E-PEEL: Electronic Peeling Equipment for Easier Living

By:

Saathveek Gowrishankar

Hyun Jun Paik

Varun Ramprakash

Design Document for ECE 445, Senior Design, Spring 2026

TA: Manvi Jha

27 February 2026

Project No. 54

1. Introduction

1.1 Problem

Traditional peelers require both firm grip strength and precise fine motor control to operate safely and effectively. For older adults and individuals living with arthritis, tremors, or other conditions that reduce hand strength or dexterity, these demands make peeling not just difficult but genuinely hazardous. The risk of cuts increases significantly when grip is unreliable or when tremors cause the blade to slip. Though it may seem so, this is not a niche concern: according to the U.S. Census Bureau, over 24 million Americans aged 18 or older require assistance with activities of daily living (ADLs) [1], and the United Nations projects that the global older adult (age 65+) population will almost double from 9.3% in 2020 to 15.9% in 2050 [2]. As this demographic grows, so does the need for developing assistive technologies that preserve functional independence at home.

Meal preparation is widely classified as an instrumental activity of daily living (IADL), a category of tasks essential for independent community living. An inability to perform IADLs, including activities such as financial management, shopping, and cooking, is a key indicator of declining independence [3]. The inability to prepare one's own meals can accelerate dependence on caregivers, contribute to nutritional deficiencies, and diminish overall quality of life. Despite this, the kitchen remains one of the least-addressed environments in assistive technology design. A broad scoping review of over 205 human-robot interaction (HRI) studies spanning 2010-2022 found that meal preparation was one of the least-supported IADL tasks across existing robotics literature [4]. Another scoping review of 100 assistive kitchen technologies further found that peeling and food preparation receive significantly less attention than other kitchen tasks, with device usability and affordability consistently cited as barriers to realistic adoption [5].

Fully autonomous robotic solutions are presented in research literature. A primary example is MORPHeus, a single-arm system that utilizes multimodal active perception to peel a wide variety of vegetables with no user intervention [6]. However, systems of this complexity are expensive, physically large, and otherwise unrealistic for use in residential environments. Additionally, research consistently shows that older adults are consistently less likely to adopt fully autonomous assistive technologies, preferring semi-autonomous designs that maintain meaningful user control [4], [5]. This reflects the need to develop systems that are transparent, interruptible, and operable without training. Any realistic peeling alternative must be sure to balance functionality with simplicity of use.

1.2 Solution

E-PEEL is a semi-autonomous peeling assist device designed to eliminate the grip strength and fine motor demands of manual peeling while still preserving the meaningful control of the user. The system consists of three primary mechanisms: vegetable rotation, blade travel, and blade contact adjustment. The user sticks a cucumber onto the prongs to hold it in place, then initiates motion via a single button press. The blade then drops down to the cucumber, stopping when it makes contact. Next, the prongs start to rotate the cucumber as the screw system moves the blade mechanism laterally across the cucumber. The blade holder uses real-time force feedback from a load cell to maintain consistent blade contact pressure. Three push buttons for forward, reverse, and pause allow the user to maintain direct control over the system's motion, enabling jam recovery and repositioning. The device operates on AC power via an external low-voltage DC adapter, eliminating battery runtime constraints.

Safety and ease of cleaning are critical design requirements, as they will determine whether the device is a realistic solution for the target users. The food-contact surfaces are removable without tools: the blade system can be removed for easy cleaning. To ensure the safety of users, the blade is enclosed by a physical guard that prevents accidental contact from above or from the side during operation. The device also enforces a state machine; pressing any other button while in the forward state immediately transitions the system to a paused state, halting both screw motion and rotation. Four LEDs provide continuous feedback on power status and screw movement allowing users to instantly and easily confirm device state.

1.3 Visual Aid

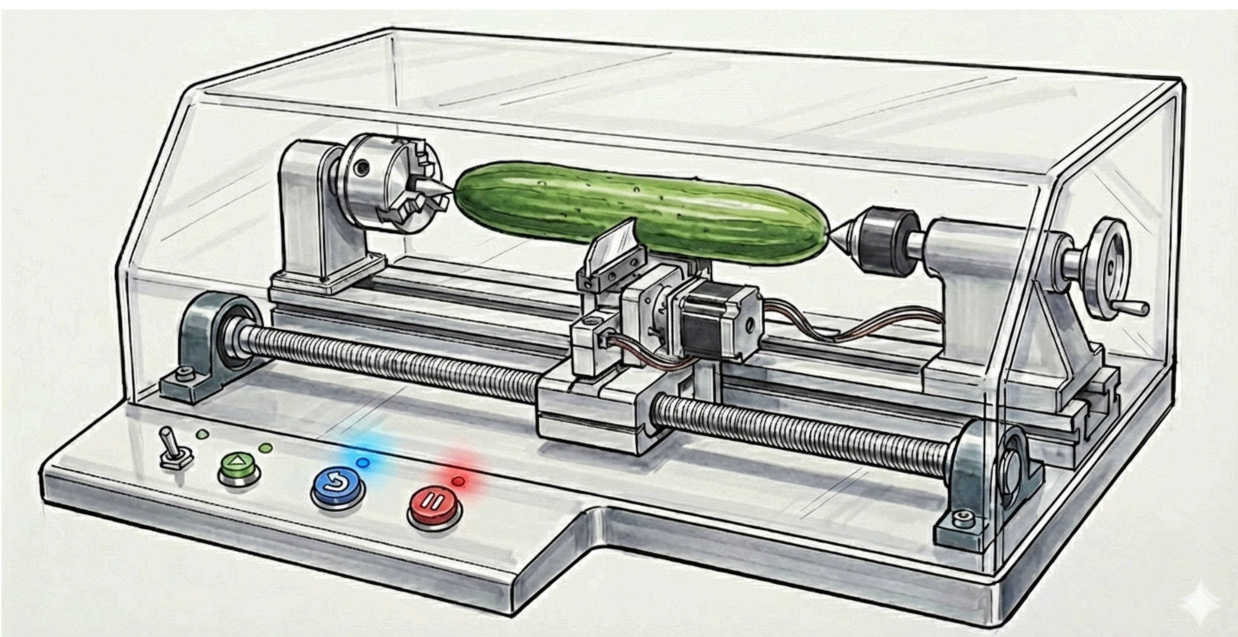

Figure 1: E-PEEL intended design (developed with the assistance of Nano Banana Pro)

1.4 High-level requirements list

The device must successfully peel at least 85% of the surface area of a cucumber (additional vegetables will be considered after success with a cucumber) within 2 minutes of initiating the peeler. Peeling coverage must be achievable using only the three control buttons; users should not have to remove the acrylic shell between the initiation and completion of peeling.

The device must respond to any user button input (forward, pause, or reverse) within 1 second of actuation, immediately halting blade movement upon a pause selection, ensuring that the user always retains consistent and meaningful real-time control over the device's behavior.

The power subsystem must deliver stable voltage of 5 V, 6-8.4 V, 12 V (within ±10%) to the stepper motor driver, servo motor, gearmotor, microcontroller, and stepper motor respectively, under full simultaneous motor load, drawing entirely from a standard 120 VAC wall outlet. All user-accessible surfaces must be isolated from any voltage exceeding 12 VDC. If the current sensor detects a sustained motor stall, the system must automatically halt the screw within 1 second to prevent motor burnout.

2. Design

2.1 Block Diagram

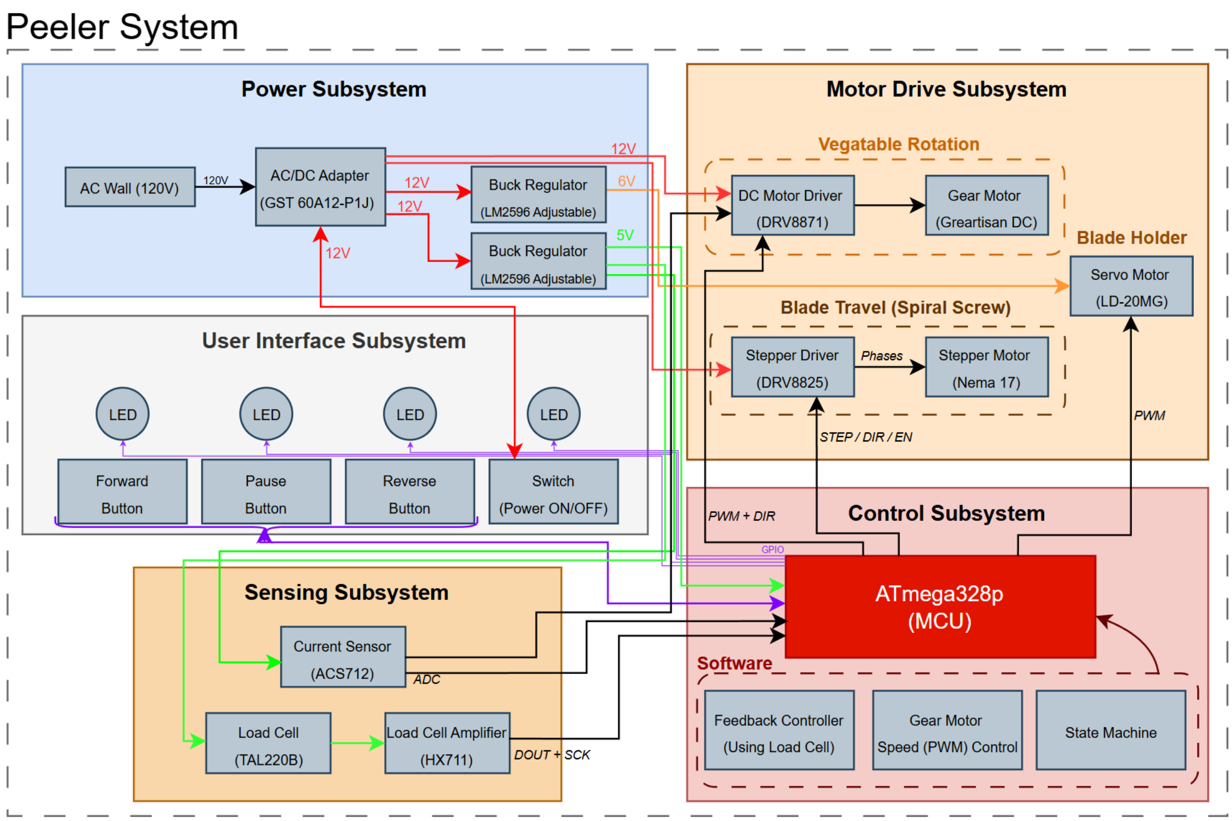

Figure 2: Vegetable peeler block diagram

2.2 Physical Design

The mechanical structure consists of three primary motions each generated by a different motor: rotational motion of the vegetable, linear translation of the blade assembly, and force-controlled blade actuation. A gear motor is connected to a fork-style holder at one end of the vegetable and an adjustable perpendicular platform at the other end. The vegetable must be trimmed flat at both ends to ensure stable mounting. The gear motor rotates at a constant speed to provide uniform angular motion during peeling. Parallel to this rotational axis, a stepper motor drives an approximately 18-inch lead screw. The stepper motor remains stationary while rotating the lead screw, which translates a moving platform along its length. The platform has a width of approximately 1.5 inches, sufficient to mount the servo motor, load cell, and blade assembly.

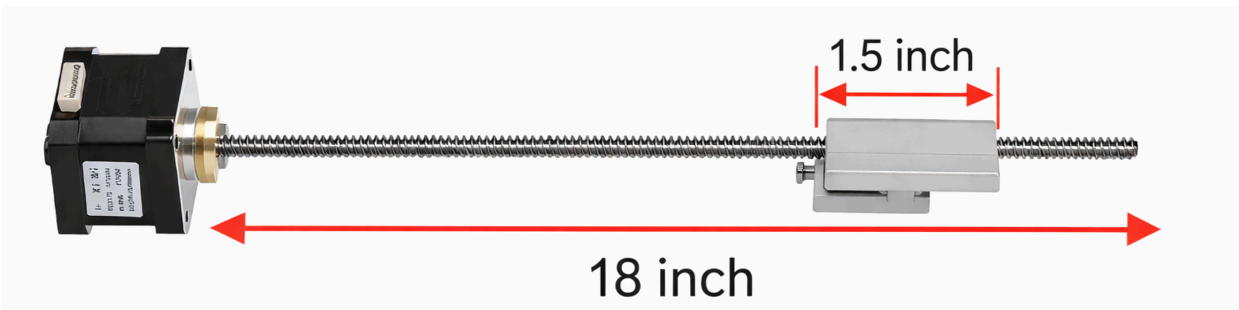

Figure 3: Example of the stepper motor with the platform

Mounted on the translating platform is the servo-controlled force regulation subsystem. One end of the load cell is mechanically coupled to the servo motor, and the opposite end supports the peeling blade. As the platform translates along the lead screw, the servo actively adjusts blade position to maintain the desired normal force against the rotating vegetable. This configuration enables controlled peeling while compensating for variations in vegetable diameter and surface irregularities.

Figure 4: Example of the servo motor with the load cell and vegetable peeler blade

To maximize usable peeling length, the gear motor axis and stepper-driven lead screw are offset relative to one another. Because the moving platform occupies approximately 1.5 inches at each end of travel, the effective usable translation length of the 18-inch lead screw is reduced to approximately 15 inches. To prevent loss of peeling coverage at the ends of the vegetable, the rotational axis is shifted inward by approximately the width of the platform. This offset ensures that the blade begins contact at the true edge of the vegetable and maintains continuous coverage throughout the full usable stroke. As a result, the system is designed to peel the entire length of vegetables up to approximately 15 inches while maintaining consistent contact force.

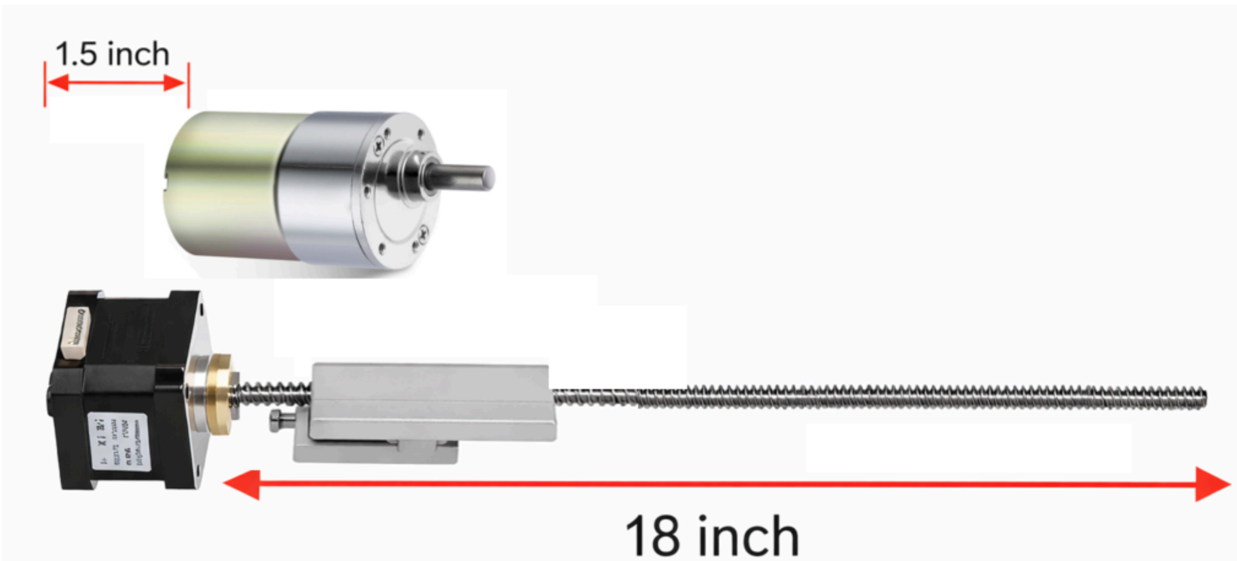

Figure 5: Dimensional layout between gearmotor and stepper-driven lead screw assembly

2.3 Subsystem Description

2.3.1 Power Subsystem

This subsystem converts 120VAC wall power into regulated DC rails to meet all other subsystem component requirements for reliability and safety. A Mean Well GST 60A12-P1J component would generate a 12V DC bus which would feed into two different buck regulators for 6V, 5V power rails. The 12V power rail is connected to the DC motor Driver (DRV8871) for the vegetable rotation and stepper driver (DRV8825) for the blade travel on the spiral screw. LM2596 Adjustable component converts 12V to 6V which powers the servo motor (LD-20MG) mounted to the blade holder . LM2596 Adjustable component converts 12V to 5V which powers the MCU for 16 MHz, current sensor (ACS712), and the load cell (TAL220B). The subsystem must maintain each rail within its specified tolerance under the worst-case scenarios to prevent unintended behaviors.

Requirements	Verification
The power subsystem must deliver stable voltage of 5 V, 6-8.4 V, 12 V (within ±10%) to the stepper motor driver, servo motor, gearmotor, microcontroller, and stepper motor respectively, under full simultaneous motor load, drawing entirely from a standard 120 VAC wall outlet.	*Equipment:* Digital multimeter, Oscilloscope, Variable load, 120 VAC wall outlet *Procedure & Results:* Power the system using a standard 120 VAC outlet, operate all motors simultaneously, and measure each voltage rail using the multimeter. Use an oscilloscope to verify that the voltage stays in an acceptable range.
All user-accessible surfaces must be isolated from any voltage exceeding 12 VDC.	*Equipment:* DMM *Procedure & Results:* When the system is powered and operating, measure the voltage between all user-accessible surfaces using a digital multimeter. Verify that no accessible surface reaches 12VDC.
If the current sensor detects a sustained motor stall, the system must automatically halt the screw within 1 second to prevent motor burnout.	*Equipment:* Stopwatch, test object/vegetable *Procedure & Results:* Operate the system normally and intentionally stall the motor, and observe the system response. Measure the time between stall detection and motor shutdown using a stopwatch and verify that the control system stops within 1 second of stall detection.

Table 1: Power Subsystem - Requirements & Verification

2.3.2 Motor Drive Subsystem

This subsystem converts electrical power and MCU commands into the mechanical motion required for vegetable rotation, blade travel, and blade contact adjustment using three motors. The vegetable rotation uses the gearmotor with a DC motor driver (DRV8871) powered by the 12V rail, which operates in one rotational direction to ensure continuous and uniform peeling. The MCU provides PWM signals to DRV8871 to control the gearmotor RPM speed. Also, the current sensor (ACS712) detects any jam or stall during the motor operation. When detected, the MCU disables the driver to stop the rotation for safety purposes. The blade travel uses a stepper driver (DRV8825) and a stepper motor (Nema 17) powered by 12V rail, which actuates the spiral screw to move the blade linearly along the vegetable. The MCU sends STEP / DIR / EN signals to the driver which generates the speed of the spiral rotation and direction of the rotation for appropriate control. The blade contact is connected to a servo motor (LD-20MG) powered by the 6V rail. It receives PWM signals from the MCU, so that the blade holder position can adjust to maintain consistent contact with the vegetable surface during peeling.

Requirements	**Verification**
12V rail at DRV8871 and DRV8825 shall remain 11.4 – 12.6V under worst case load (gearmotor + stepper active).	*Equipment:* Oscilloscope, DMM *Procedure & Results:* Probe at driver VM pins (GND reference) when running the worst case motion where the both motors operate simultaneously for 30s. Record the min/avg/max and scope ripple voltage output in a table.
6V rail at the servo connector shall remain 5.7 - 6.3V during operation.	*Equipment:* Oscilloscope, DMM *Procedure & Results:* Command servo to sweep full range repeatedly (worst torque condition) and probe at servo V+ pin and note the voltage in notebook.
At a fixed setpoint near 100RPM, steady speed shall remain within ±10% 10s.	*Equipment:* MCU log *Procedure & Results:* Hold a fixed duty that gives ~100RPM. Log RPM for 10s and compute min/avg/max. Save the log and computation in notebook for reference.
DRV8825 STEP pulse width shall be $t_{STEP\ high} \geq 2.2\mu s$ and $t_{STEP\ low} \geq 2.2\mu s$ for step rate.	*Equipment:* Oscilloscope, DMM *Procedure & Results:* Probe STEP pin at DRV8825 module input and measure both $t_{STEP\ high}$ and $t_{STEP\ low}$. Record the measured values.

Table 2: Motor Drive Subsystem - Requirements & Verification

2.3.3 User Interface Subsystem

This subsystem provides manual control inputs and visual status feedback for operating the peeler. A power switch enables and disables the system, while the Forward, Pause, and Reverse push buttons send user commands to the MCU through dedicated GPIO inputs. The MCU interprets these button commands within the state machine to control the blade positioning motion and overall operation. Four LEDs driven by MCU GPIO outputs provide clear indication of the current operating state (forward, paused, reverse, and power ON/OFF), allowing the user to confirm the machine's status at a glance. This subsystem interfaces directly with the Control Subsystem for logic level signaling for the buttons and LEDs.

Requirements	**Verification**
The power switch shall cut off the system power such that MCU VCC < 0.5V within 1s after switching OFF, from any operating state (including during active peel).	*Equipment:* Oscilloscope, DMM *Procedure & Results:* While the system is idle (when the switch is ON and not during active peel), measure MCU VCC. Flip the switch OFF, and record time until VCC < 0.5 V. Repeat this process while motors are running. Record the time and VCC respectively.
Each operating state shall drive the correct LED pattern within ≤ 0.1s. Forward button → Forward LED ON only Pause button → Pause LED ON only Reverse button → Reverse LED ON only Power switch ON → Power LED ON only Power switch OFF → all LEDs OFF.	*Equipment:* Visual inspection. *Procedure & Results:* Confirm the LED pattern by turning on and off each state.
The system shall never indicate two motion states simultaneously and only one of [Forward, Pause, Reverse] LEDs should be ON at any time during operation.	*Equipment:* Visual inspection. *Procedure & Results:* Run through all state transitions and observe the three LEDs. At any given state, only one LED should be ON while the other two remain OFF.
The command shall be triggered on release edge (not on press). Holding a button shall not cause repeated state transitions, with no extra events due to bouncing.	*Equipment:* Visual inspection. *Procedure & Results:*

	Press-and-hold each button for 2s and confirm no repeated transitions occur during hold. When released, it triggers exactly one operation. For each button (especially pause button), perform 10 trials to make the system robust.

Table 3: User Interface Subsystem - Requirements & Verification

2.3.4 Sensing Subsystem

This subsystem measures physical quantities needed for safe and consistent peeling and provides these measurements to the Control Subsystem for feedback and protection. A load cell (TAL220B) mounted in the blade holder measures the normal force applied by the blade to the vegetable. Its low-level signal is amplified by the HX711 load cell interface, which sends force readings to the MCU over a digital clocked interface (SCK). In addition, a current sensor (ACS712) is connected to the DC motor drive so it can measure the current. These measurements allow the MCU to detect stall or jam conditions so the system can pause or limit actuation to prevent motor burnout and improve overall safety. The Sensing Subsystem is powered by the Power Subsystem and interfaces directly with the Control Subsystem through digital and analog signal connections.

Requirements	**Verification**
HX711 shall operate in 80 samples per second (SPS) mode, and the MCU shall successfully read and log force measurements at ≥ 75 samples per second during peel operation.	*Equipment:* MCU log *Procedure & Results:* Configure HX711 in 80 SPS mode. Log timestamped force readings for 10 seconds and count the total number of samples collected. Compute the sample rate ($\frac{Number\ of\ samples}{Duration\ time}$) and validate if it is ≥ 75. Show the calculated sample rate with the total sample collected using 80 SPS mode.
Blade normal force shall be maintained within 1.0 – 2.0N for ≥ 85% of peel duration. Normal force shall not exceed 3N at any time during peel for safety.	*Equipment:* Load cell, measured data logging on MCU *Procedure & Results:* Run the device and measure the normal force

	applied to the cylindrical vegetable (e.g. cucumber). Check the log to confirm whether the normal force stays within the specified range, and collect the samples that fall within this range. Report any instance when the normal force exceeds 3N during peel duration. Save the log in the notebook every time when processed. Visually inspect the peeled vegetable and validate if the surface is peeled more than 85%. Capture a picture (or video) of the result and compare with the original unpeeled state. Calculate the sample rate within the normal force range and numerically confirm if it is ≥ 85.
When gearmotor current exceeds 2A continuously for ≥ 0.2s, measured from ACS712, MCU shall disable DRV8871 within ≤ 0.2s.	*Equipment:* DDM, MCU log *Procedure & Results:* Manually stall the motor briefly and check if the current sensor detects the increasing current on the log. When it exceeds the threshold we set, measure the time until it disables the driver. Record the log and timestamp to verify with numerical values.

Table 4: Sensing Subsystem - Requirements & Verification

2.3.5 Control Subsystem

This subsystem is implemented using the ATmega328p microcontroller and serves as the central controller of the overall peeler's operation. It is powered from the regulated 5V power rail provided by the Power subsystem and interfaces directly with the User Interface, Sensing, and Motor Drive subsystems to execute the system finite state machine while ensuring safety and consistency. The ATmega328p reads the Forward/Pause/Reverse buttons through GPIO and acquires the blade force data readings from the HX711 and measures the motor current from ACS712 using the internal ADC. Based on these inputs, it performs software-based feedback control including force regulation, jam detection, and state transitions. The MCU generates necessary control outputs for all motors, including PWM for gearmotor speed control, STEP / DIR / EN pulse generation for the DRV8825, and PWM for servo motor blade position adjustment.

Requirements	**Verification**
MCU VCC shall be within the range 4.75–5.25 V during all operations. (idle + all motors active). Ensure MCU to never exceed max protection VCC > 6V.	*Equipment:* Oscilloscope, DDM *Procedure & Results*: Run worst-case mode (gearmotor + stepper + servo moving + sensor reads). Probe VCC at MCU pins and check whether it is between the range. Also see if it overshoots the max protection value. Record all data and label if the min/max stay within range.
With all subsystems operating (PWM gearmotor + stepper motor + servo motor updates + sensor reads), the MCU shall maintain: - gearmotor PWM frequency 15 – 25kHz - stepper STEP pulse width ≥ 2.2µs high and low simultaneously. - servo PWM frequency 50Hz ±2Hz	*Equipment:* Oscilloscope, DDM *Procedure & Results*: Run worst-case mode and probe PWM pin, servo signal pin, STEP pin. Measure frequencies and pulse widths and validate each part is within the required range. Record all data from the logsheet and mark down which passes and fails.
MCU GPIO pin shall not sink more than 20mA in normal operation (never exceed 40 mA abs max). Total VCC/GND current through MCU pins shall stay < 200mA abs max.	*Equipment:* Oscilloscope, DDM *Procedure & Results*: Compute $I \approx \frac{5V - V_{forward}}{R}$ to find the theoretical current flowing in each LED output. When I ≤ 20mA is theoretically verified, measure the actual current and verify if each pin current ≤ 20mA, and the total is safely below limits.

Table 5: Control Subsystem - Requirements & Verification

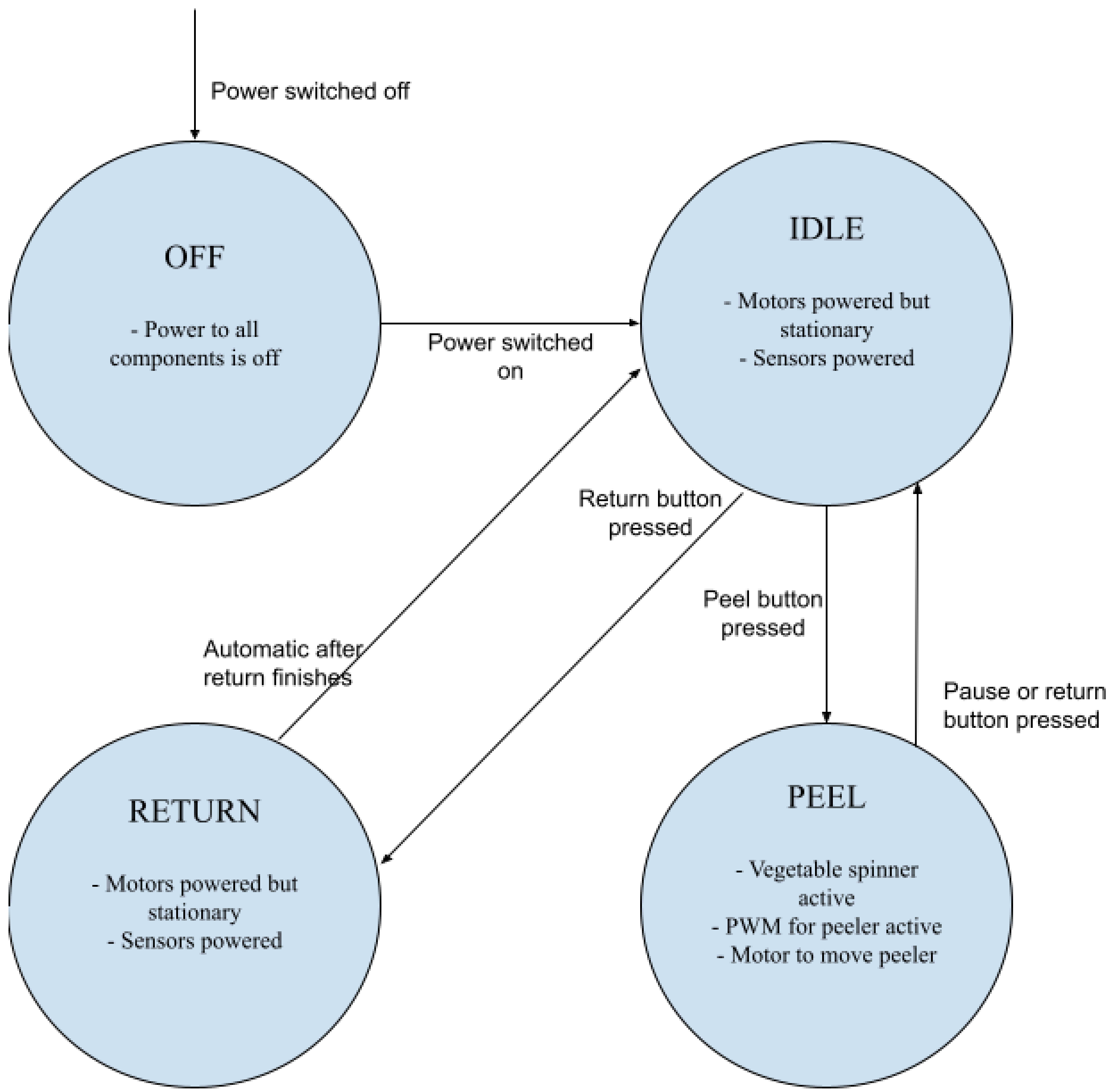

Figure 6: Finite State Diagram

2.4 Tolerance Analysis

2.4.1 Consistent Peeling Force

- Target Force Value: Normal force 1.5 N and maintain force within 1N - 2N since peeling force varies with vegetable type and skin toughness.

- Safety Limit: Never exceed 3N.

The critical risk in our design is the ability to maintain a consistent peeling force while accounting for sensing tolerances. The target normal force is 1.5 N, and the blade remains within a force band of 1 N to 2 N, since the required peeling force varies depending on vegetable type and skin toughness. For safety, the applied force must never exceed 3 N. The blade contacts the vegetable at approximately 30°, meaning the effective vertical displacement of the blade due to servo motion depends on the geometry of the lever arm. If L is the servo horn radius and θ is the servo angle, the vertical displacement near the operating point is approximated by $y \approx L \sin\phi$, and small servo angle uncertainty produces a displacement error $\Delta y \approx L\cos\phi\ \Delta\theta$. Since force near the operating point behaves approximately linearly as $F \approx ky$, where k is the effective stiffness of the blade mount and contact interface, the servo-induced force disturbance becomes $F \approx kL\cos(30^\circ)\Delta\theta$. Using the servo accuracy of 0.3° (0.00524 rad), this relationship allows us to bound the allowable stiffness required to maintain force regulation.

The load cell measurement uncertainty must also be included in the tolerance analysis. The selected load cell has a 5 kg full-scale capacity, corresponding to 49.05 N. The datasheet specifies static errors of 0.03% full-scale for nonlinearity, hysteresis, and repeatability. Each corresponds to 0.0147 N, resulting in a combined static error of 0.044 N. Additionally, corner load error of 0.05% full-scale contributes 0.0245 N, and temperature variation of approximately 10°C results in a zero shift of 0.147 N per 10°C, which yields 0.0735 N for a ±5°C variation. Summing these worst-case contributions gives a total measurement uncertainty of approximately 0.142 N. Compared to the allowable half-band of 0.5 N, this measurement error is relatively small but must be accounted for in the force budget.

Although prior literature suggests that vegetables may peel successfully at approximately 1.5 N, the exact required peeling force will be determined experimentally. Initial characterization will be performed using a cylindrical vegetable (e.g., cucumber) to minimize geometric variability and establish a controlled ground condition. The nominal force at which consistent, clean peeling occurs will be defined as the standard reference. With the determined measurement, we will then evaluate performance across additional vegetable types with varying skin toughness. The system does not need to match an exact theoretical value. However, it must reliably maintain force within the empirically determined peeling band. The 5 kg load cell was selected to provide sufficient structural margin for overload conditions, angled contact forces, and mechanical misalignment. Based on this tolerance analysis, the servo-actuated force regulation subsystem can feasibly maintain consistent peeling force within the required bounds while satisfying safety limits.

3. Cost and Schedule

3.1 Cost Analysis

For our labor costs, we can assume that each member works for approximately 15 hours per week at an hourly rate of $40/hr, yielding $600 per week, and we can multiply this number by 11 weeks to get $6600 per member. We need to multiply this number by 3 to account for each member in the group, resulting in a total labor cost of $19,800. In summation with the cost of parts, this results in an approximate total cost of $19,946.99.

Big Parts	Components	Quantity	Description		Price	
	Mean Well GST60A12-P1J	1	12V Adapter	DigiKey	$18.60	
Power	LM2596 Adj. Buck Converter	1	12V to 6V Buck Converter (for servo)	Amazon	$7.99	(5 pack)
	LM2596 Adj. Buck Converter	1	12V to 5V Buck Converter (for logic)	Amazon	$0.00	
	DRV8871 breakout modules	1	DC motor driver module/board	Amazon	$13.99	2 pack
	DRV8825 breakout modules	1	stepper driver module/board	Amazon	$8.99	3 pack
Motor Drive	NEMA 17	1	stepper motor	Amazon	$14.99	
	Greartisan DC 12V 100RPM	1	gearmotor	Amazon	$14.99	
	LD-2527MG / HPS-2527MG	1	servo motor	Amazon	$13.99	
	ShangHJ S18X4	1	Load cel	Amazon	$9.99	2 pack
Sensing	HX711 breakout modules	1	load cell amplifier module	Amazon included with load cell)	$0.00	
	ACS712-05B breakout modules	1	current sensor module	DigiKey	$2.92	
	SWITCH ROCKER SPST 20A 125V	1	Rocker power switch	DigiKey	$1.01	
	Momentary push buttons	3	Forward/Pause/Reverse buttons	DigiKey	$4.65	
User Interface	General Green LED	1	Forward	ECE		
	General Yellow LED	5	Pause	DigiKey	$0.85	
	General Blue LED	5	Reverse	DigiKey	$1.20	
	General Red LED	1	ON/OFF	ECE		
Control	ATMEGA328P-PU	1	MCU	ECE		
	28-pin DIP socket	1		Don't Need - soldering mcu on		
Small Parts						
	0.1 µF ceramic (X7R), ≥50V	25		ECE		
	1 µF (electrolytic or ceramic)	2		ECE		
	10 µF (mix of electrolytic + ceramic)	5		ECE		
	33 µF, 50V electrolytic	3	(one per buck VIN)	Digikey	$0.36	
Capacitors	47 µF, ≥25V electrolytic	3	(DRV8871 VM bulk)	Digikey	$0.30	
	100 µF, 50V electrolytic	4	(24V bus + DRV8825 VMOT + extra)	Digikey	$1.12	
	220 µF, ≥10V electrolytic	1	(5V rail bulk)	Digikey	$0.14	
	470 µF, ≥25V electrolytic	1	(12V rail bulk)	Digikey	$0.35	
	1000 µF, ≥10V electrolytic	3	(6V rail bulk)	DigiKey	$1.05	
	16 MHz crystal	1	(for 16 MHz crystal)	DigiKey	$0.46	
	22 pF ceramic	2	(for 16 MHz crystal)	ECE		
	330 Ω	4	(LED series resistors)	ECE		
	220 Ω	1	(servo PWM series)	DigiKey	$0.10	
	1 kΩ	1	(ACS712 → ADC RC filter)	ECE		
Resistors	100 Ω	15	(series resistors on signals)	DigiKey	$0.23	
	10 kΩ	10	(pullups/pulldowns/reset)	ECE		
	30 kΩ	1	(DRV8871 ILIM)	ECE		
	10 Ω resistor OR ferrite bead	1	(AVCC filter)	ECE		
Connectors						

Power / Motors	Same Sky (CUI) PJ-002AH	1	5.5×2.1 mm barrel jack: (matches the Mean Well plug)	DigiKey	$0.66	
	Phoenix Contact 1715721	8	2-pin screw terminals: recommended usage 24V IN (1) 24V bus distribution / buck VIN feeds (1–2) 12V OUT distribution (1–2) 6V OUT distribution (1) 5V OUT distribution (1) DC motor output (1)	DigiKey	$11.42	
	Phoenix Contact 1715747	2	4-pin screw terminal: (stepper A+/A-/B+/B-) 4-pin connector: (load cell → HX711)	DigiKey	$5.82	
	Samtec TSW-103-07-G-S	1	(servo)	DigiKey	$0.62	
Signals	Pololu #854	1	2×3 ISP header	Amazon	$5.99	10 pack
	Samtec TSW-106-07-G-S	1	6-pin header: (3 buttons) Qty: 2 (if you also want FTDI serial header)	DigiKey	$1.16	
	Samtec TSW-108-07-G-S	1	8-pin header: (4 LEDs)	DigiKey	$1.43	
	Samtec TSW-104-07-G-S	1	4-pin header/connector: (HX711 → MCU)	DigiKey	$0.88	
	Samtec TSW-103-07-G-S	1	(ACS712 VCC/OUT/GND)	DigiKey	$0.74	
	Fuse	1	for 24V input protection	ECE		
					$146.99	

Table 6: List of Components and Costs

3.2 Schedule

Week of	Steps to be executed	Responsibility
3/2	- **Design Review with TA and Prof.**	Everyone
	- Order parts	Saathveek
	- Finish PCB design - check with TA and get it approved before submitting it to order	Varun and Jun
	- If parts come in, meet with Gregg at the machine shop and ask him to build our device	Everyone
3/9	- **Breadboard Demo with TA and Prof.**	Everyone
	- Solder parts onto PCB	Jun
	- Test PCB behaviors	Varun and Jun
	- Meet with Gregg if we haven't yet, ask him to build our device	Everyone
3/16	SPRING BREAK	
3/23	- Pick up our device from the machine shop	Everyone
	- Start assembling with our PCB	Everyone
	- Fix and submit new PCB design if needed	Saathveek
3/30	- Continue assembling device, connect the motors	Everyone

	and test the overall device behavior	
	- Modify design if needed based on testing, talk to machine shop if we need to change anything	Varun and Saathveek
	- Research on ways the design or parts may need to be changed, and order the parts	Varun
	- Reassemble or modify the device with new parts	Everyone
4/6	- Finalize assembly of the device	Everyone
	- Final testing of the device	Everyone
	- Progress Demo	Everyone
4/13	- Fix last bugs	Everyone
	- Work on final demo	Everyone
	- Prepare final presentation	Everyone
	- Ensure that the device works as intended in the requirements	Everyone
4/20	- Make final changes/fixes to the demo/presentation as needed before the final presentation	Everyone
	- Mock Demo and Video Assignment	Everyone
4/27	**- Final Demo Presentation**	Everyone
5/4	**- Final Paper and Lab Notebook due**	Everyone (individual for notebook)

Table 7: Time Table for project progression

4. Discussion of Societal Impact, Engineering Standards, Ethics, and Safety Considerations:

4.1 Ethical Considerations in Design

Engineering design requires careful consideration of the safety and trust of those who will interact with the product. Principles from both the IEEE Code of Ethics [7] and the ACM Code of Ethics [8] provide several general guidelines to abide by in this aspect, emphasizing avoiding harm, being transparent about limitations, and keeping potential societal effects in mind. These principles heavily influence the development of the E-PEEL device.

Because this product involves a motorized blade and moving mechanical parts in addition to being driven by electrical power, the major ethical consideration is user safety. The design intentionally minimizes user interaction during the peeling operation by communicating system state and including safeguards that prevent hazardous behavior. The goal of this device is to assist individuals with reduced grip strength, arthritis, tremors, or other motor limitations. Thus, the project properly aligns with the ethical goals of using engineering to enhance accessibility and quality of life.

4.2 Safety Hazards

4.2.1 Mechanical Safety

The primary safety hazard in the system is accidental contact with the peeling blade. Several design choices have been made to mitigate this risk. An acrylic cover prevents access to the blade. Load-cell force sensing limits blade pressure to a safe range. Control logic ensures that the system can easily and safely be stopped and reversed, and the device stops if abnormal force or current is detected.

4.2.2 Electrical Safety

The system receives power from a standard 120V AC wall outlet and converts it to lower DC voltages required for operation. Dealing with high voltages presents shock, so electrical isolation and proper power handling are critical design considerations. To reduce the risks, the device uses a certified AC/DC adapter to perform the conversion externally. All internal wiring will be insulated and will not be exposed to the user, especially from the food contact and blade regions to prevent accidental exposure to moisture. Users will be instructed to operate the device with dry hands to avoid introducing water during cleaning. The circuit will include overcurrent protection to prevent overheating and short circuits.

4.2.3 Motor Safety

If the gearmotor is jammed, the motors may overheat. The current sensor allows the microcontroller to monitor the current being sent through the motor, and if abnormal current is detected, the system automatically stops to avoid motor damage and overheating.

4.3 Transparency About Limitations

Transparency about system limitations is also critical. The device is semi-autonomous, and it is designed for specific types of vegetables. Documentation will be provided that clearly communicates operating procedures to prevent unsafe or unrealistic conditions or expectations. Although food-safe materials would ideally be used in production of this product, the goal is primarily to create a prototype that demonstrates peeling functionality.

4.4 Societal Impact

The E-PEEL device is designed to improve independence in daily living for individuals with limited motor control. By enabling safer meal preparation, the system has potential societal benefits including increased accessibility and reduced reliance on caregivers. Compared to complex robotic solutions, this device offers a simpler and more accessible solution.

5. Citations:

[1] D. M. Taylor, “Americans With Disabilities,” U.S. Census Bureau, Nov. 2018. [Online]. Available: https://www.census.gov/content/dam/Census/library/publications/2018/demo/p70-152.pdf

[2] United Nations, “World Population Prospects 2022: Summary of Results,” 2022. [Online]. Available: https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf. [Accessed: Feb. 13, 2026].

[3] M. P. Lawton and E. M. Brody, “Assessment of older people: Self-maintaining and instrumental activities of daily living,” The Gerontologist, vol. 9, no. 3, pp. 179–186, Sep. 1969, doi: 10.1093/geront/9.3_Part_1.179.

[4] S. A. Olatunji, Y.-L. Tsai, S. Gowrishankar, M. A. Bayles, and W. A. Rogers, “Robots for older adults: A scoping review,” 2025.

[5] R. Hu, A. Ogawa, B. García De Soto, and T. Bock, “Trends, challenges, and opportunities in assistive and robotic kitchen technologies for aging society: A scoping review,” in Proc. 41st Int. Symp. Automation and Robotics in Construction (ISARC), Lille, France, Jun. 2024, doi: 10.22260/ISARC2024/0073.

[6] R. Ye, Y. Hu, Y. Bian, L. Kulm, and T. Bhattacharjee, “MORPHeus: A multimodal one-armed robot-assisted peeling system with human users in-the-loop,” arXiv:2404.06570, May 2024, doi: 10.48550/arXiv.2404.06570.

[7] IEEE, “IEEE Code of Ethics,” 2020. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html

[8] ACM, “ACM Code of Ethics and Professional Conduct,” Association for Computing Machinery, 2018. [Online]. Available: https://www.acm.org/code-of-ethics