INSTITUTO TECNOLÓGICO Y DE ESTUDIOS SUPERIORES DE MONTERREY

Curso:

Laboratorio de Mecatrónica

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Reporte

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Introduction

The goal of this activity is to obtain the necessary parameters for the creation of a technical datasheet for the Rubik's cube solver machine which was designed during the two sprints of the project. Existing datasheets, particularly those corresponding to stationary robots, 3D printers, or other similar machinery, are to be used as reference in the definition of the critical parameters reported within and the overall format of our datasheet.

Procedure

A brief search was conducted with the objective of determining which parameters are the most useful for the end user of a device such as the one which was designed. In this case, it was decided to focus on four categories: geometry and mass properties, electrical requirements, movement and motors, and operating conditions. The Rubik's cube solving machine comprises various electronic and mechanical components, all of which help define the limits of operation of the device as a whole.

Given that a detailed 3D CAD model containing all of the components, as well as their respective materials, was generated during the first sprint of the project, the geometric and mass properties of the device can be estimated with relative ease. The output calculations generated by SolidWorks are shown in Figure 1. The reported build volume, nominal volume, and weight of the machine can all be estimated through this approach. Other important values corresponding to this category are the required dimensions of the Rubik's cube and the composition of the machine's outer surfaces. Neither parameter must be calculated, and they can readily be added to the datasheet simply based on the design's characteristics.

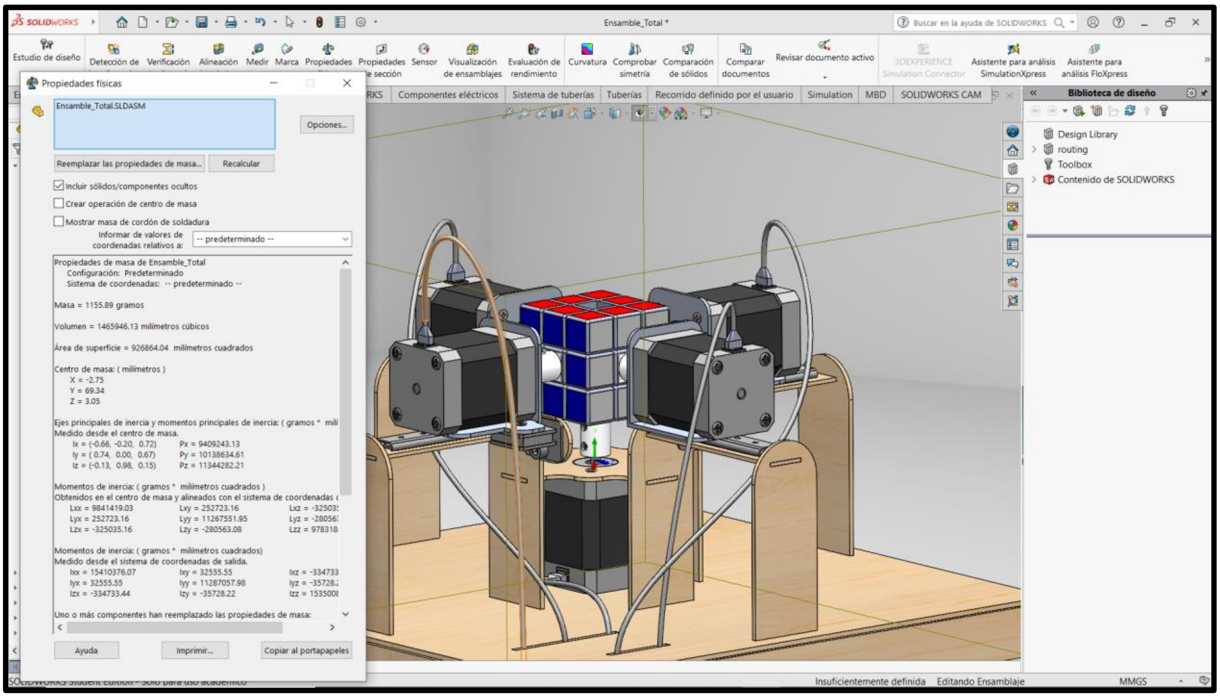


Figure 1. SolidWorks estimation of geometry and mass

The electrical aspects of the device must be determined as a function of the constituent components such as the microcontroller, drivers, motors, and power supply. Here it is necessary to consider that the consumption and output levels are represented as ranges because the energy requirements vary depending on the activation of the motors. The input conditions are defined by the characteristics of the power supply since it provides the electrical power utilized for operating all other components. From the datasheet, the following value is obtained: an input AC voltage between 85 and 264 VAC with frequencies between 47 and 63 Hz. The output parameters of the power supply are also important to ensure that all devices operate at the required levels without risk of damage. In this case, the nominal output voltage of the source is between 14.4 and 16.8 V, with a constant current limiting for an output power greater than 280% and rated for more than five seconds. In this design, the power supply powers the motors and an Arduino board, but said microcontroller provides the logic voltages used for instructing the drivers. It is necessary to specify this difference to the user, and thus, from the datasheets corresponding to the Arduino Nano and the A4988 stepper motor driver the following information can be obtained. The logic input voltages of the driver are identical to the logic output of the Arduino, and the range is from -0.3 to 5.5 V. On the other hand, this logic voltage is used to command when the driver channels the operating voltage from the source to the motors. The driver is capable of commutating voltage in the range of 8 to 35 V, but the current is capped at 2 A. In brief, these are the primary electrical parameters that may be of interest to the user.

The motion parameters of the Rubik's cube solver fundamentally depend on the stepper motors which were selected. The output power of the motor should be sufficient to cause a clean rotation of the Rubik's cube faces and, thus, the value should be reported. In this case, the selected NEMA 17 model has a nominal value of 0.1067 hp as stated in its datasheet. The resolution of the motor determines how well the desired positions can be reached, in this case the datasheet specifies a resolution of 1.8° which corresponds to 50 pulses for each of the 90° turns that the robot realizes. The velocity and cycle time of each rotation depends on the Arduino code which was written for this application. The following image shows the manner in which the control pulses are produced.

```
digitalWrite(DIR, HIGH);

  for(int x = 0; x < 50; x++) {
    digitalWrite(STEP_1,HIGH);
    delayMicroseconds(500);
    digitalWrite(STEP_1,LOW);
    delayMicroseconds(500);
  }
  delay(500);
}
```

Figure 2. Generation of pulses for drivers in Arduino

Here, it can be seen that a pulse is generated every 1000 microseconds, or every 0.001 seconds; a rotation of 90° is used to fully turn the faces of the Rubik's cube and this requires 50 pulses. Thus, 0.05 seconds represents the minimum cycle time of the robot for one rotation. This means that the number of full steps per second is 1000 pulses per second, which is considerably lower than the motor's rated value of 3000 pulses per second. The real cycle time must consider the 500 millisecond delay which occurs between movements, resulting in an approximate cycle of 550 milliseconds.

The final set of parameters define the recommended working conditions of the Rubik’s cube solver. The operating temperature depends on the critical operating temperatures of each of the electronic components; in this case:

- Power supply: -40°C a 70°C
- Drivers: -20°C a 85°C
- Stepper motor: max. 130 °C

The operating temperature for this robot is consequently from -20°C to 70°C so as to ensure that none of the components fail. Within the power supply’s datasheet, it was observed that humidity levels are specified, so the robot should also operate in environments with relative humidities between 20 and 90 percent. The final critical operating parameter is the light level required by the vision system to capture adequate images of the Rubik’s cube, which according to the investigation is between the range of 5000 to 6500 K.

The vision system comes with a prebuilt base that fits the cube perfectly under the IP camera. It also comes with a preinstalled light to increase contrast and improve image analysis, even at low light. The program sets the necessary camera and image parameters for an optimal detection of colors, the only input necessary by the user is the change in orientation of the cube after the system detects the colors on one face.

The correct order of faces to show to the system is the following: Up, Right, Front, Down, Left, Back. The correct orientation is the same as the universal rubik’s standard.

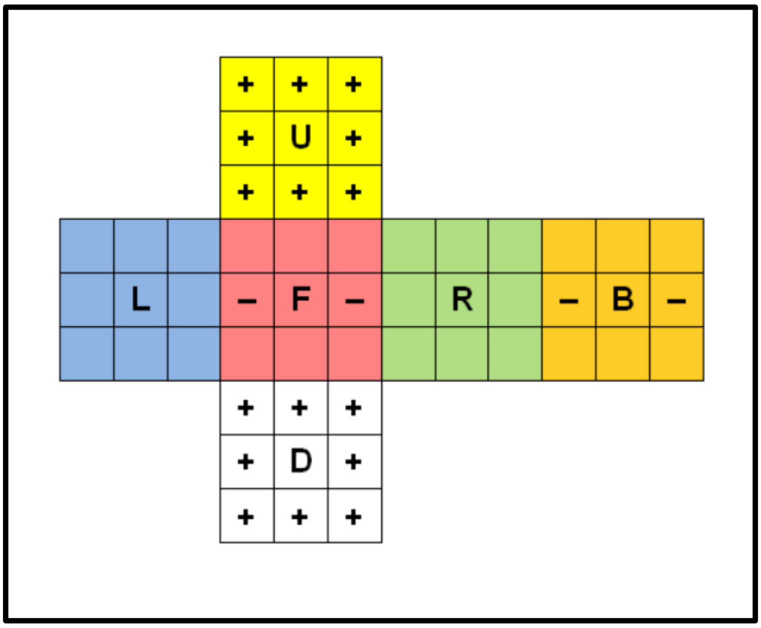


Figure 3. Orientation of faces of the Rubik's Cube

Datasheets

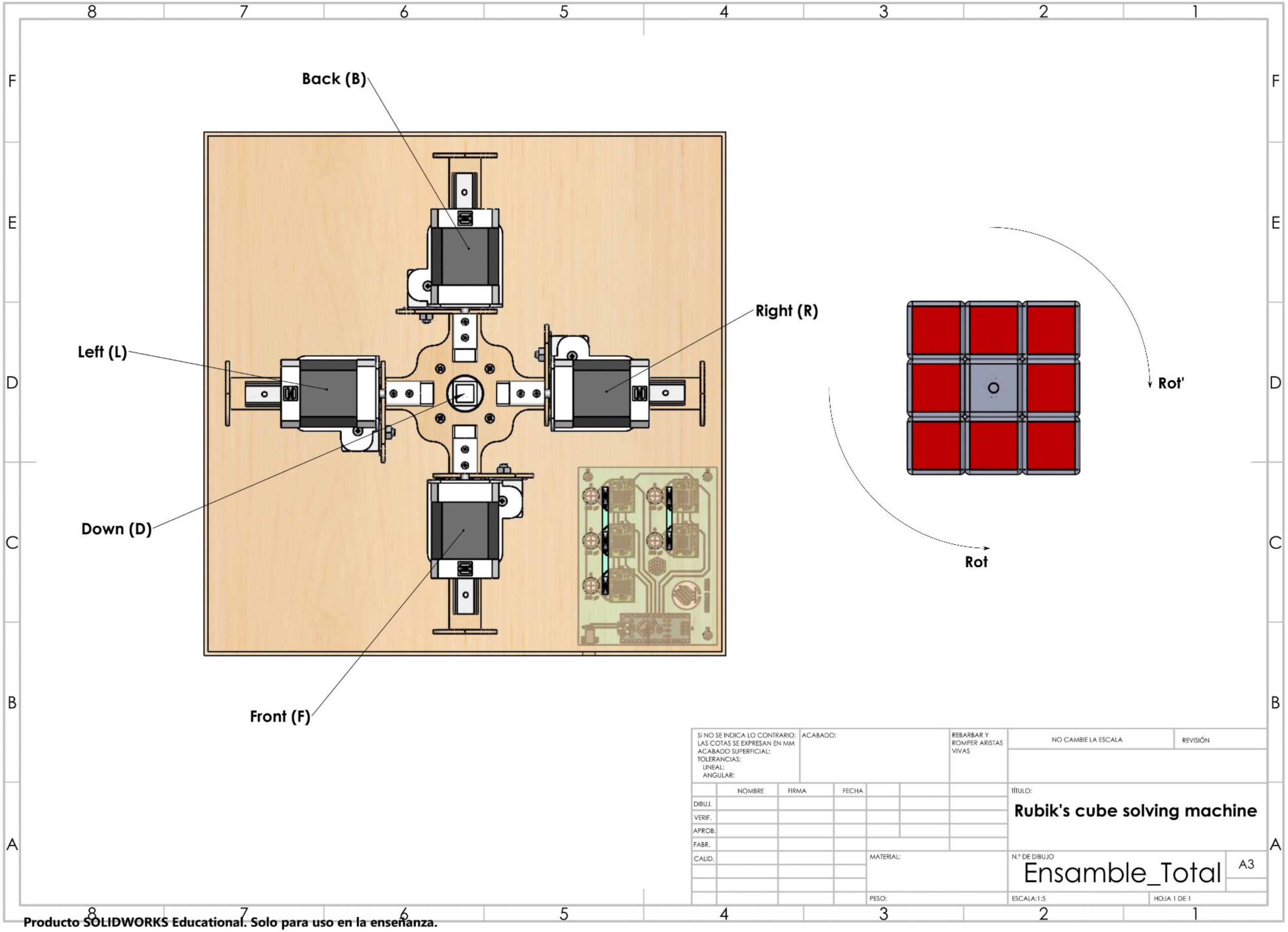
Rubik's cube solving machine

Device	
Build volume (x, y, z)	326 x 326 x 220 mm
Volume	1456.94 cm^3
Weight	1155.89 g
Base material	MDF sheets
Required Rubik's cube dimensions	54 x 54 x 54 mm (3X3)

Motor	
Control Pulses	50 pulses per 90°
Turn velocity	1000 steps per second
Cycle time	550 ms
Output Power	0.1067 hp

Operating Conditions	
Ambient operation temperature of driver	-20°C ~ 70°C
Permitted ambient humidity	20% ~ 90% relative humidity
Vision system luminous intensity	5000 ~ 6500k

Electrical	
Input power supply	85 ~ 264 V/AC (47 to 63 Hz)
Output power supply	14.4 ~ 16.8V
Driver logic input voltage	-0.3 ~ 5.5 V
Driver load supply voltage (Output)	8 ~ 35 V
Power supply current	Constant current limiting for output power >280% rated for more than 5 seconds
Driver output current	±2 A


Back (B)
Left (L)
Right (R)
Down (D)
Front (F)
Rot'
Rot
SI NO SE INDICA LO CONTRARIO:
LAS COTAS SE EXPRESAN EN MM
ACABADO SUPERFICIAL:
TOLERANCIAS:
LINEAL:
ANGULAR:
ACABADO:
REBARBAR Y ROMPER ARISTAS VIVAS
NO CAMBIE LA ESCALA
REVISIÓN
NOMBRE
FIRMA
FECHA
DIBUJ.
VERIF.
APROB.
FABR.
CALID.
MATERIAL:
PESO:
TÍTULO:
Rubik's cube solving machine
N.º DE DIBUJO
Ensamble_Total
A3
ESCALA:1:5
HOJA 1 DE 1
Producto SOLIDWORKS Educational. Solo para uso en la enseñanza.

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