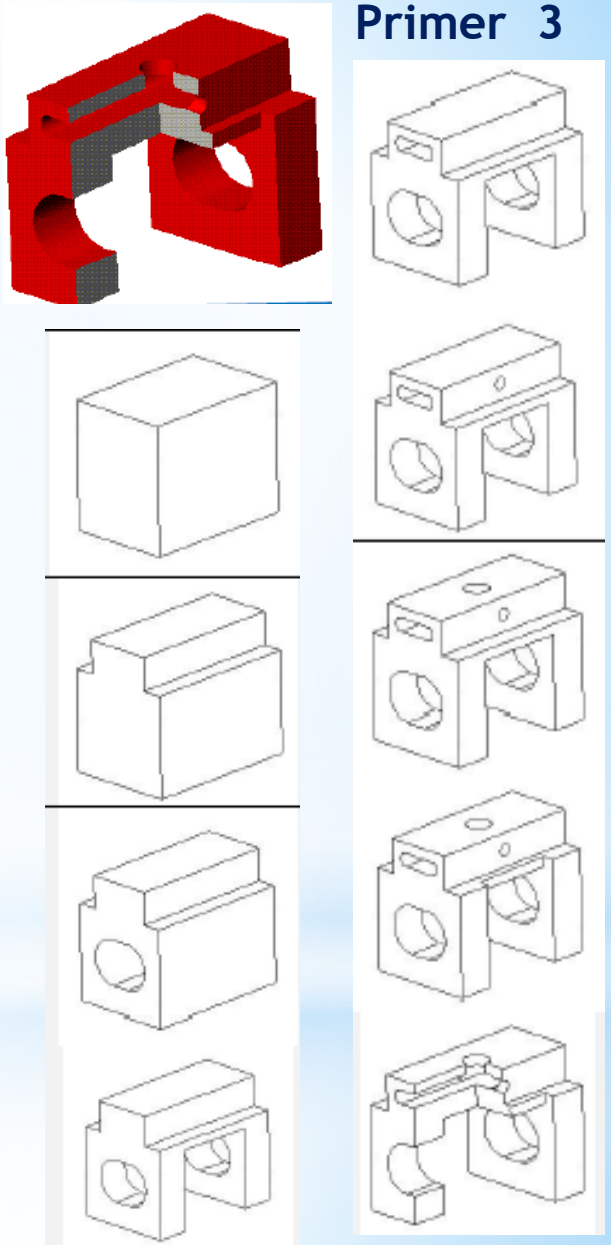

Primeri projektovanja

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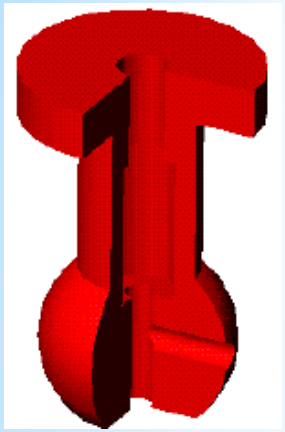

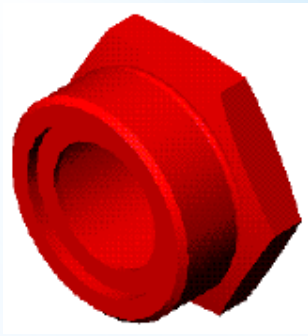

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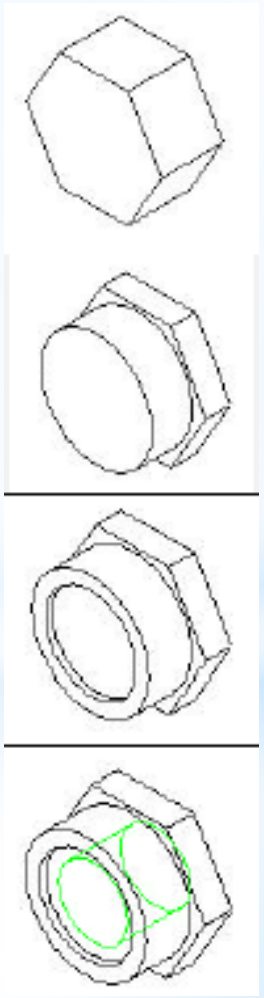
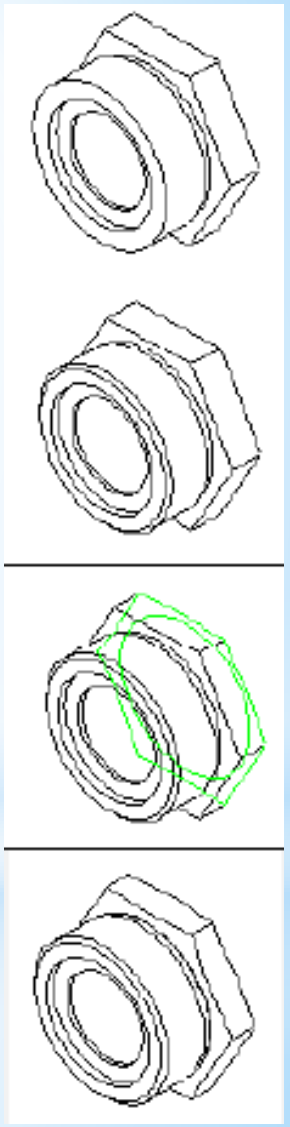
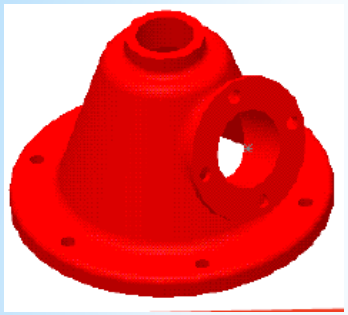
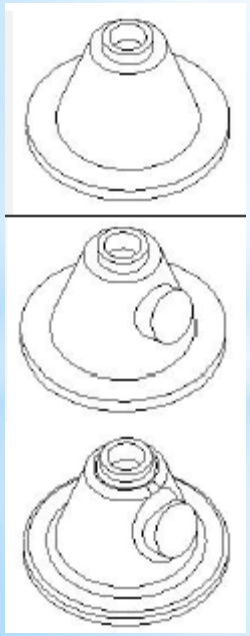


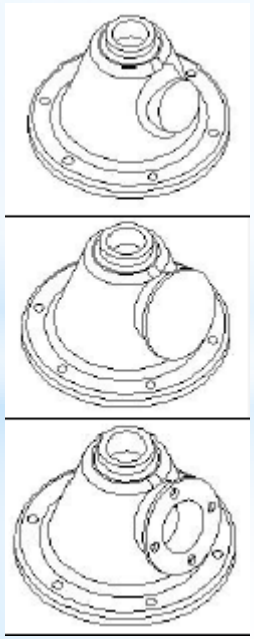


Primeri projektovanja

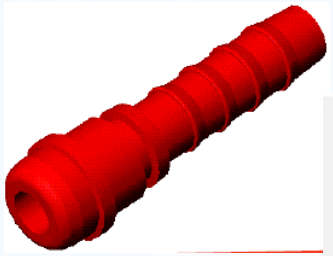
Primer 6

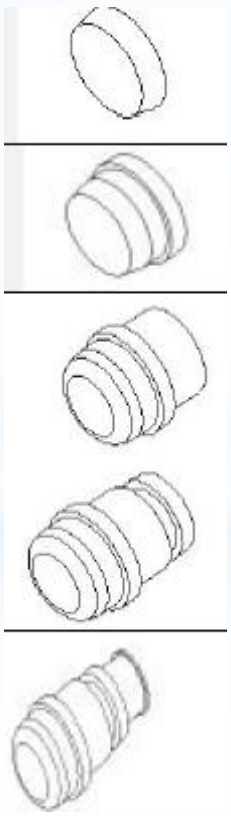


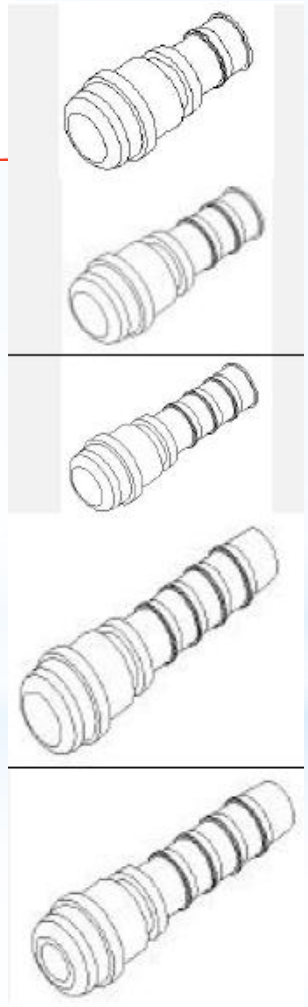


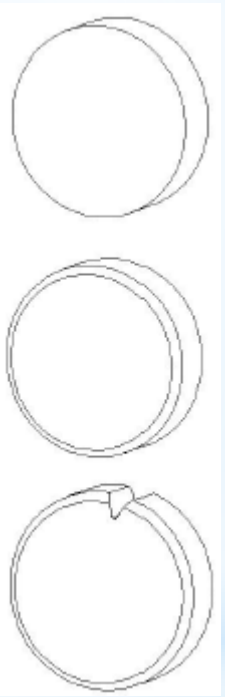


Primer 7

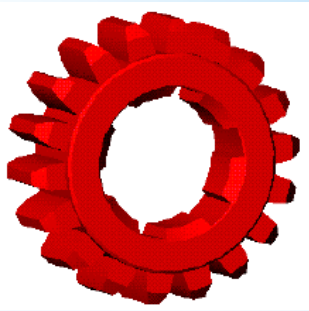


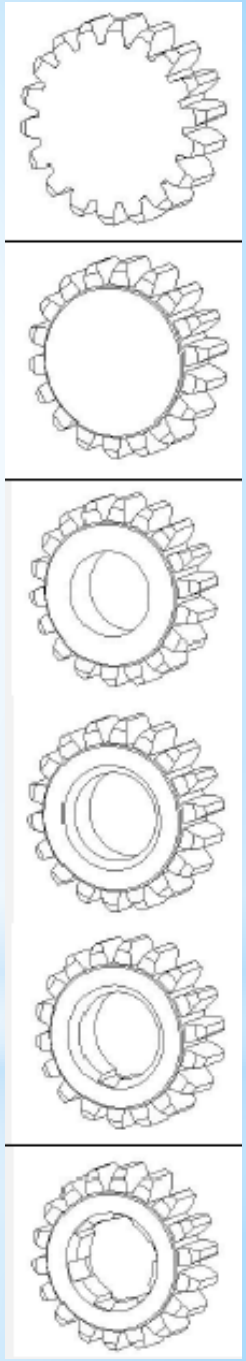






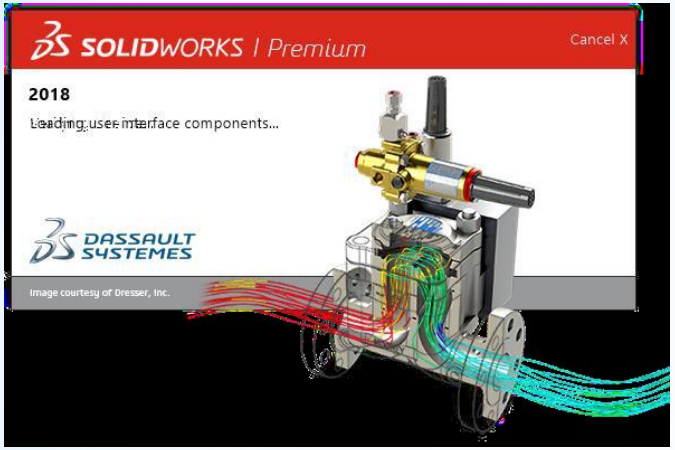
Primer 8



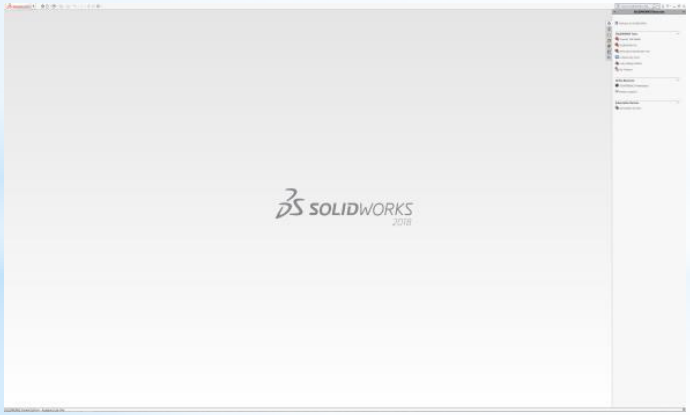


Postupak 3D modeliranja

- **Pokretanje i priprema SolidWorks programa**

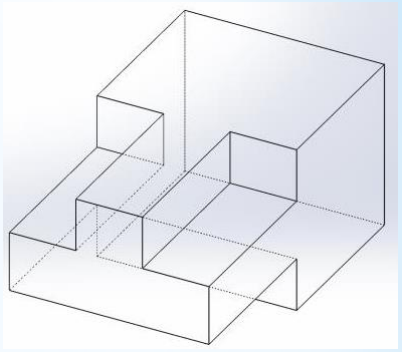


Pokretanje SolidWorks programa

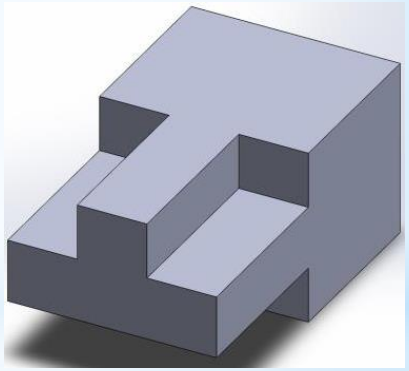


Početna podloga nakon pokretanja

Primer 3D modela



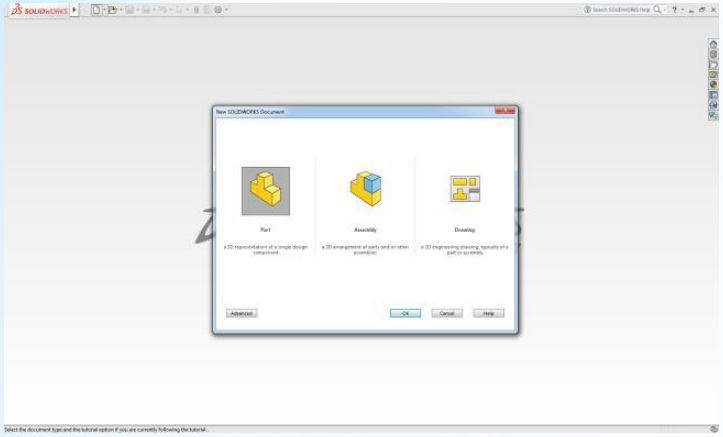
Žičani 3D model



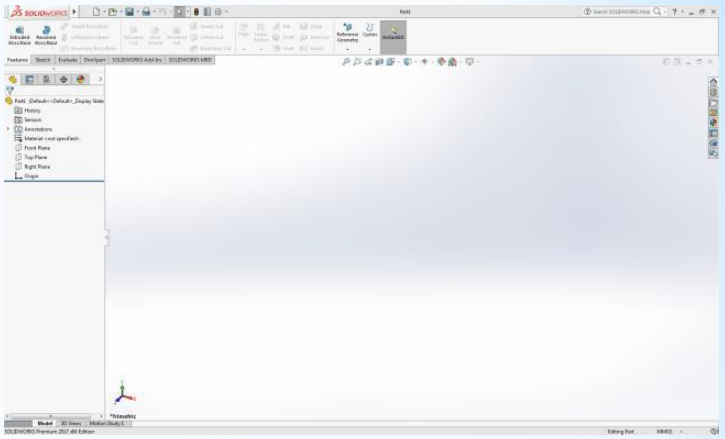
Puni (solid) 3D model

Postupak 3D modeliranja

- **Pokretanje i priprema SolidWorks programa**

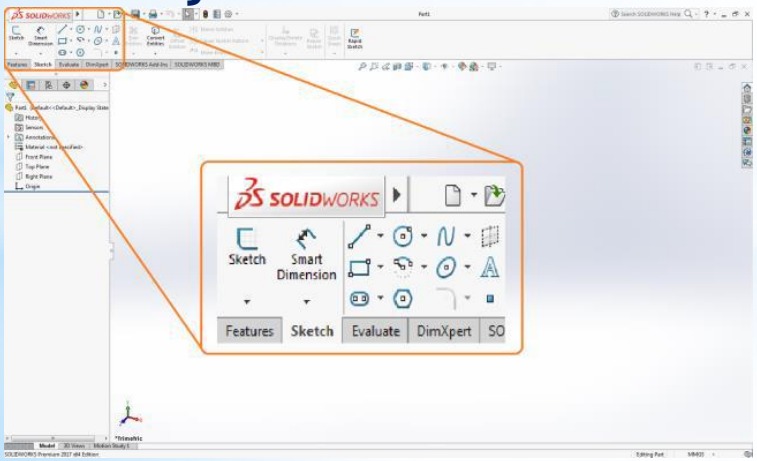


Okvir za izbor novog dokumenta

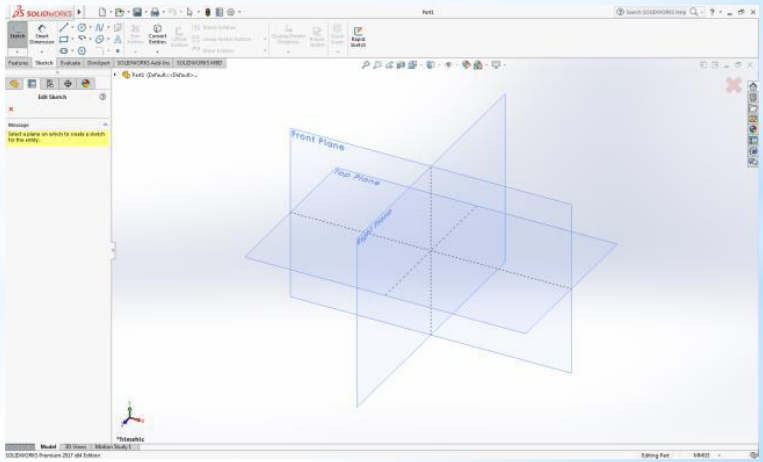


Radno okruženje SolidWorks

- **3D kreiranje modela**



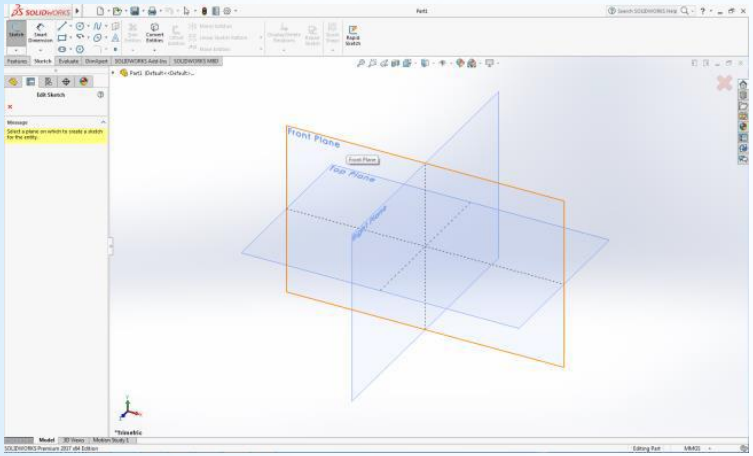
Izbor 2D modula za skiciranje - Sketch



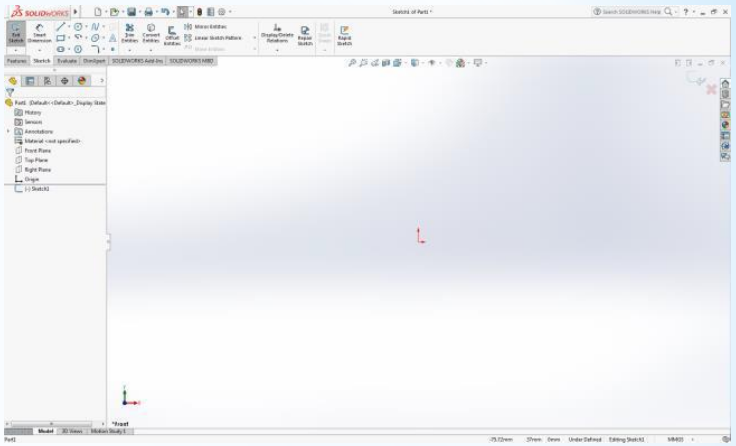
3D koordinatni sistem SolidWorks

Postupak 3D modeliranja

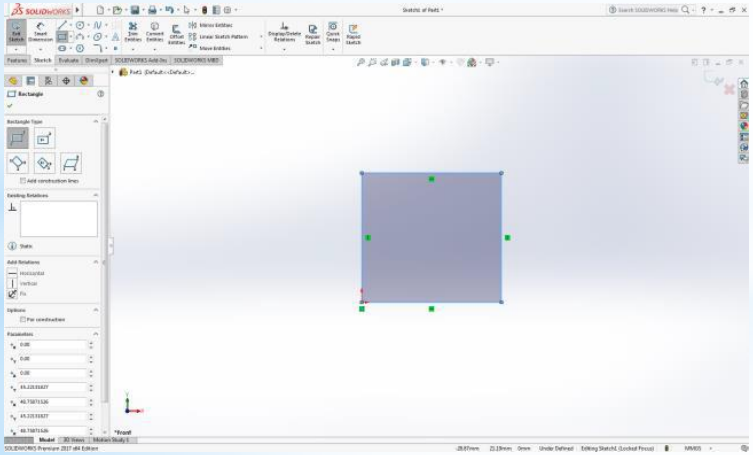
- **3D kreiranje modela**



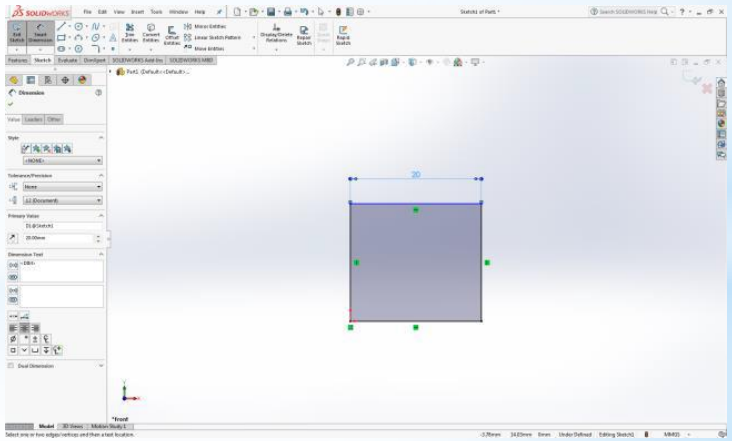
Izbor Front-alne ravni



Ortogonalni prikaz Front ravni



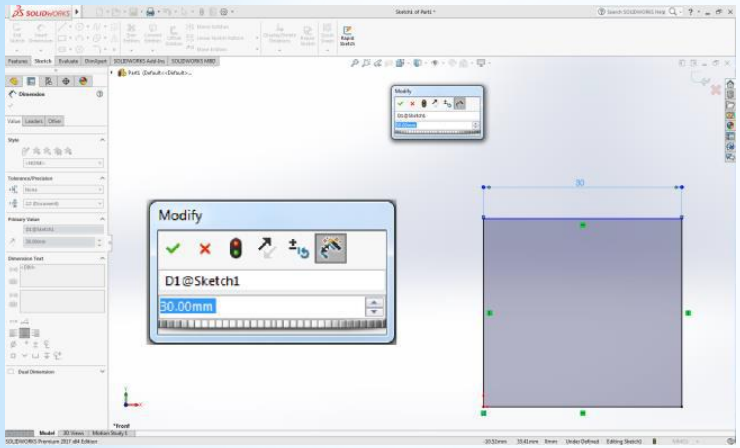
Kreiranje pravougaonika



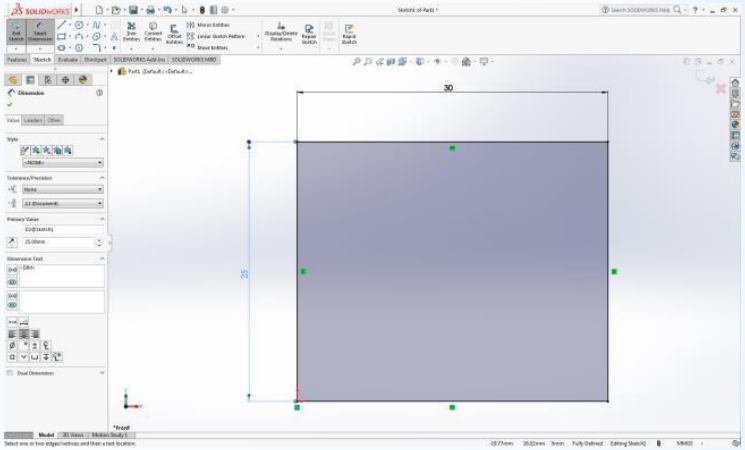
Kotiranje stranice

Postupak 3D modeliranja

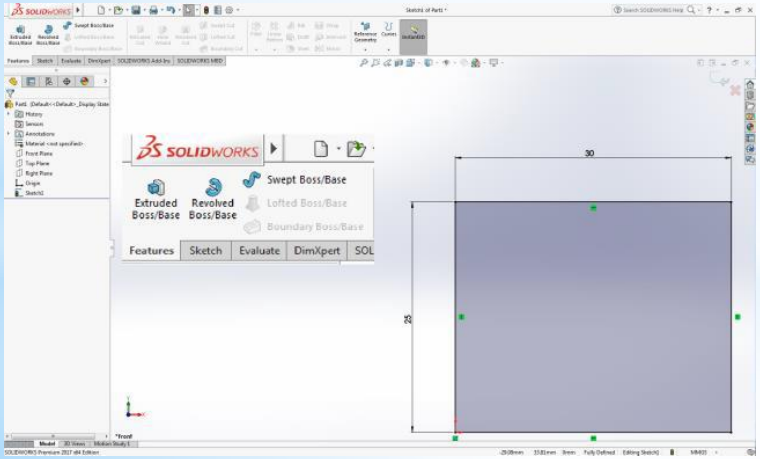
- **3D kreiranje modela**



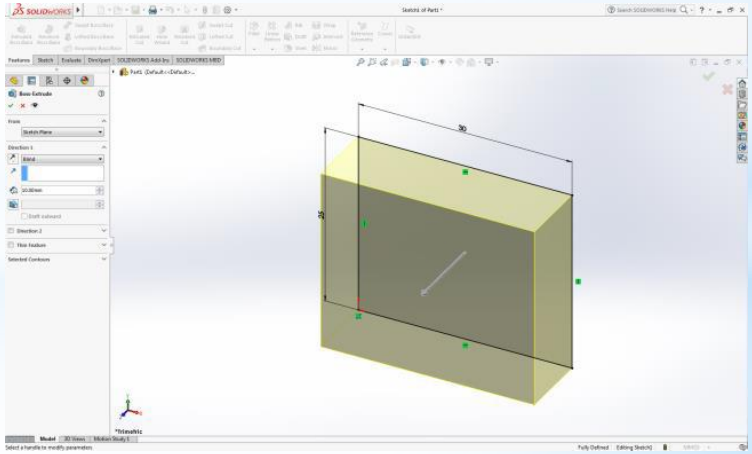
Modifikovanje kote



Kotiranje druge stranice



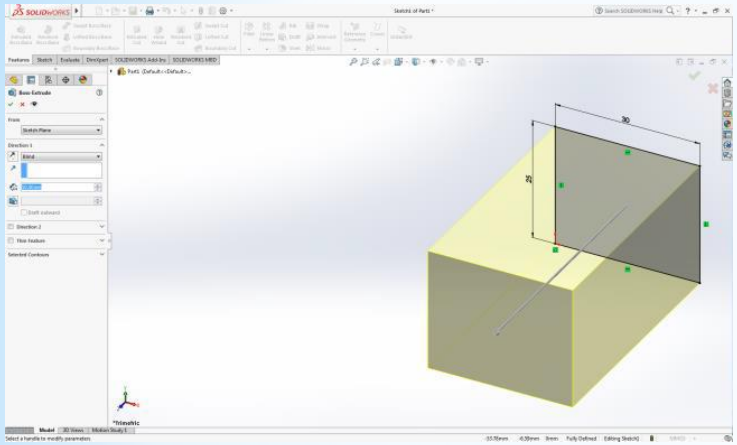
Dodavanje 3 dimenzije Features



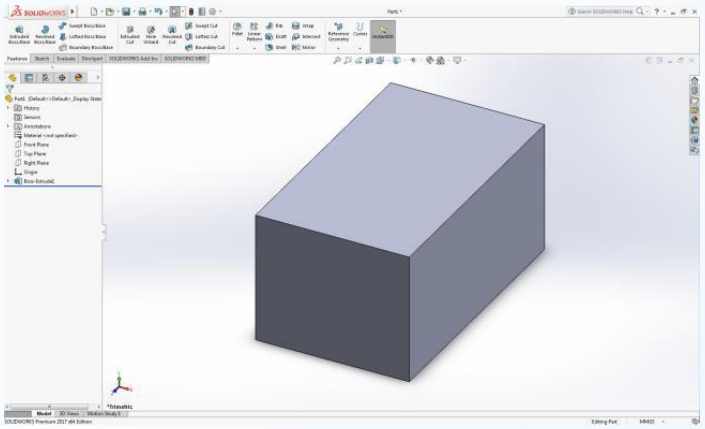
Dobijeni 3D osnovni deo

Postupak 3D modeliranja

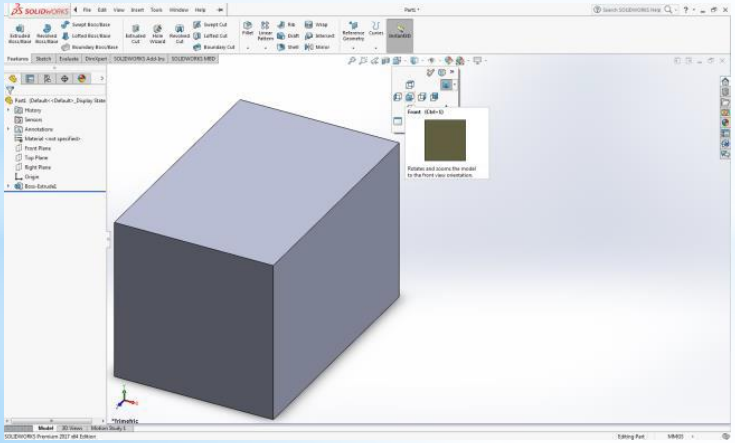
- **3D kreiranje modela**



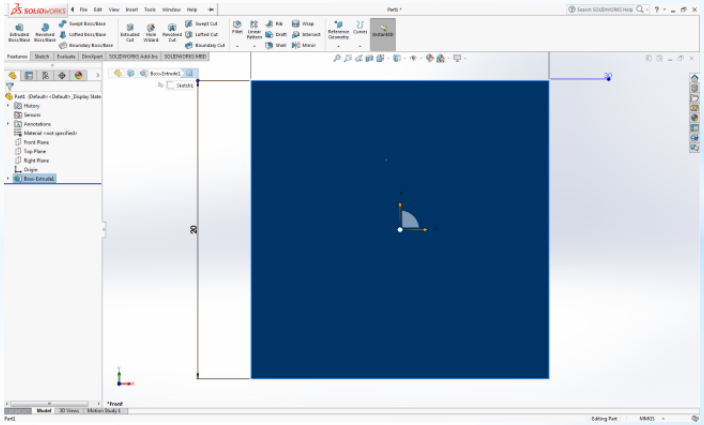
Unos debljine (Depth)



Modelirani 3D deo



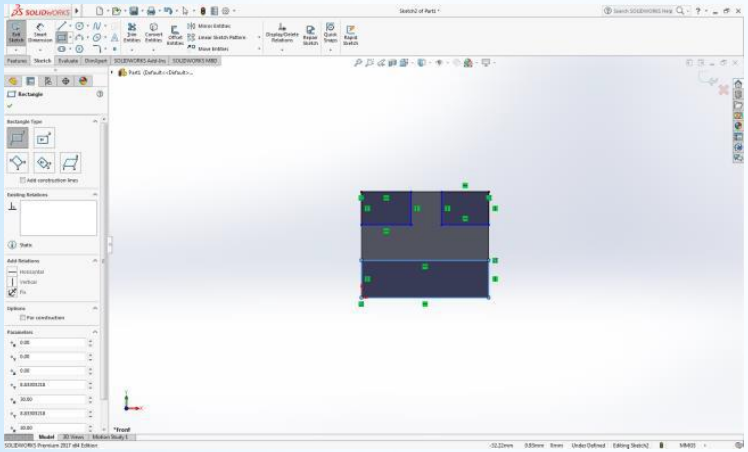
Rotiranje dela



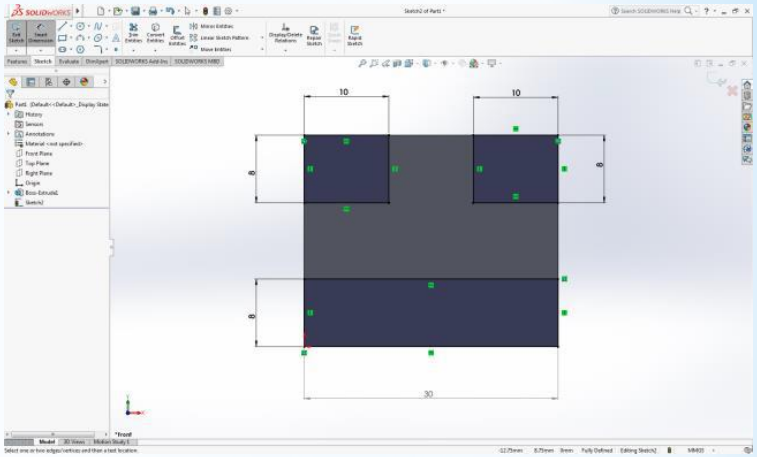
Izbor površine

Postupak 3D modeliranja

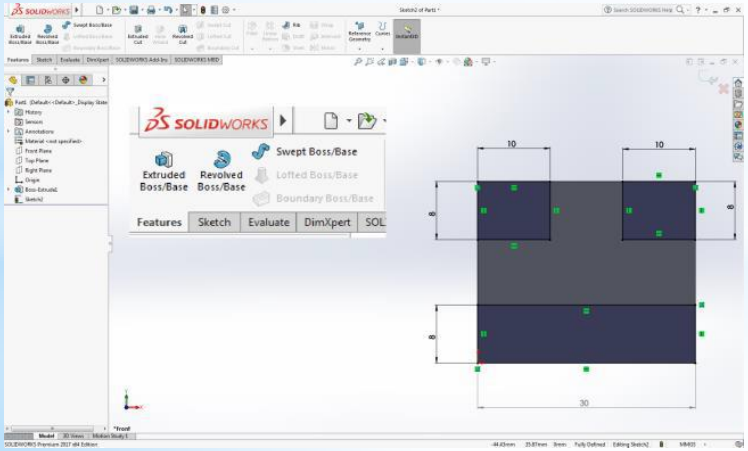
- **3D kreiranje modela**



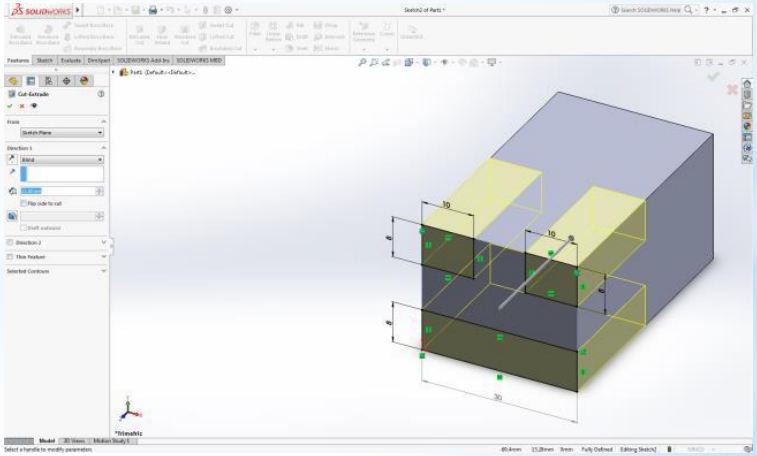
Izbor tačaka - kreiranje novih elemenata



Kotiranje (modifikovanje) mera



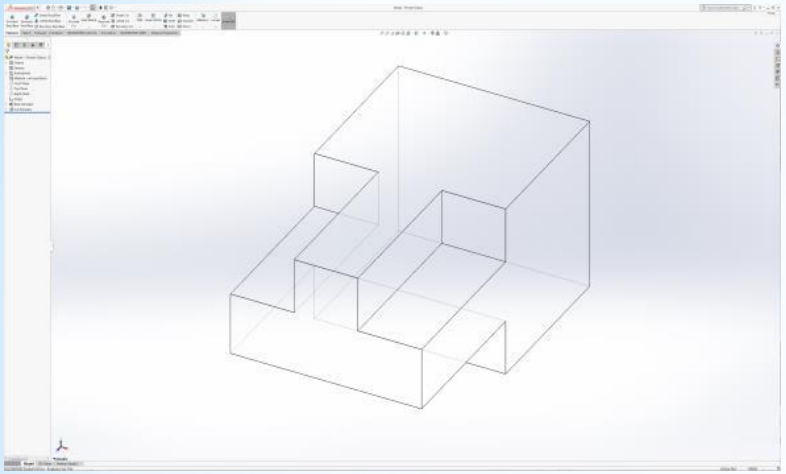
Dodavanje 3 dimenzije skicama



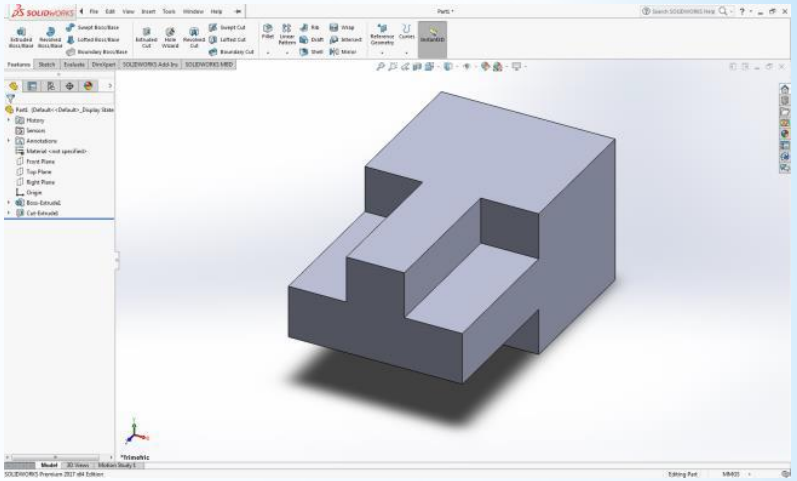
Oduzimanje zapremine *Extrude Cut*

Postupak 3D modeliranja

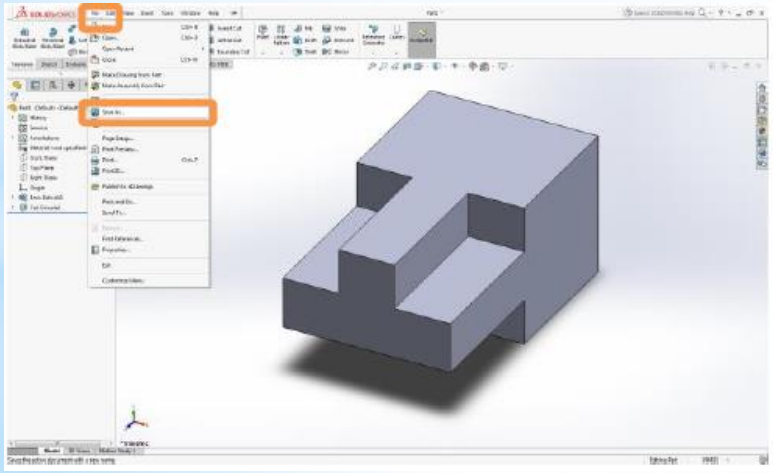
- **3D kreiranje modela**



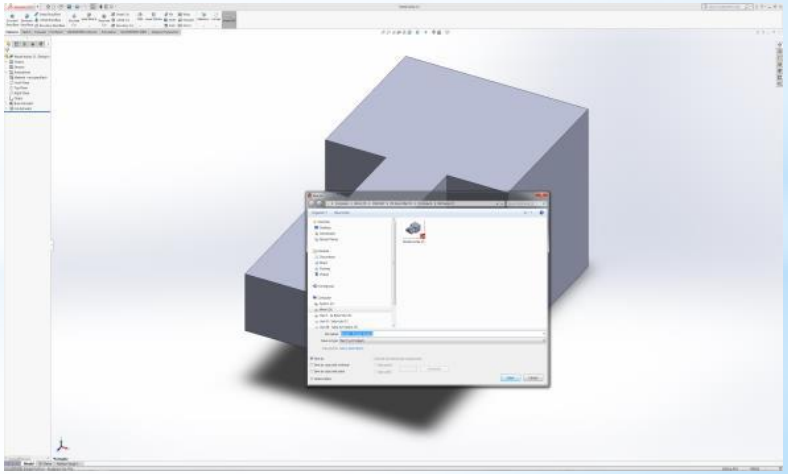
Dobijeni deo u žičanom prikazu



Dobijeni deo u osenčenom prikazu



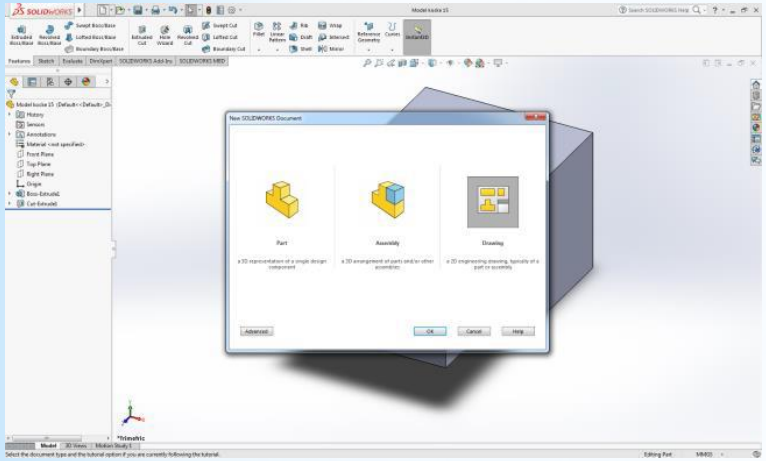
Čuvanje 3D modela – kreiranje fajla



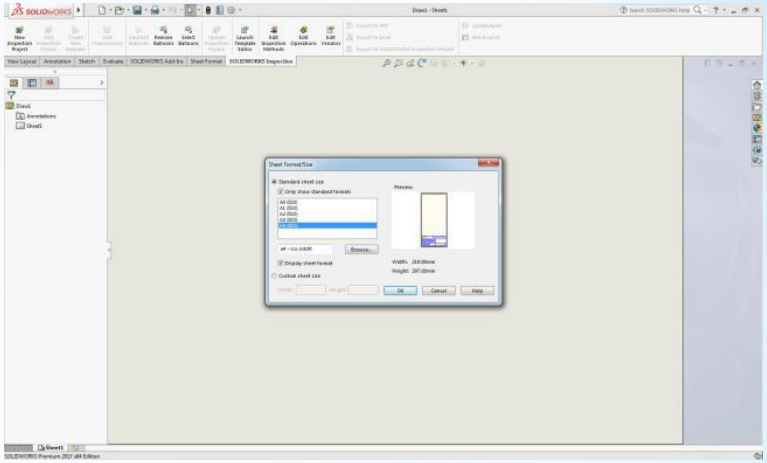
Izbor lokacije za čuvanje fajla

Postupak 3D modeliranja

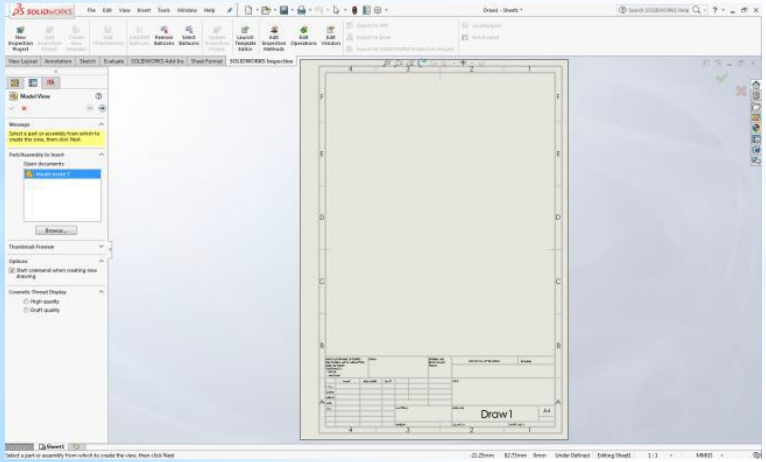
- **Kreiranje tehničke dokumentacije**



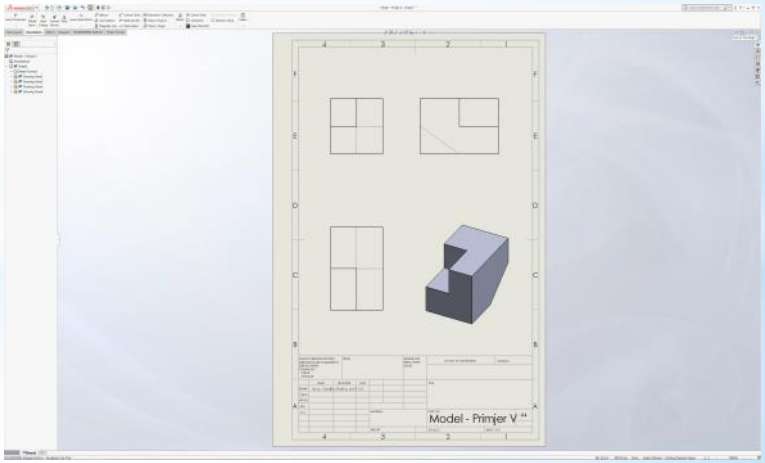
Izbor modula *Drawing*



Izbor formata papira (A4) i zaglavlja



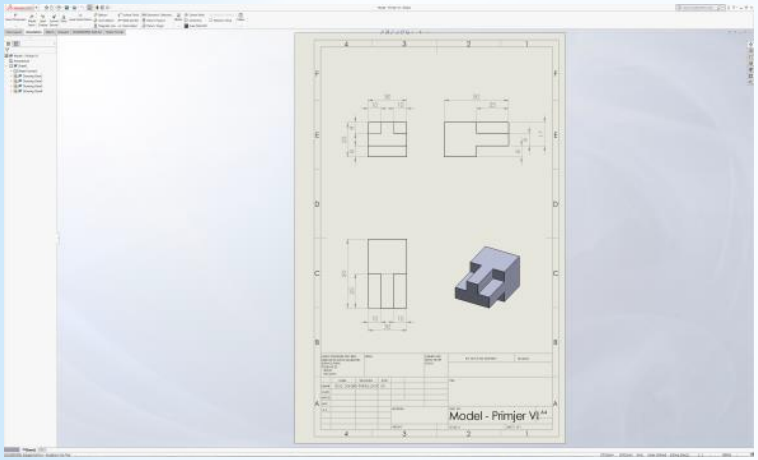
Izbor 3D modela dela



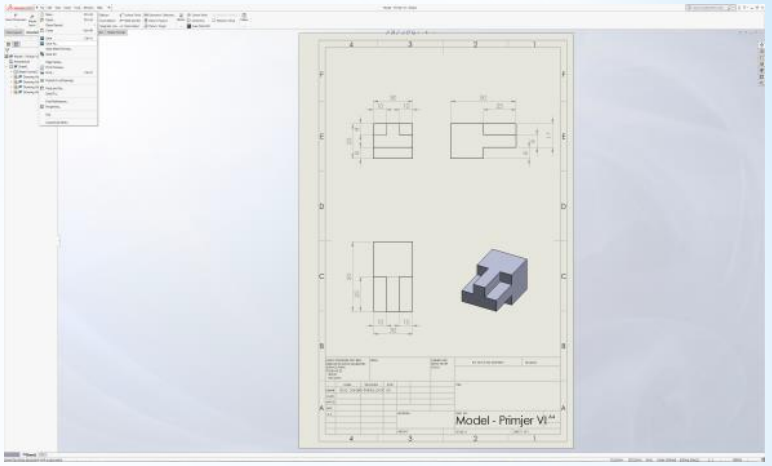
Kreiranje projekcija i 3D pogleda

Postupak 3D modeliranja

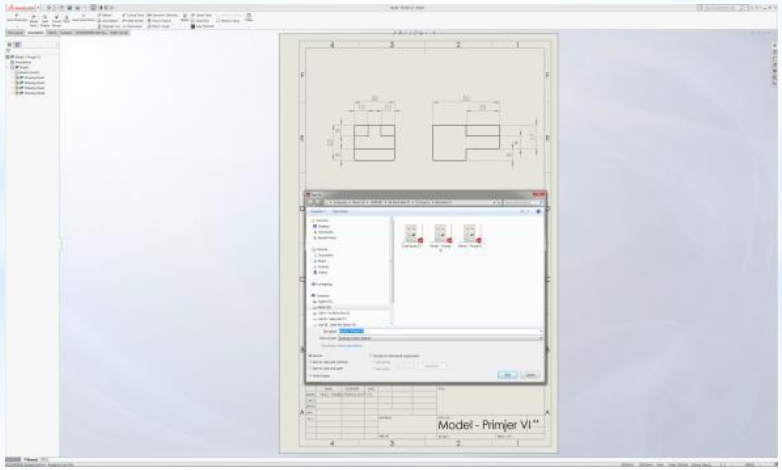
- **Kreiranje tehničke dokumentacije**



Kotiranje mera sa projekcija



Čuvanje crteža (*Save as...*)

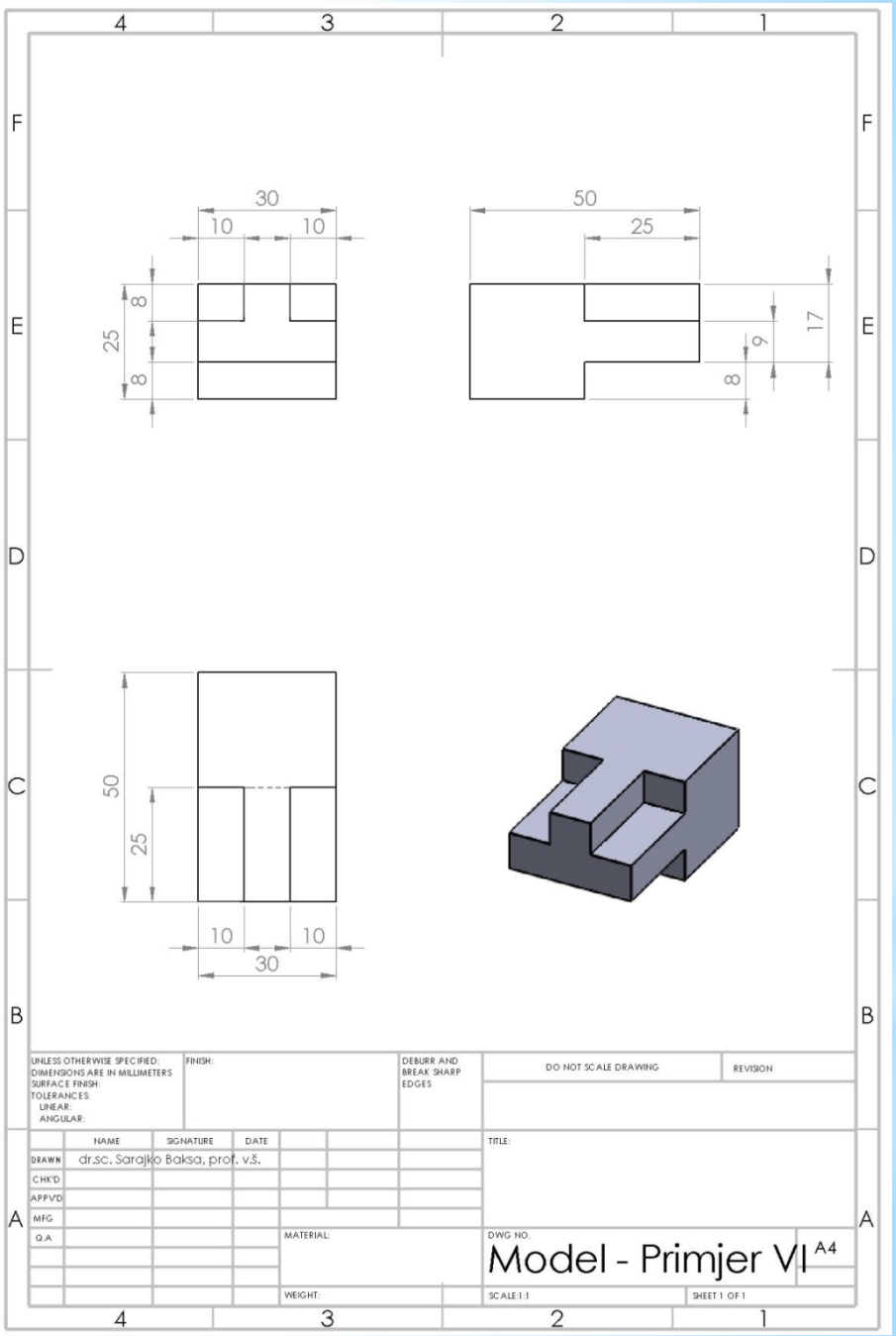


Izbor lokacije i čuvanje fajla

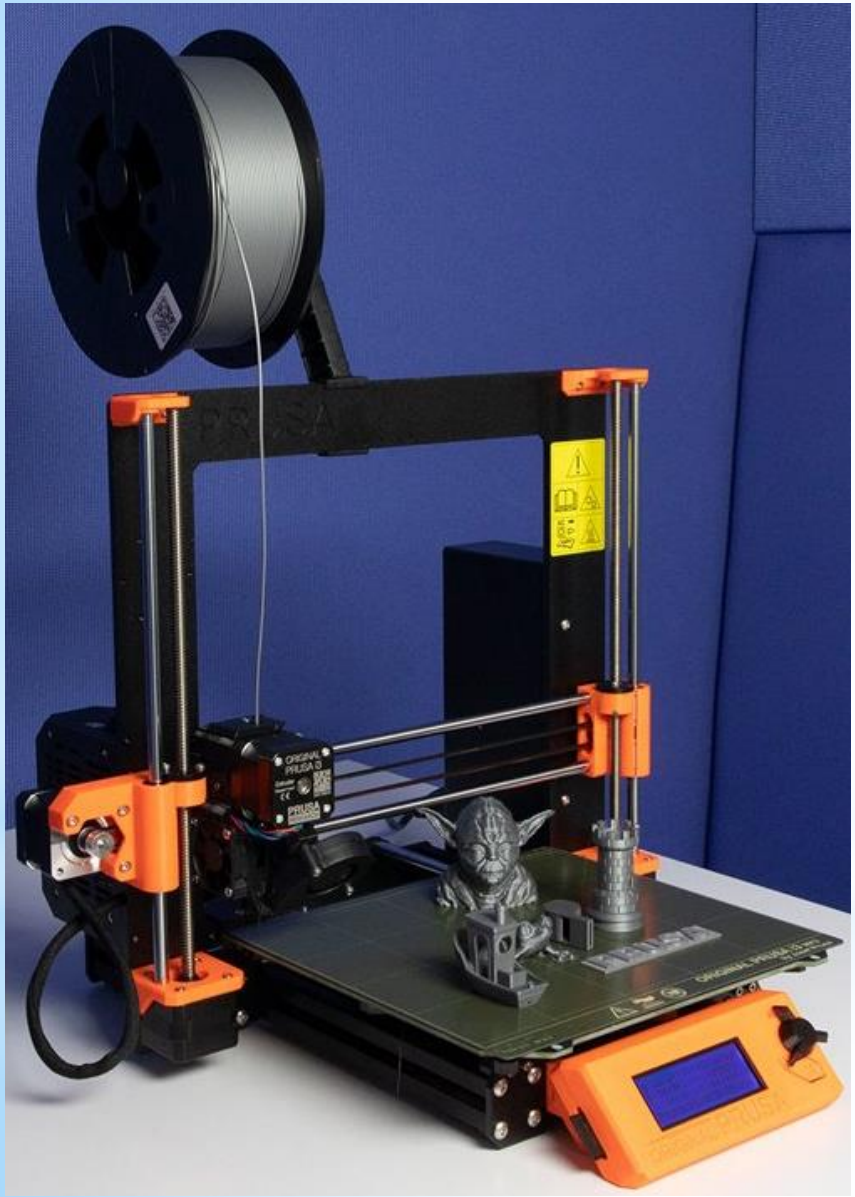
Postupak 3D modeliranja

- **Kreiranje tehničke dokumentacije**

Kreirani radionički crtež

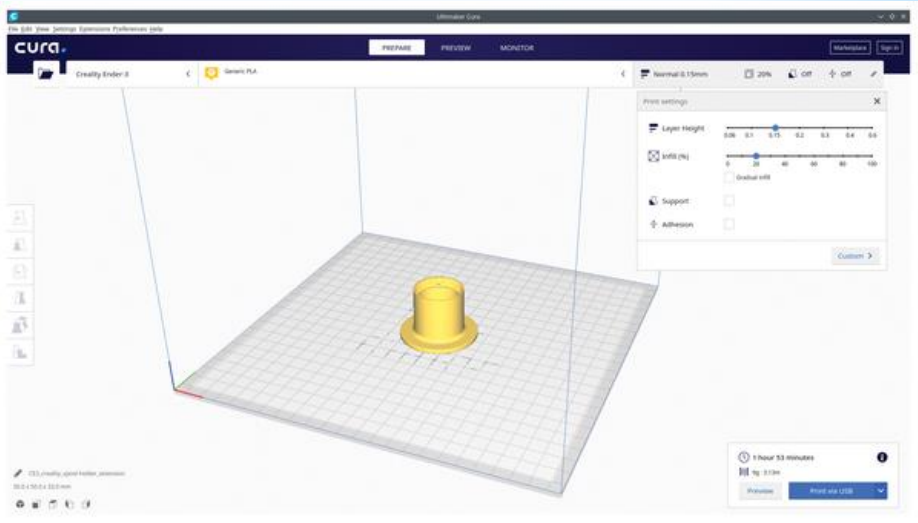


3D ŠTAMPA



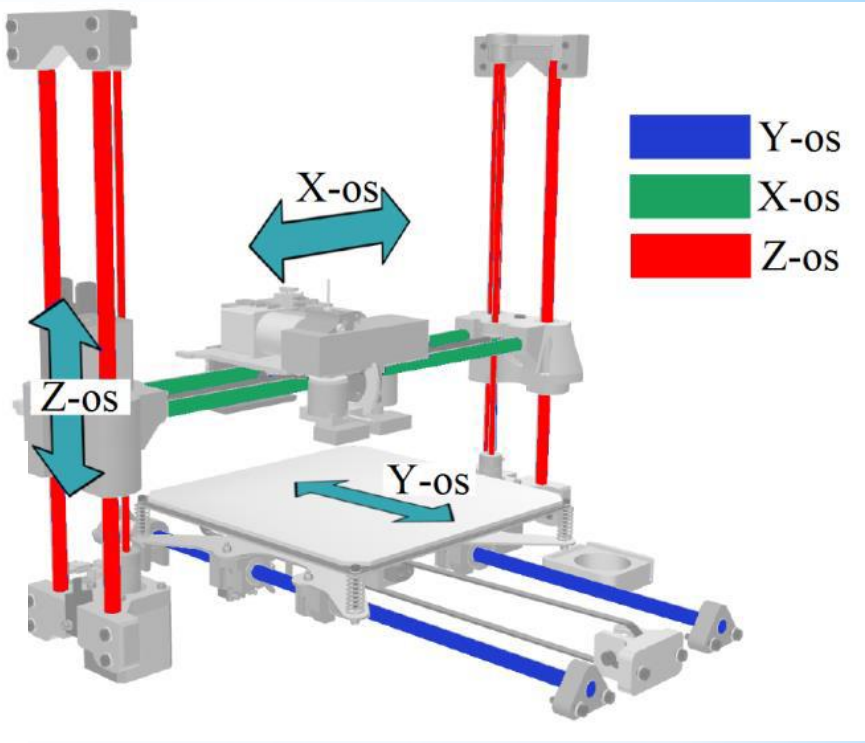
Cura

Powered by Ultimaker

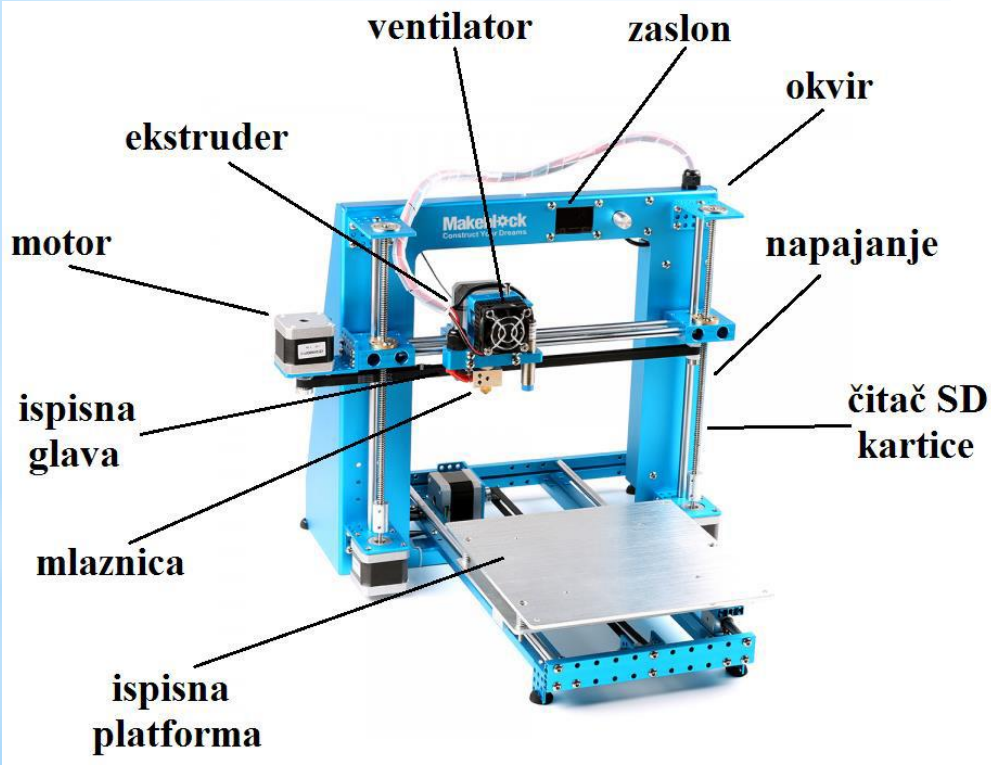


FDM štampači

Radna zapremina štampača - maksimalna veličina objekta koji se može štampati po XYZ dimenziji (osi). (npr 30x30x40cm)



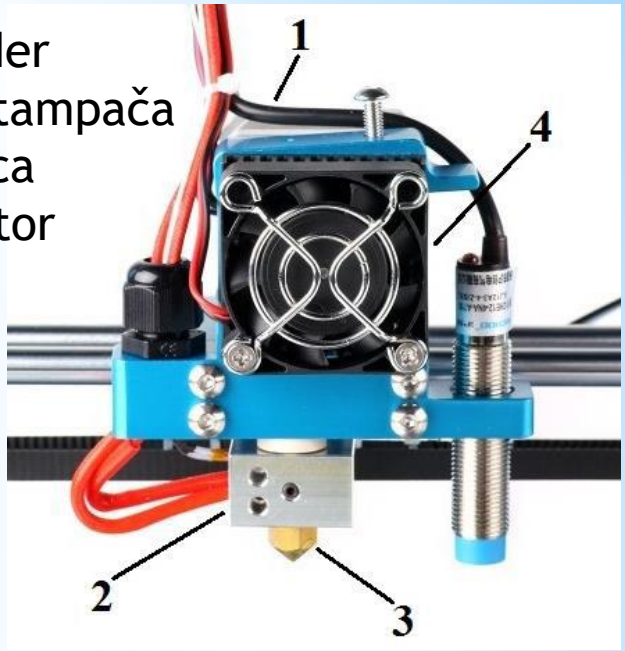
- **Delovi štampača**



Većina 3D printera kojima je **filament** (žica) materijal, koriste debljinu 1,75 mm ili 3 mm. Popularan je filament od 1,75 mm

FDM štampači - delovi

(1) ekstruder
(2) glava štampača
(3) mlaznica
(4) ventilator



- **Ekstruder**

(exstruder) - deo koji dovodi žicu filamenta do glave štampača. Smešten je iznad glave štampača.

- **Glava štampača**

(hot end) - najvažniji deo 3D printera. Mesto gde se polimer topi i ekstrudira u malim sitnim slojevima. Karakteristike: - maksimalna temperatura štampe - veličina mlaznice i mogućnost promene - hlađenje.

- **Mlaznica**

(nozzle) - nalazi se na vrhu glave iz koje izlazi polimer. Mora biti zamenjiva i njena veličina je bitna. Uglavnom su između 0,25 i 0,8 mm. Najčešća je od 0,5 mm.
Manja mlaznica - glađa površina, preciznija i detaljnija štampa
Veća mlaznica - brža štampa, bolje prvo prianjanje, manje potpornih struktura, bolja pouzdanost

- **Ventilator**

Hladi materijal.
Može ih biti od 1-3.

- **Platforma**

Omogućava održavanja temperature na objektu kako bi se sprečilo njegovo savijanje. Omogućava bolje prianjanje slojeva materijala. Presudna je kod prvog sloja materijala. Temperatura grejanja je između 40° i 110°C. Prekriva se folijom po potrebi.

FDM štampači - delovi

- **Kućište**

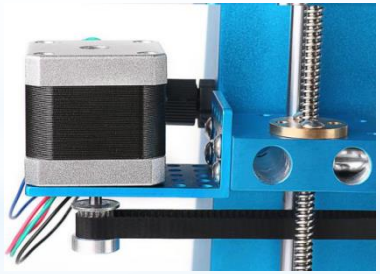
Omogućava 3D štampu bez računara ili korištenja softvera. Potrebna je SD kartica za čitanje G-kod fajla. Moguće je i podešavanje parametara 3D štampača.

- **Napajanje**

3D pštampači rade sa 12 ili 24 V napajanjem.

- **Motori**

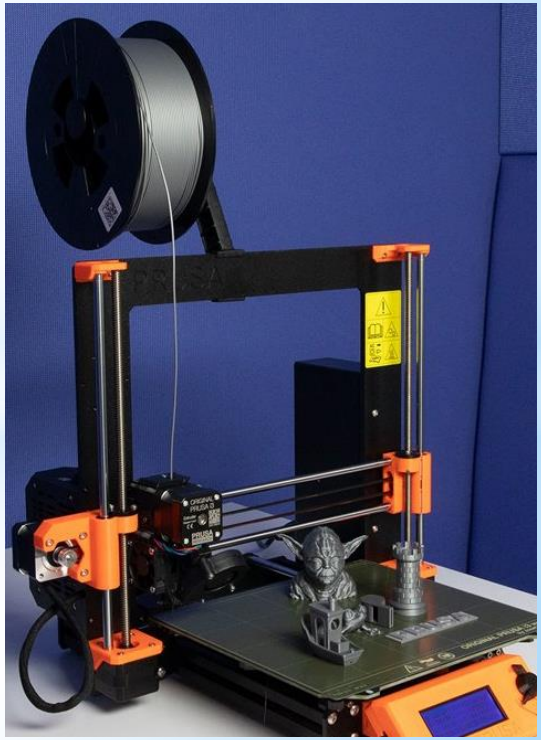
3D štampači sadrže koračne motore koji se okreću u koracima. To im daje preciznu kontrolu nad vlastitim položajem. Većina koristi motore NEMA 17 sa 200 koraka po obrtaju.



- **Matična ploča**

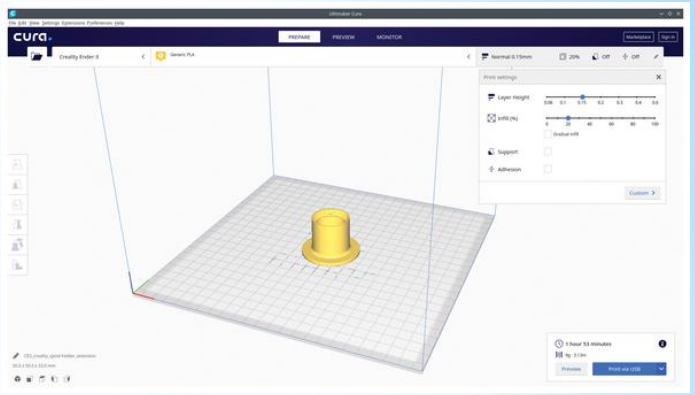
Mozak 3D štampača. Preuzima fajl (G-kod) i prema njemu usmerava štampu. Sadrži mirkokontroler i sve strujne sklopove potrebne za pokretanje motora, čitanje senzora i komunikaciju s računarom.

Filament



Softver za 3D štampu - Ultimaker Cura

Besplatan softver za 3D štampu

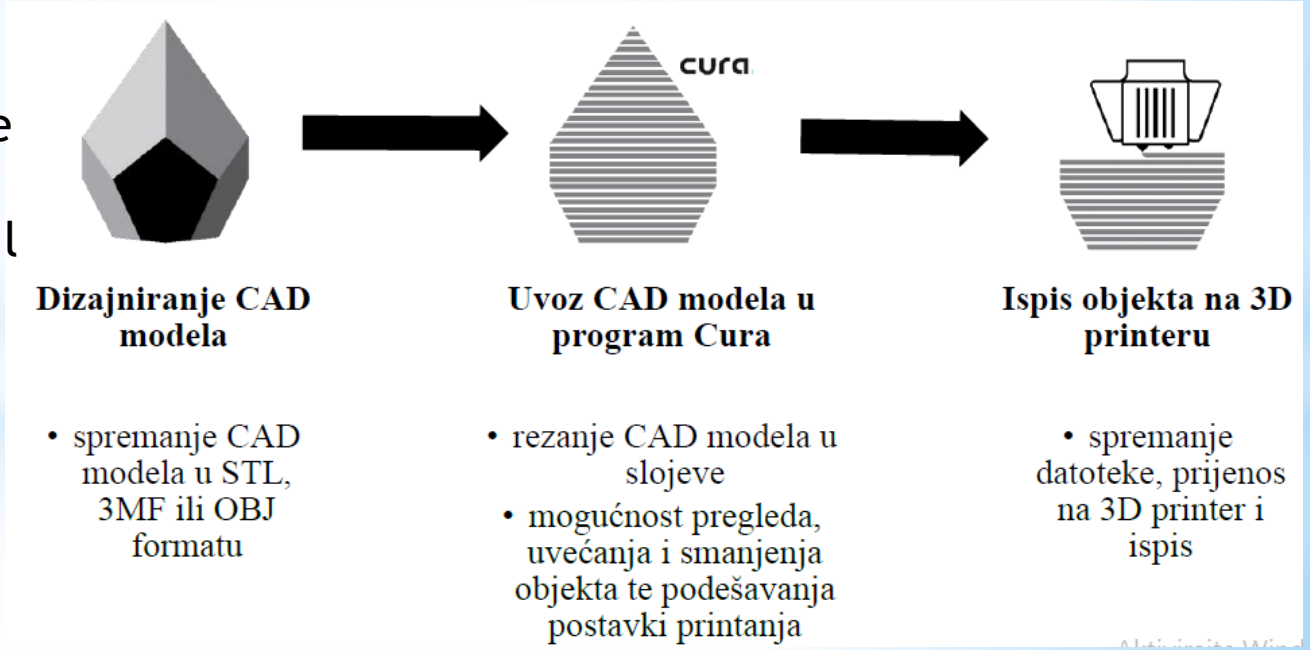


Program **Cura** stvorio je David Braam. Cura je besplatni program s licencom AGPLv3.

Cura prvenstveno služi za rezanje CAD modela u slojeve i stvaranje G-koda prepoznatljivog 3D štampaču, sadrži mogućnost podešavanja više od 200 postavki štampe prema vlastitim željama i potrebama.

Svaki CAD model koji se dizajnira za štampanje mora se pretvoriti u fajl prepoznatljiv 3D štampaču.

Cura reže CAD model u tanke slojeve i eksportuje u datoteku razumljivu 3D printeru.

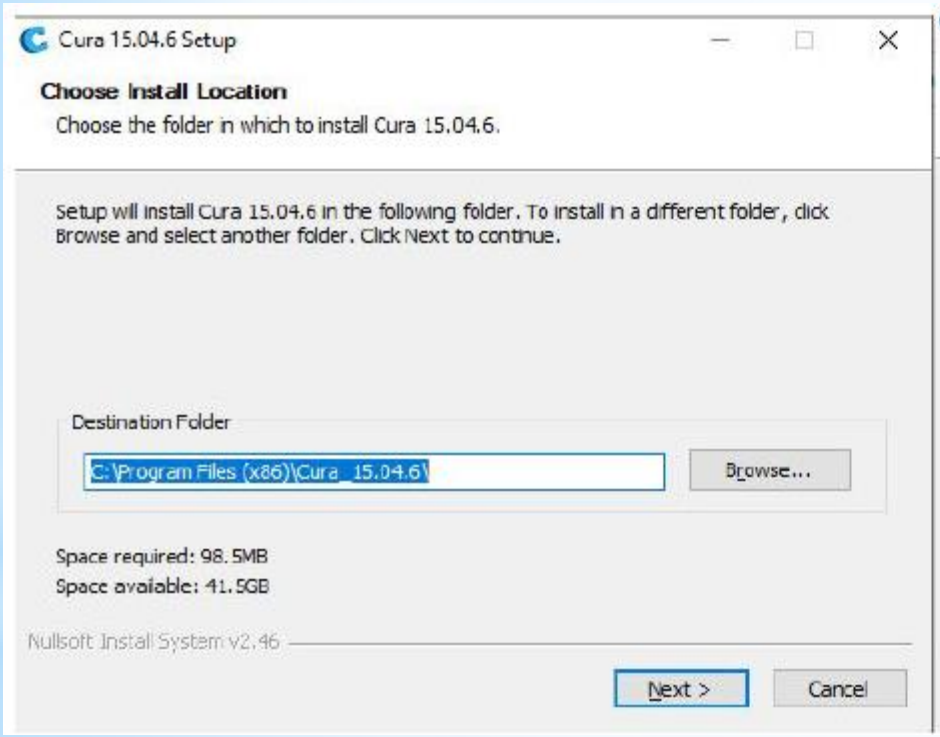


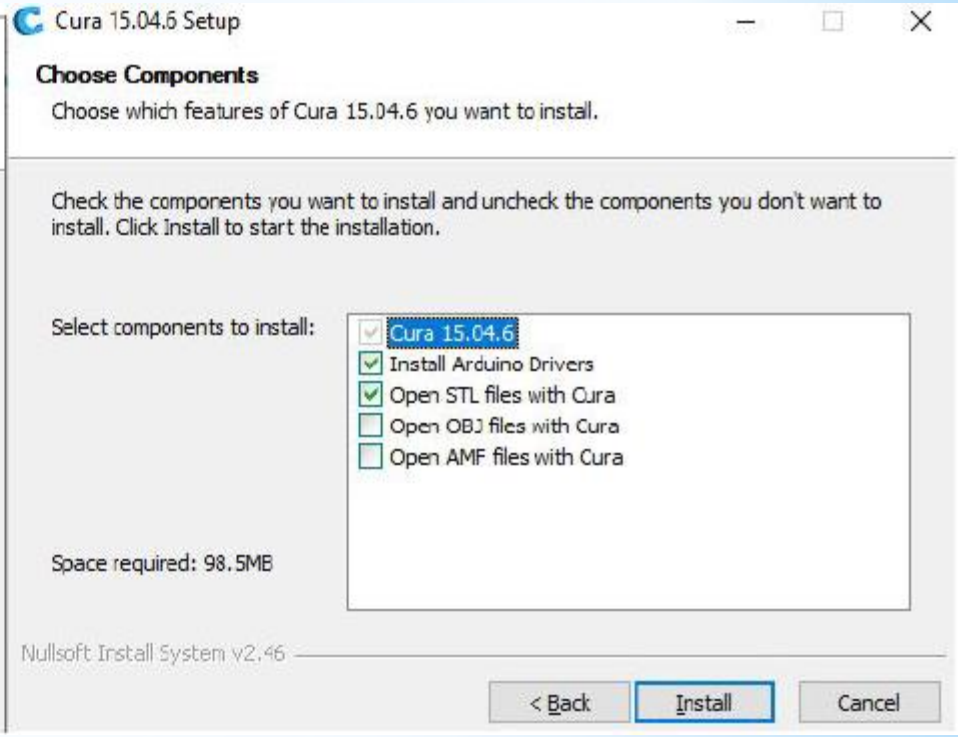
Ultimaker Cura

Instaliranje

Ukuicati u google pretraživaču: ***Cura ultimaker download***

Izabrati operativni sistem računara (npr Windows x86)





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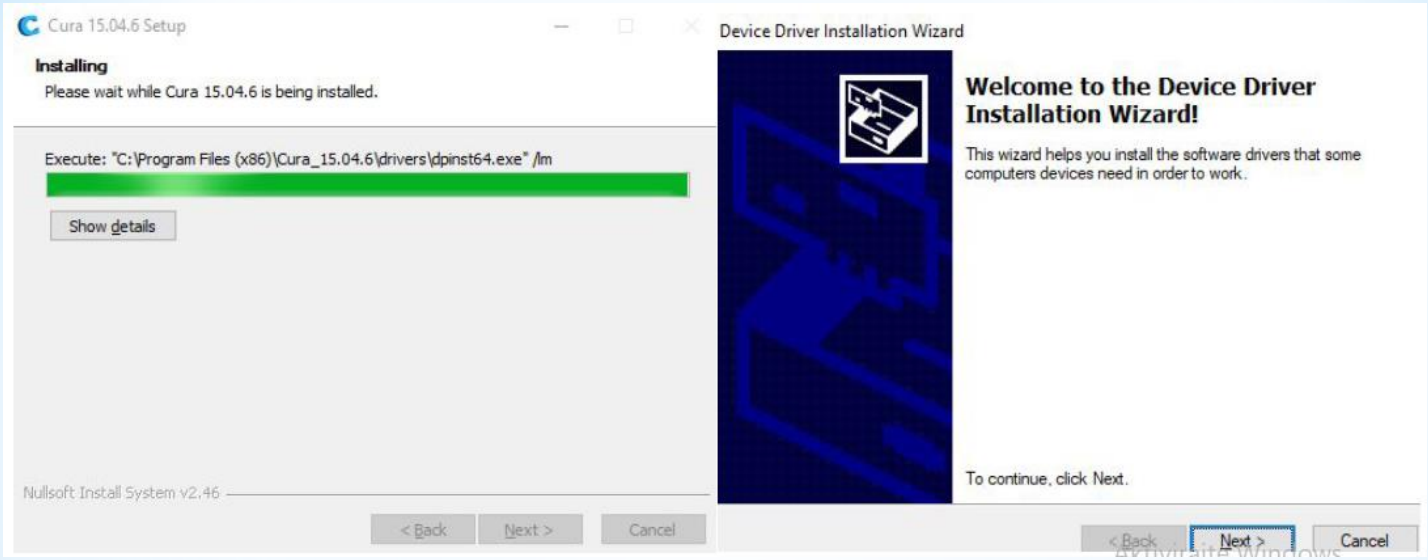

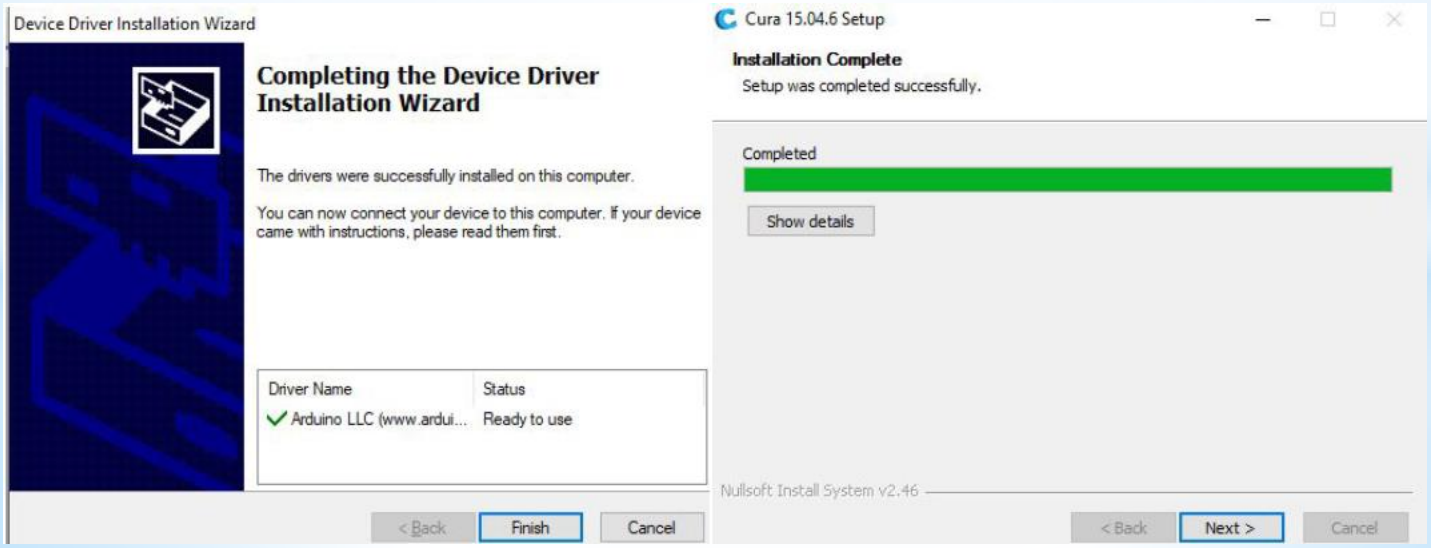

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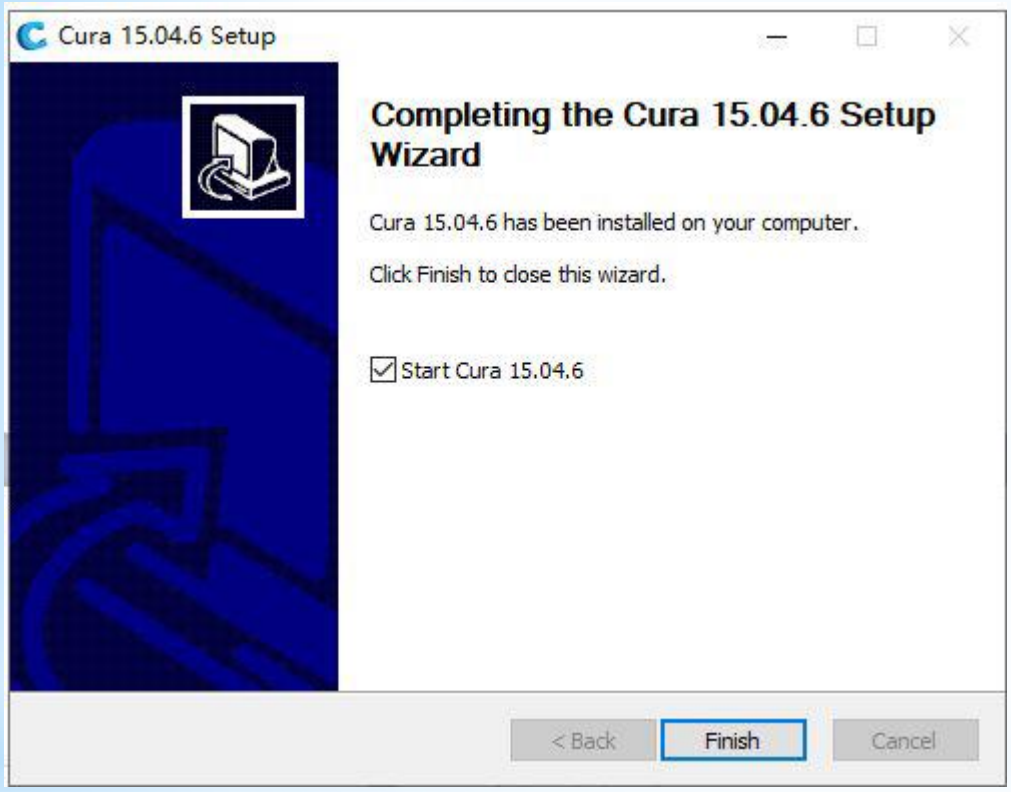
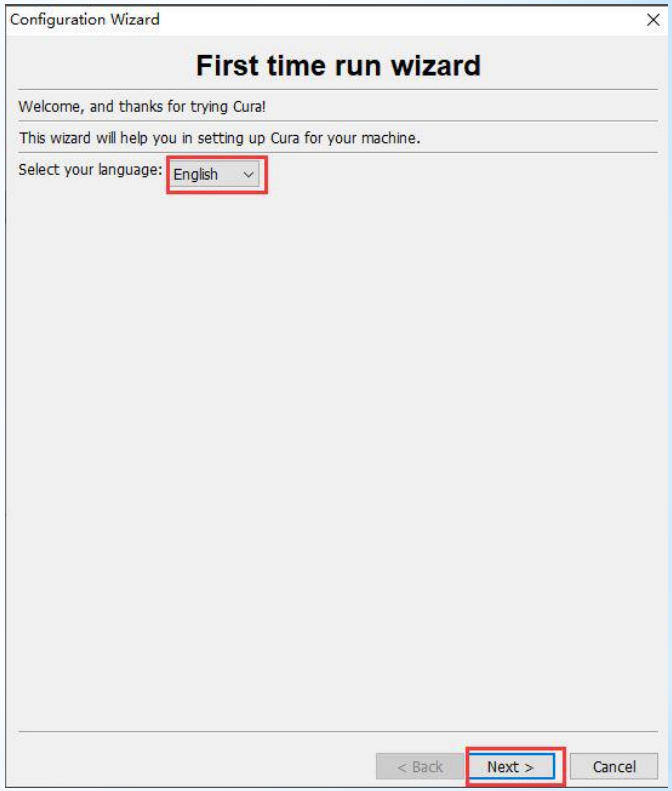
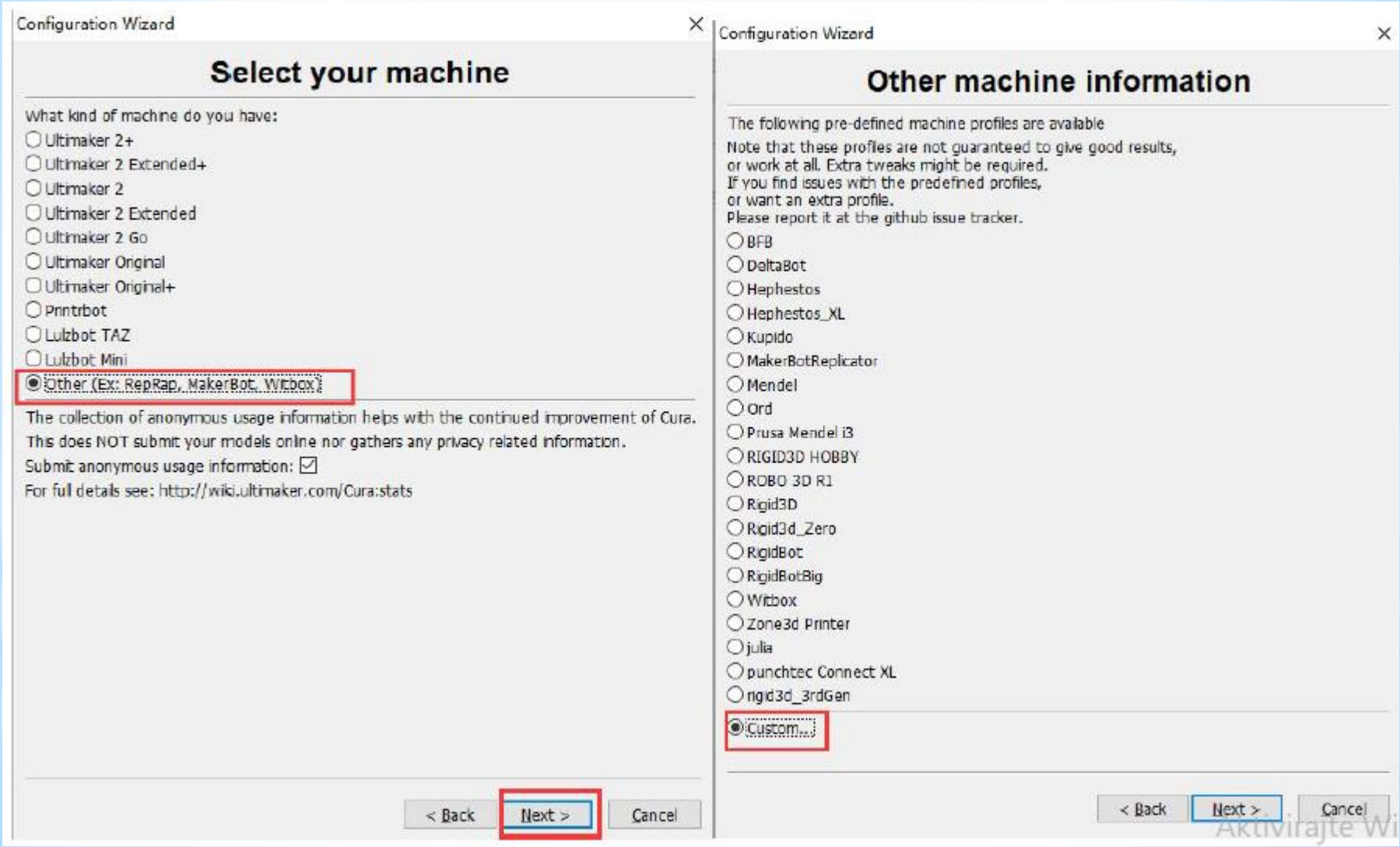




Click "Finish" and start Cura

Ultimaker Cura

Select your machine, choose "Other"



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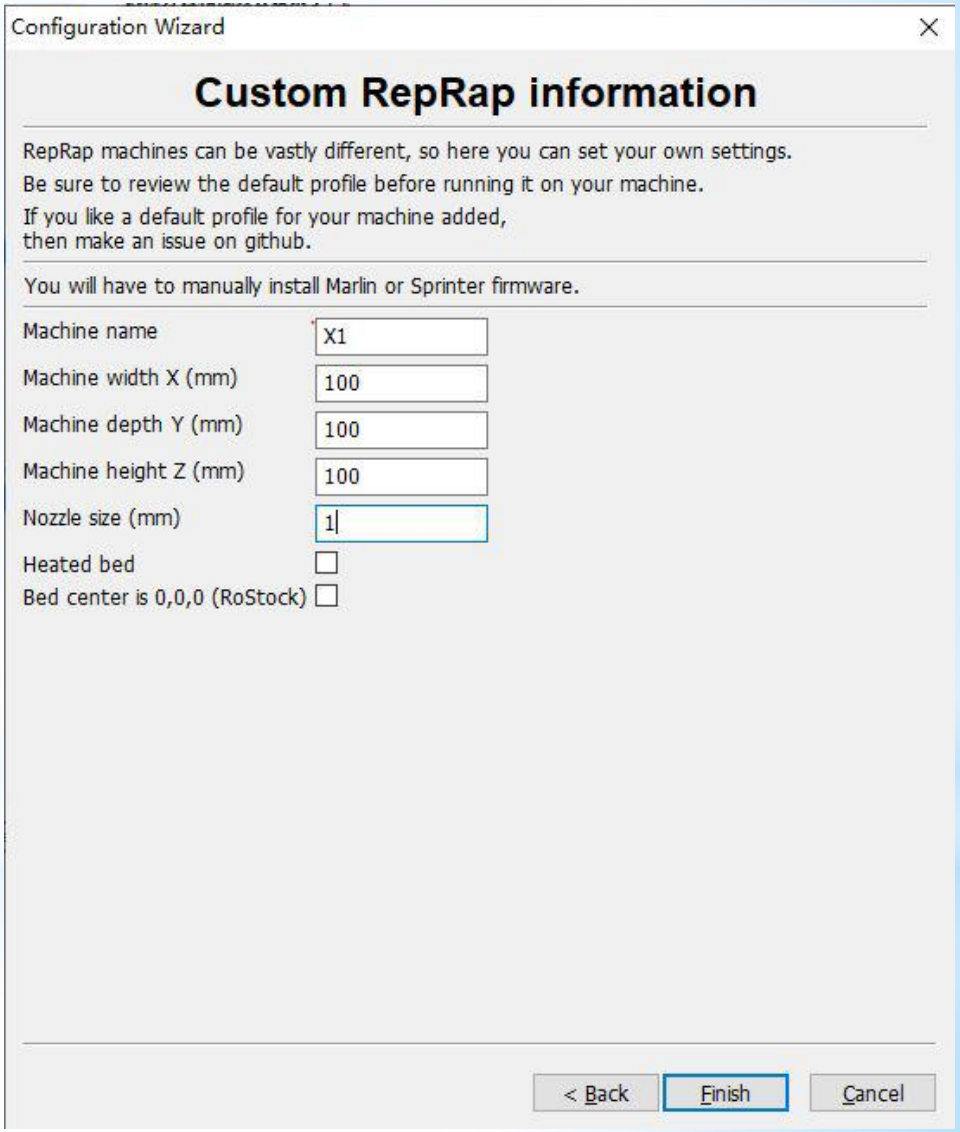
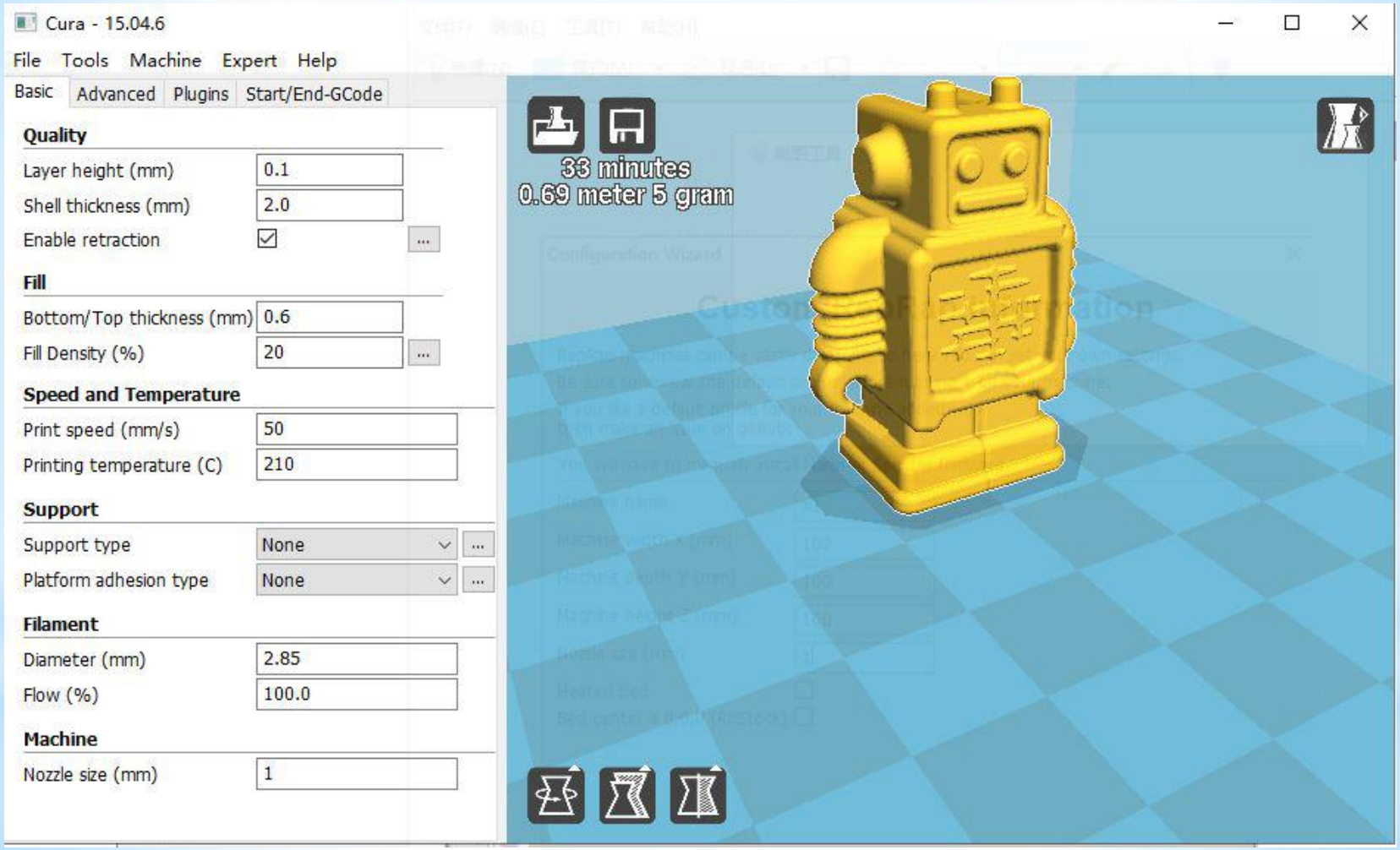
Enter and select the following values as the below picture showed, then click “Finish” .

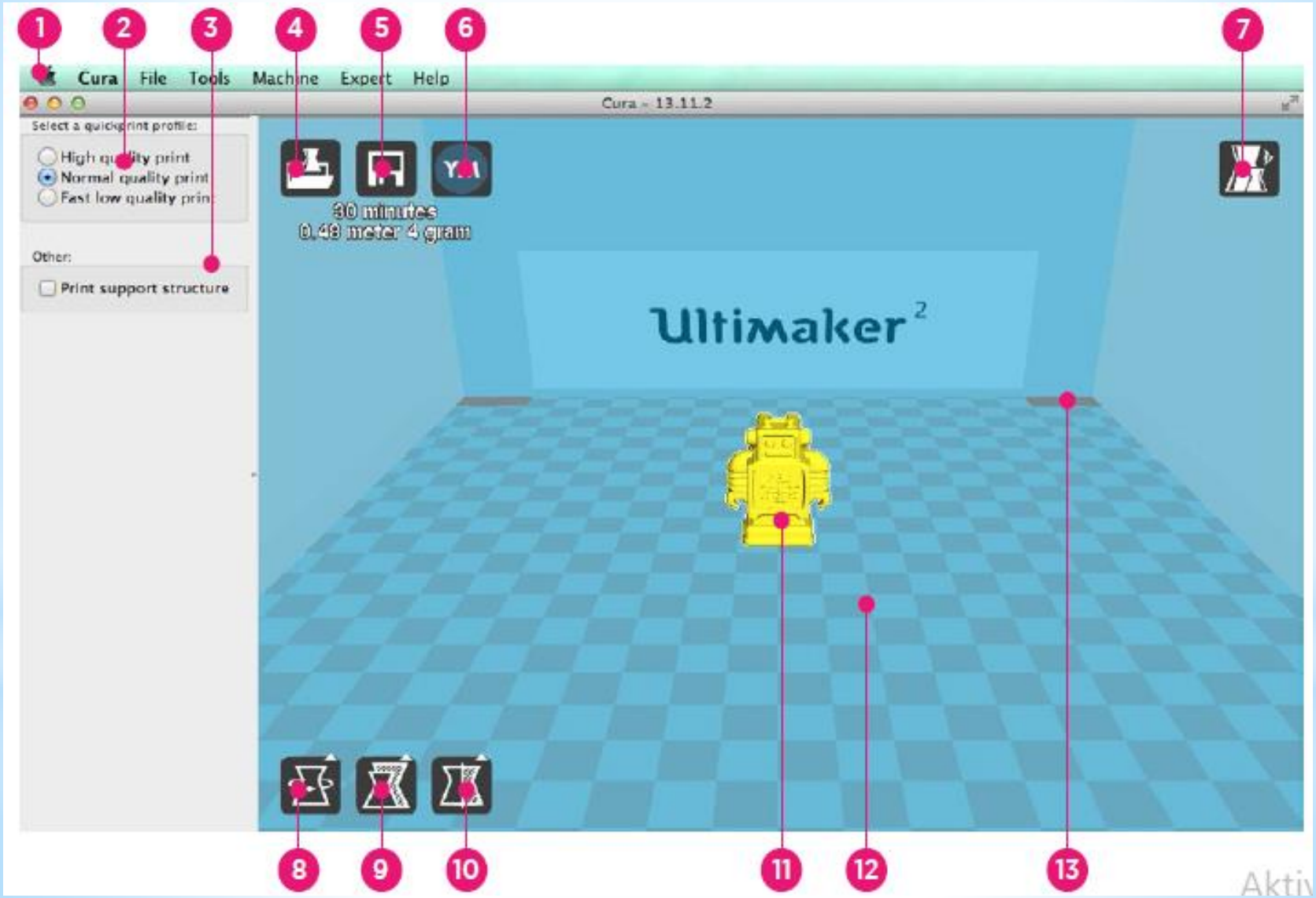


Ultimaker Cura

You have finished the installation!



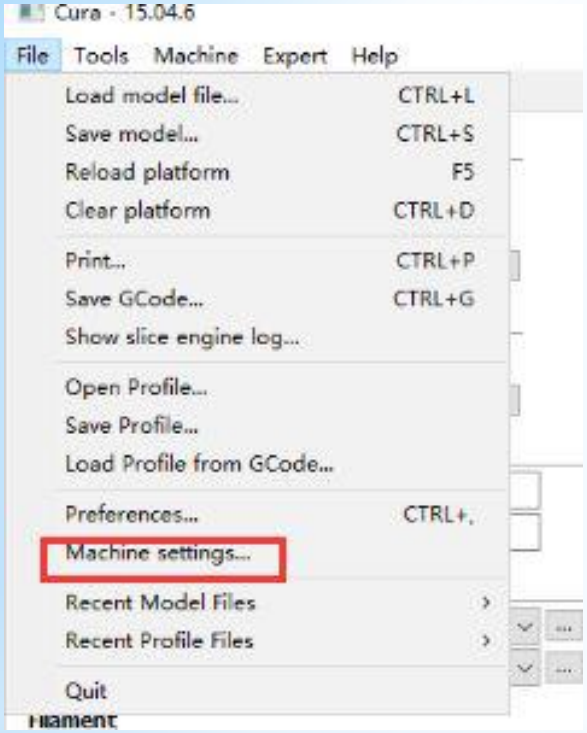
Ultimaker Cura

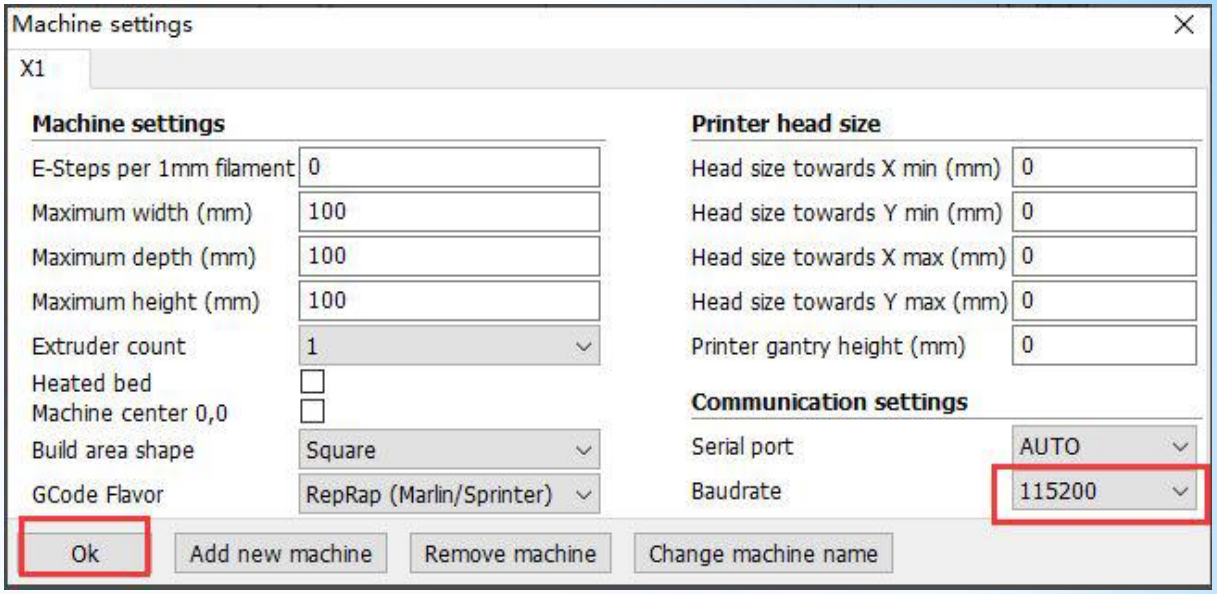


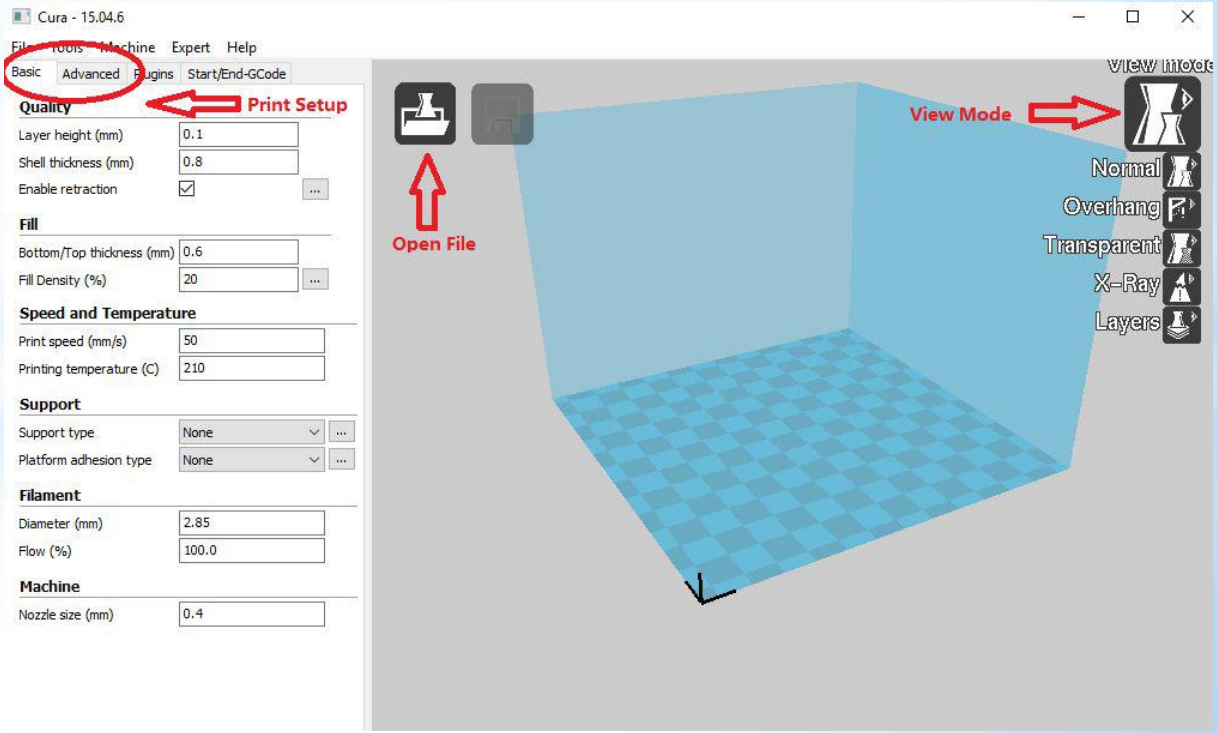
Ultimaker Cura

1. **Menu bar** In this bar you can change settings, machines and profiles.
2. Make a selection in 3 different **quick print profiles**.
3. The option to print with **support structure**.
4. A button which gives you the opportunity to **load objects**.
5. With this button you can **save prepared files** to your Ultimaker SD-card.
6. Through this button you can share 3D files on **YouMagine.com**.
7. A prepared model can be **viewed in other modes** to check it's printpath.
8. The option to **change the rotation** of the object you like to print.
9. The option to **change the Scale** of the object you like to print.
10. The options to **Mirror the model** you like to print.
11. The model you have loaded through the load file button.
12. This is a visualisation of the **print area** of your Ultimaker.
13. The grey squares in the build area are the **no go zones**. In your Ultimaker 2 these are the metal clips were you can't print.

Ultimaker Cura







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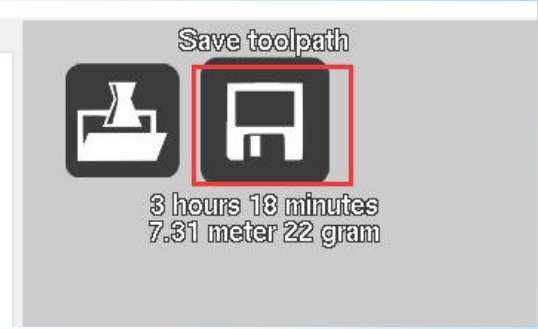
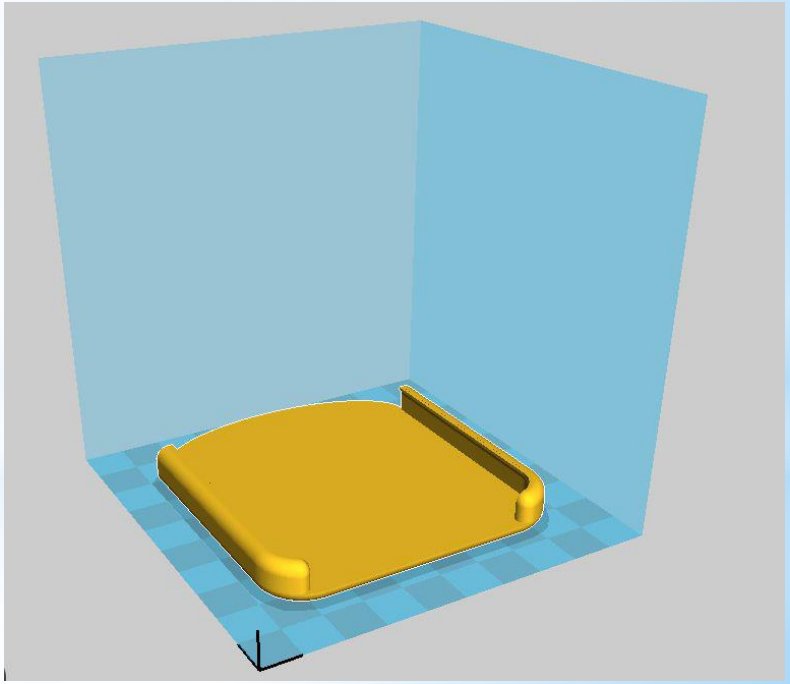


1. Open file: Use to open your STL or OBJ file, you can drag and drop the files here too.
2. View Mode: Let you switch between Layers and Normal view.
3. Print Setup: Printer-specific settings which user can access to all the settings (Basic Mode and Advanced Mode) and can be changed.
4. Save to Disk: When you are finished, save the G-code to your hard disk or SD card for the printer.

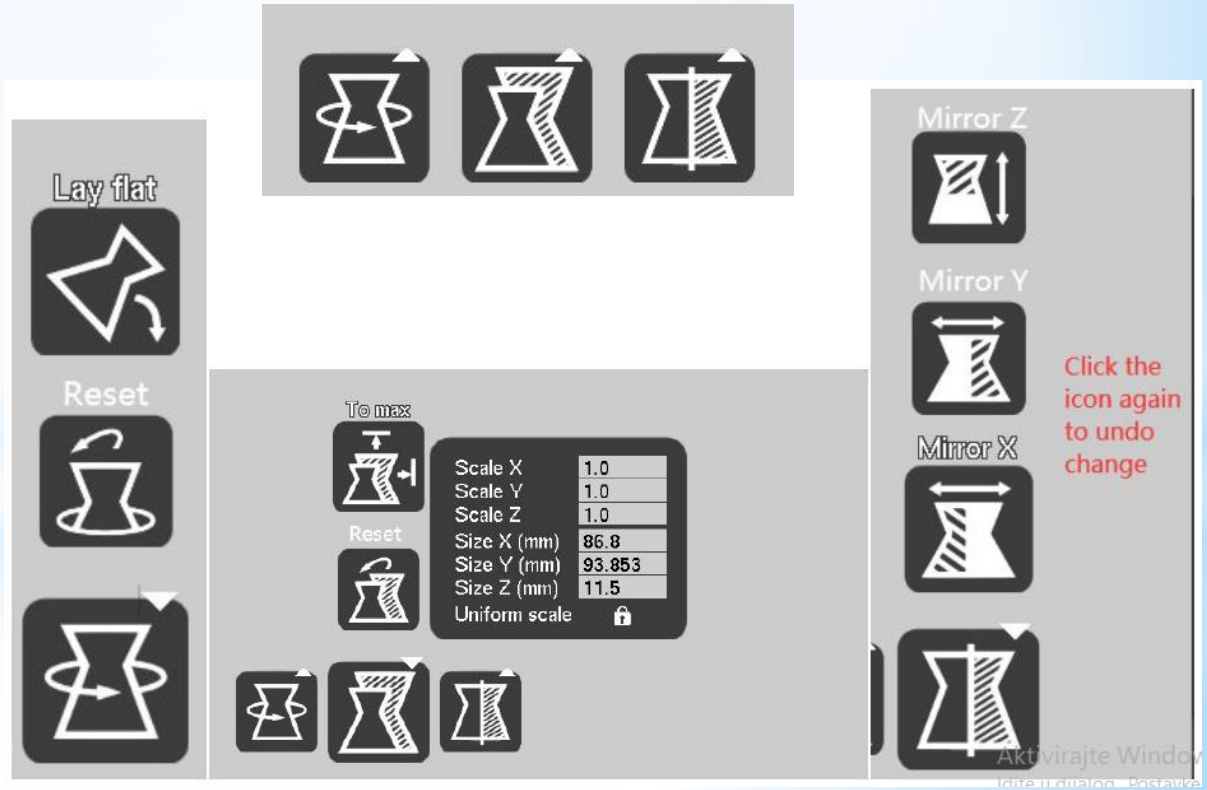
1. Load a 3D model into Cura using the "Load" button or clicking the File > Load model file.
2. Explore different view mode. In Normal View, you see the entire object (the way it will look when printed).



Ultimaker Cura - parametri štampe

1. When you click the model, it will pop Rotate, Scale, Mirror icon. You can scale, rotate or mirror
2. it on the build platform. Just play with these functions, you can undo the changes by clicking
3. Reset button or clicking the icon again in Mirror option.

In Layer View, you can go through layer by layer with the scrollbar at the bottom right. When switching to Layer View, it may take a short time before the layers are calculated and displayed (depending on the model and on your computer hardware).



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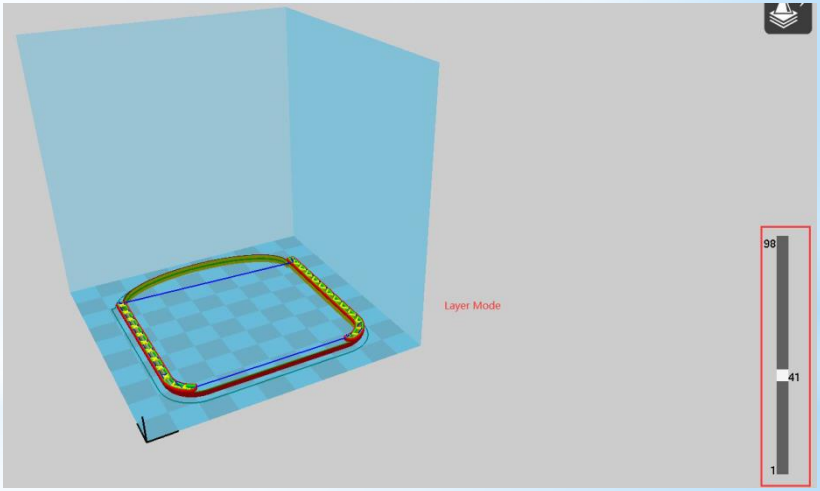
3. Reset button or clicking the icon again in Mirror option.

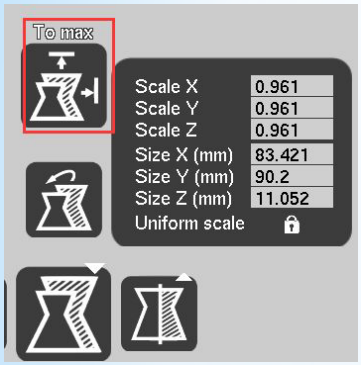
If one of dimension is larger than the printing size of the printer (X,Y,Z=100mm), you can't transfer the STL file into G-code file. You need to click Scale button to change the scale.

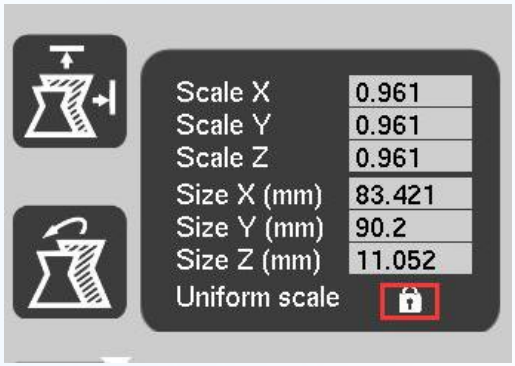
You can scale the model to the appropriate dimension quickly by click the To max button



Ultimaker Cura

Remember to keep the "Uniform Scaling" always locked, otherwise the printed model will be distorted. To close the Scale box, click the Scale button a second time.





Right-click the model to open the context menu. Here, you can undo the changes to the model and center it on the platform again. You may also duplicate the object, if you wish to print several copies of the model.

Ultimaker Cura

For now, we work in Basic Mode. The values you can manipulate it to obtain the best printing quality:

- Layer Height (recommended 0.1 or 0.2mm). The smaller the layer height value, the better printing quality - that will increase print time, however, probably result in failure of printing as well.
- The Shell Thickness setting (recommended 0.8mm) of Cura determines the thickness of the object's wall. It has to be an integer multiple (1x, 2x, 3x, etc) of the nozzle diameter. A thickness setting of 0.8mm means that the walls will be 2 lines wide (as the nozzle of X1 printer has a diameter of 0.4mm).
- The Bottom/Top Thickness (recommended 0.8mm). If you print an object with a large flat top, you may want to print more layers in order to close the top surface completely. This avoids the unwanted "pillowing" effect. (Again, the value must be integer multiples of the nozzle diameter).
- Infill Density(recommended 20%) determines how much plastic is printed inside the object. A higher value means that more plastic will be printed. Typically, 10% to 20% are sufficient to build strong objects. In case, you wish to print the object completely hollow, set the density to 0%.

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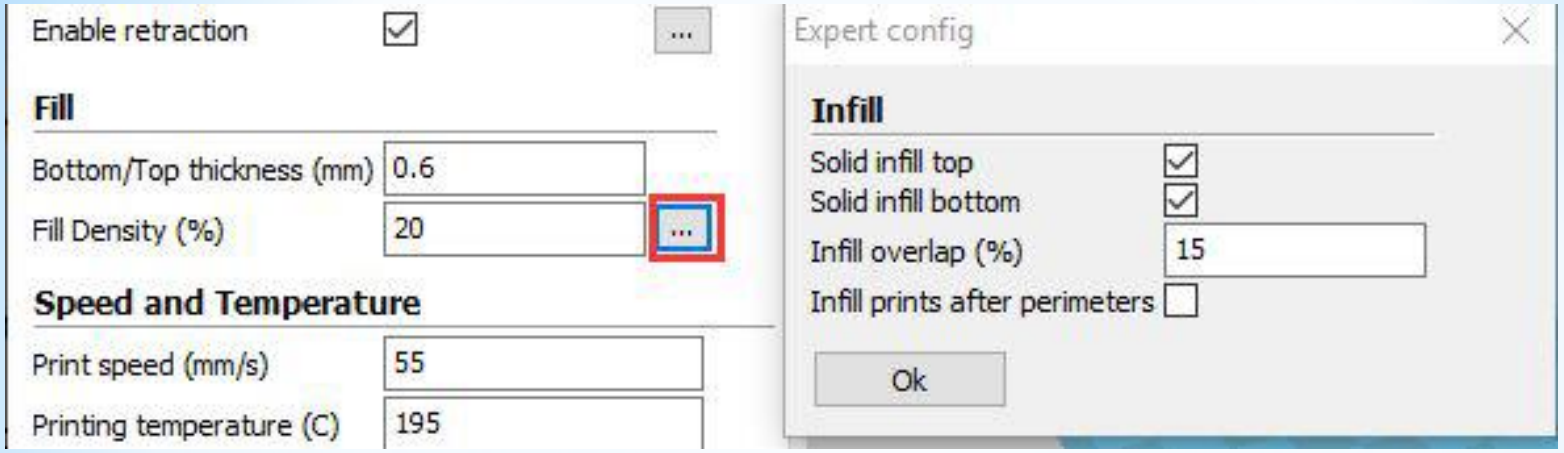


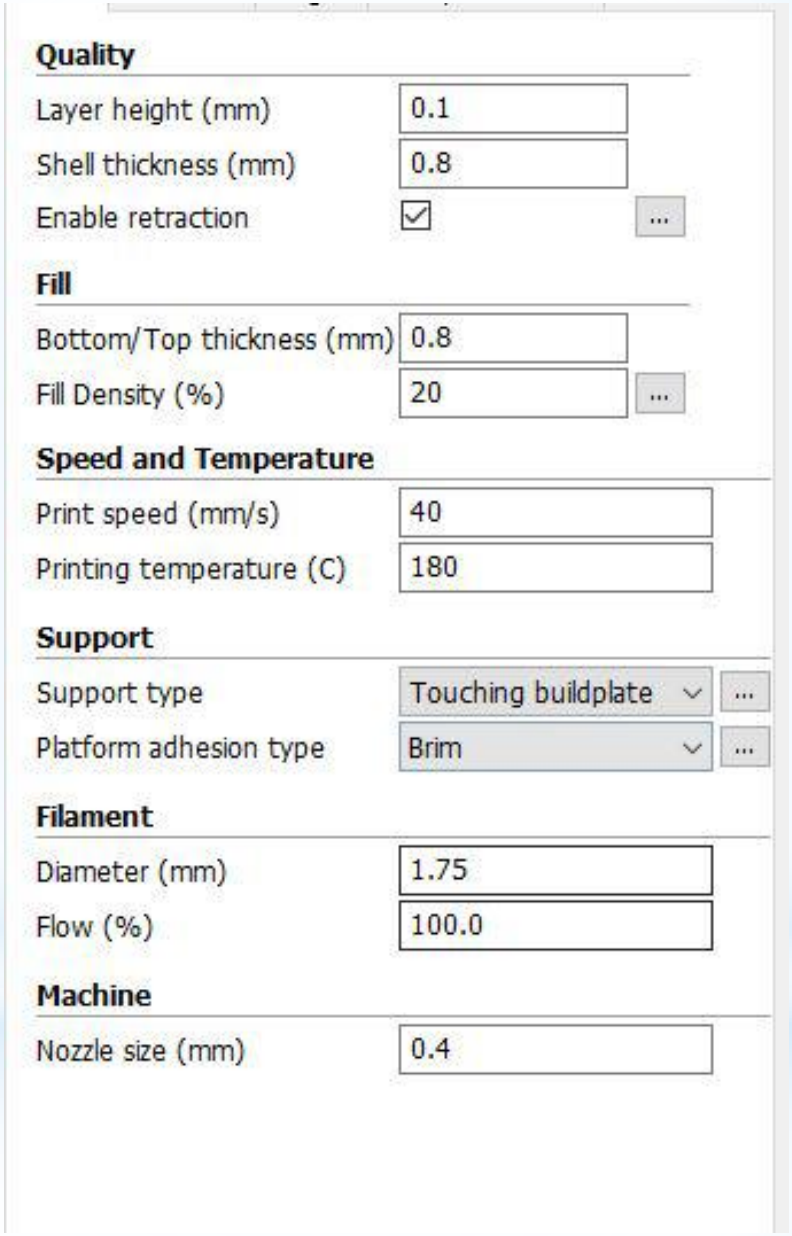
- Print Speed (recommended 10- 40mm/s). The larger the print speed value, the faster print speeds.
- Printing Temperature (recommended 180 - 230°C). The larger the printing temperature value, the higher the nozzle temperature.
- Select the "Support Type" option. Supports are needed when your model has overhanging parts or parts floating in the air, if you select “None”, overhanging part may collapse, and even failed to print. So, it is better to select “Touching buildplate” or “Everywhere”. Touching buildplate only creates support where the support structure will touch the build platform. Everywhere creates support even on top of parts of the model.

Ultimaker Cura

- Select the "Platform adhesion type" option(recommend Brim option). Different options that help in preventing corners from lifting due to warping. If you select “None” for the model which contact areas between the bottom and the print platform is small, the edge will be lifted, even failed to print. Brim adds a single layer thick flat area around your object which is easy to cut off afterwards. Raft adds a thick raster below the object and a thin interface between this and your object.
- Diameter of the filament is 1,75mm
- Flow (%) of filament is the entire amount of the material that needs to be extruded for your model. The Flow value is usually set to 100%, so the extruded amount equals the amount of material required. You only need to increase this setting if you use very soft materials.
- The machine nozzle size is 0.4mm. The below is the recommended X1 3D printer setting. (*Printer settings vary in shape, orientation and complexity of the 3D model.)

Cura will calculates layer height, print duration and other settings according to the quality you selected.

Ultimaker Cura



Ultimaker Cura

- **Generisanje G-code fajla**

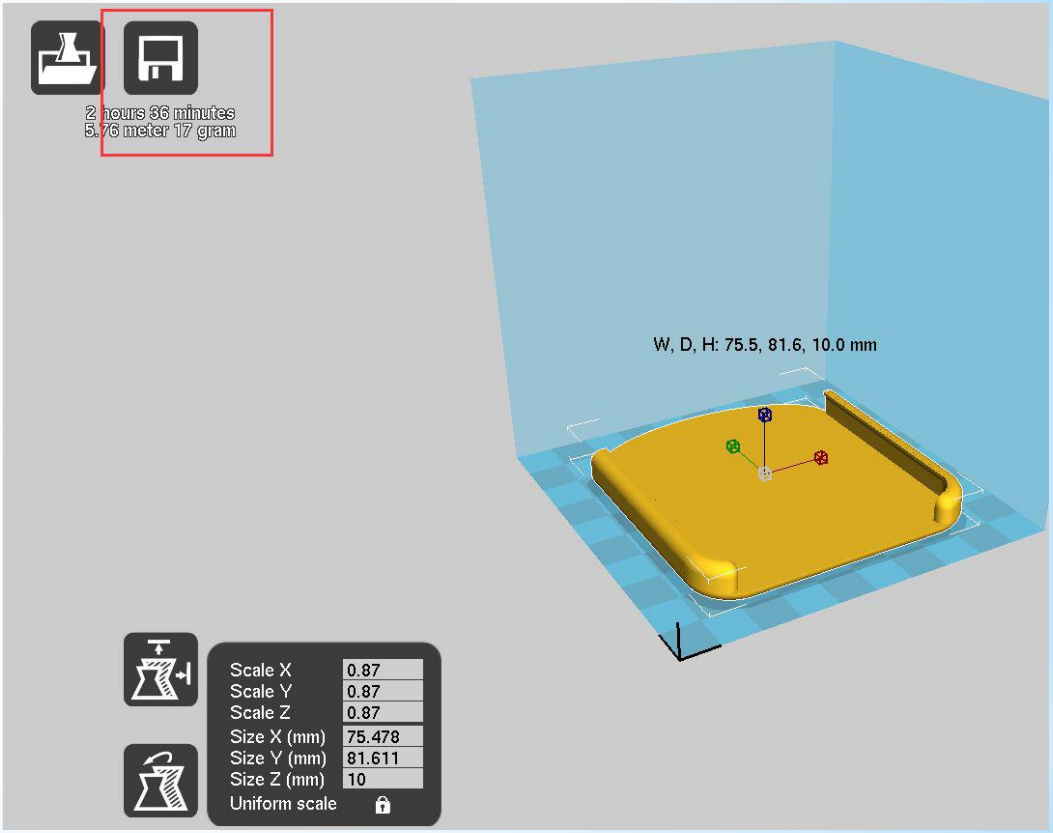
Izabrati *Save to Disk button* ili

File > Save Gcode

Uneti *file name* i izabrati destinaciju fajla.

Fajl se može sačuvati direktno na SD card a zatim karticu uneti u 3D štampač

Nakon: *Select Gcode File (*.gcode)* izabrati *Save*.



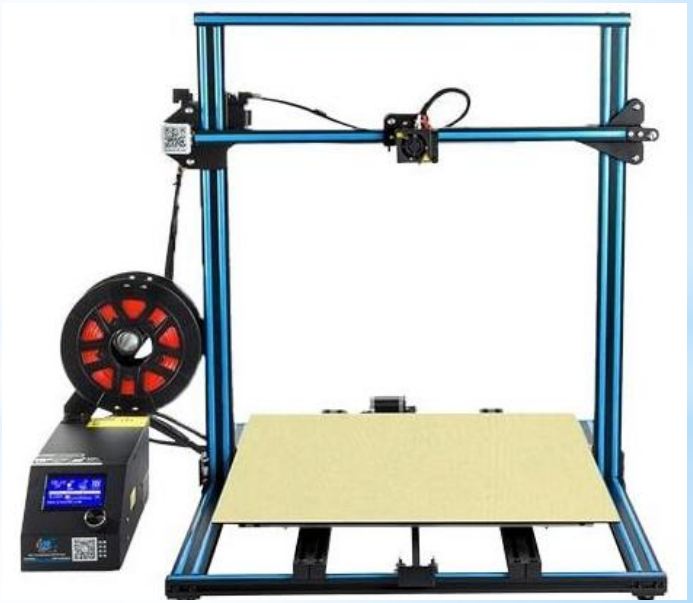
Štampanje na 3D štampaču - VEŽBE

- Modeliranje 3D delova u softveru za 3D modeliranje - *SolidWorks*
- Kreiranje STL fajla
- Pokretanje softvera za štampu: *Ultimaker Cura*
  - Podešavanje parametara štampe
  - Kreiranje g-koda
- Štampanje na različitim štampačima
  - Nivelacija platforme
  - Posipanje spreja na platformu
  - Posmatranje prvog sloja štampe
  - Posmatranje daljeg toka štampe
  - Skidanje komada
  - Dorada po potrebi

Štampanje na različitim 3D štampačima - VEŽBE

Creality CRX

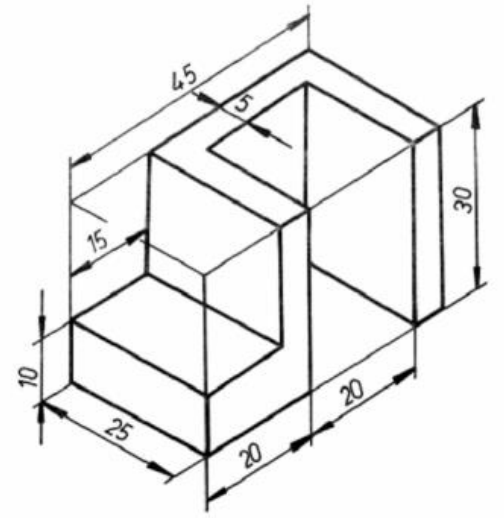
Creality CR-10 S

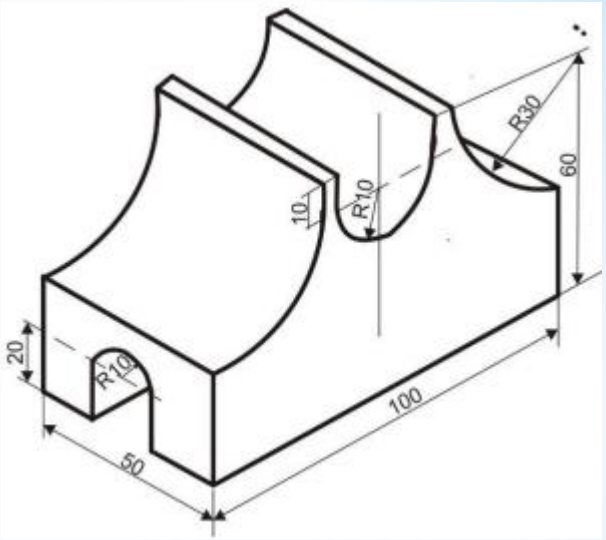


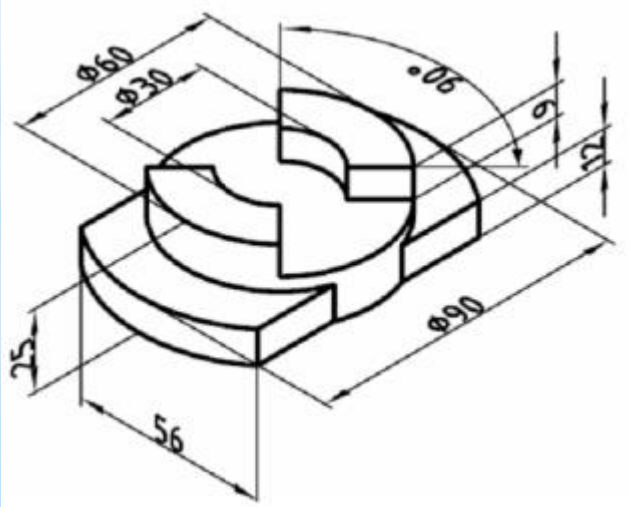
Creality CR-10 S5

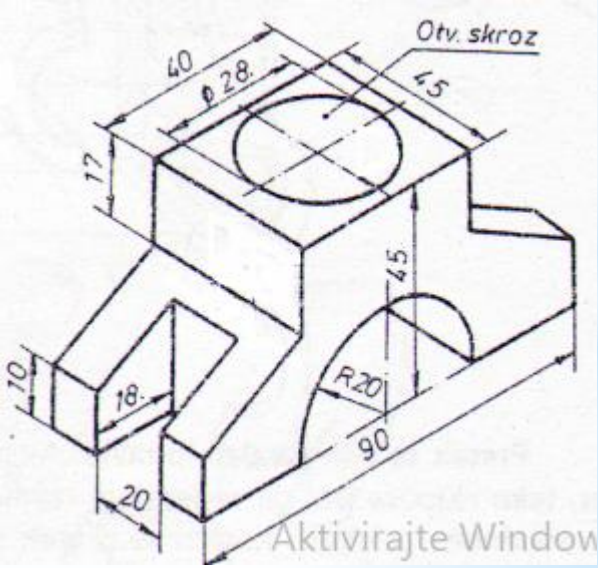
Štampanje na različitim 3D štampačima - VEŽBE

- **Primeri za vežbe**









HVALA NA PAŽNJI