

Obot: An Automated Oboe Player

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Abstract

The Obot is an automated oboe performance system that uses a real double reed and a layered airflow control mechanism to reproduce human oboe playing. The system integrates a pump, a servo controlled vent, and a mechanical reed clamp to achieve precise pressure regulation, while a 3D printed bridge with eight solenoids provides key actuation for the main and octave keys. Obot can reliably perform excerpts from Swan Lake and produce stable pitches across the G4–C6 range. This project demonstrates a practical approach to automating double reed instruments and establishes a foundation for future developments.

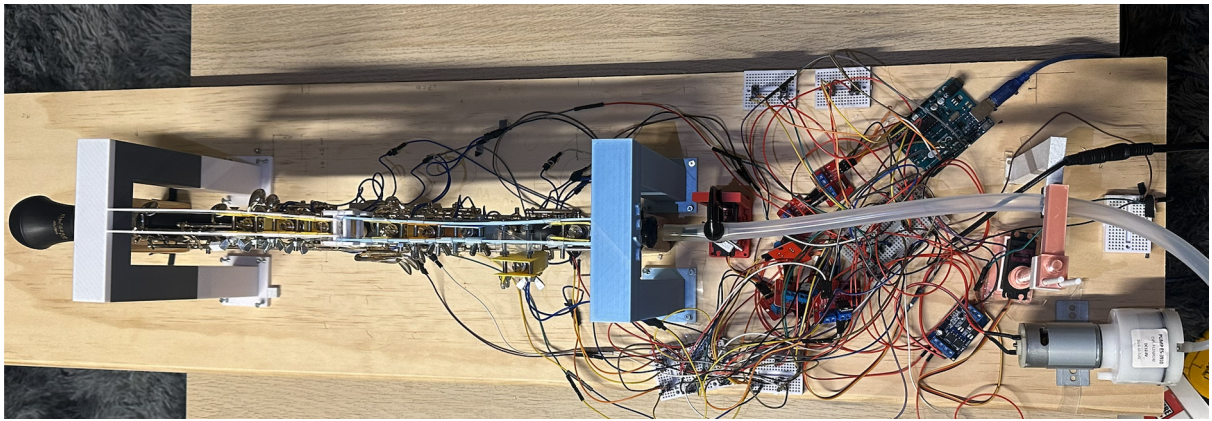


Figure 1: The full image of OBOT

1. Introduction

This paper introduces the Obot: an automated oboe performance system capable of producing most pitches within the instrument’s natural range.

The sound production mechanism of the oboe is based on the coupled vibration of the double reeds[1] under high air pressure. It is extremely sensitive to airflow strength, internal pressure, reed clamping force, and key sealing and synchronization.

Compared with automated instruments that rely mainly on striking, plucking, or keystrokes, the challenge of the oboe lies in the fact that the control of the sound source (the reed) and the control of fingering (the keys) are highly coupled in time. Even a slight fluctuation in airflow

can cause pitch deviation or articulation failure.

The Obot system proposed in this study uses an air pump[2] controllable air pressure release hole, and servo[3] clamp to achieve segmented control of the air path, and completes automatic operation of the keys through a solenoid[4] array mounted to a 3D-printed[5] sliding bridge.

It can reliably perform excerpts from *Swan Lake*[6]. The overall structure of Obot consists of three parts: Section 4 describes the Airflow and reed control: pump, silicone tube, 1 mm² controllable vent hole, servo-driven “lip-like” pressure plate, and servo-driven clamp (to simulate lip pressure);

Section 5 describes the Key actuation: eight linear-motion solenoids mounted on a 3D-printed bridge with lateral sliding alignment, covering six main keys and two octave keys[7];

Section 6 describes the Control and circuitry: Arduino controller[8], independent MOSFET drivers[9], and time-division pulse triggering (about 15–20 ms) to suppress heat accumulation. Musical events are organized as timestamped key vectors.

2. Related Work

Oboe is considered one of the most difficult musical instruments to learn.

Across the global landscape of musical robotics, a wide variety of instrument playing machines can be found, ranging from robotic pianists to percussionists and even woodwind performers. However, robots that are capable of playing double reed instruments remain extremely rare. In particular, functional oboe playing robots are almost nonexistent. Among the limited documentation available, the only notable example is the oboe robot called OB built by Godfried-Willem[10].

The fundamental distinction between Obot and Godfried-Willem’s design lies in the treatment of the reed. His system relies on an acoustic impedance converter to simulate reed vibration and airflow behavior, allowing the instrument to resonate without a physical reed. In contrast, Obot uses a real double reed, driven by an actual airflow path and a mechanically controlled a reed clamping mechanism. This makes Obot the first documented oboe playing robot in the world that uses a real double reed.

During the development process, the author also examined a wide range of related robotic musical systems for inspiration. Notable examples include Gil Weinberg’s Shimon, [11] Troy Rogers’s Robot Rickshaw, [12] Patrick Flanagan’s Jazari [13]. These systems provided valuable insights into mechanical design, timing control, and expressive performance. The project that influenced Obot the most was Bryan Jacobs’s flute/composer[14]. Obot adopts a similar approach by using linear motion solenoids as key actuators, and its structural support

for the solenoid array draws inspiration from the “bridge” like mounting architecture seen in flute/composer.

3. Airflow and Reed Control

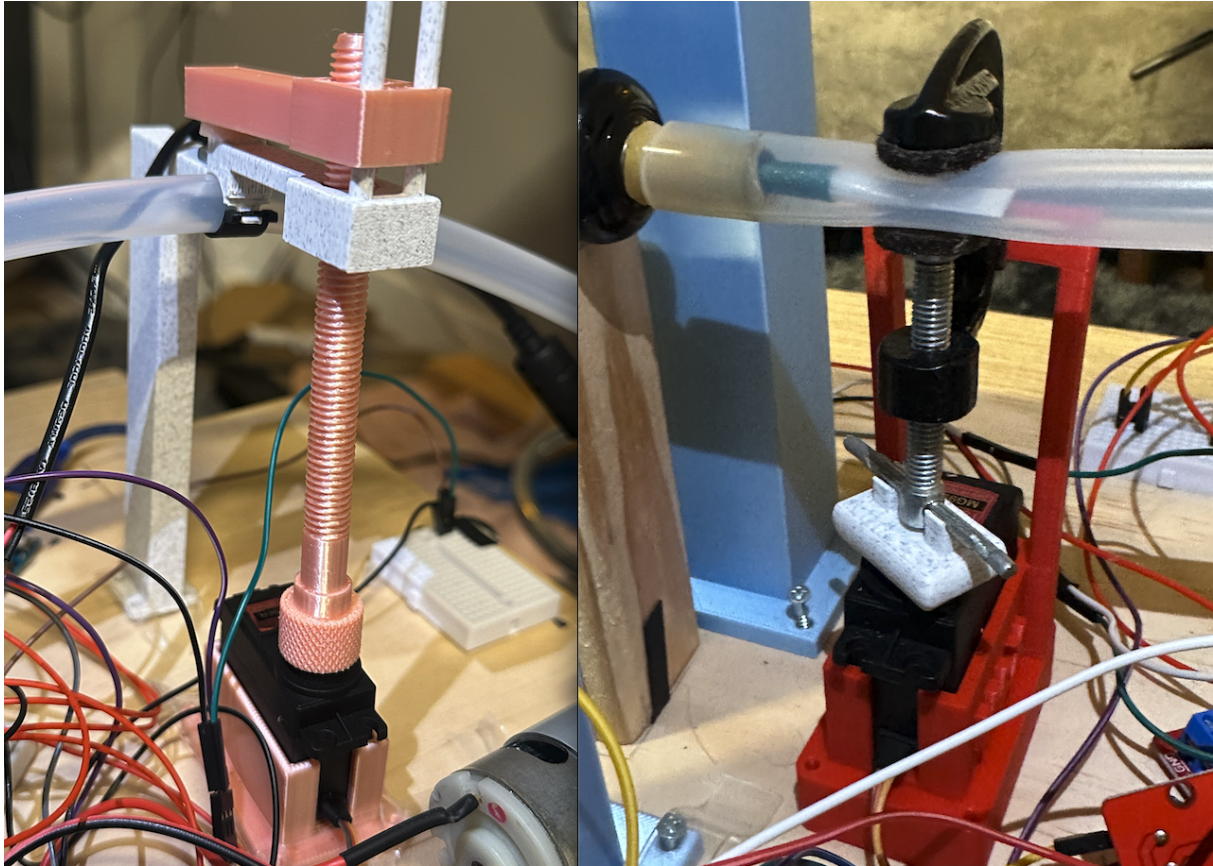


Figure 2: The Controllable Pressure-Release(Vent hole)(Left)and The clamp system that simulated human lips(Right)

3.1 Early Attempts and Issues

In the initial stage, I connected the pump directly to the reed using a silicone tube (1 cm inner diameter) and used thumb and index finger to simulate lip pressure[15] for the first sound test. This method confirmed that appropriate airflow plus slight pressure can activate the double reed.

However, once the reed was inserted into the instrument, the repeatability of tone color, pitch, and attack decreased.

Each test required about 5–10 minutes of readjustment, and during demonstrations or performances, any failure often required long recalibration, limiting reliability and usability.

3.2 Clamp Mechanism and Structural Improvement

To replace manual clamping, the system used a one sided metal vise as the clamp, with a 360° servo controlling the tightening and loosening to simulate lip pressure.

In the early setup, the servo was hot glued[16] to the vise and supported by two wooden sticks; when rotating, the weak structure caused lateral displacement, and the glue deteriorated quickly.

But in the improved version, a 3D printed reinforced base and bracket replaced the glue connection, forming a rigid assembly. This significantly reduced structural drift, increased clamping force, and improved positional repeatability.

3.3 Tube Compression and Replacement

The original silicone tube had too small an inner diameter, squeezing the sides of the reed, increasing the distance between the two blades, which hindered coupling vibration.

The narrow inner wall could also contact the reed and cause damage.

Replacing it with a larger diameter tube greatly improved note stability and responsiveness.

3.4 Controllable Pressure-Release Hole and Servo “Lip” Plate

To refine pressure control, a 1×1 mm vent hole was drilled in the tube. Manually covering it with a finger could continuously vary internal pressure.

I therefore designed a servo driven miniature pressure plate above the vent hole, providing programmable “finger like” coverage.

I 3D printed a clearance platform connected to the servo through a threaded shaft. When the servo rotates, the screw turns and the plate moves linearly downward along the thread, gradually covering the hole until fully sealed.

This mechanism prevents lateral wobble, making the motion more linear and stable.

The result is the servo plate greatly increased pressure resolution and response, reducing setup time from about ten minutes to one to three minutes.

3.5 PWM and Pump Inertia

Different notes require different amounts of air pressure. Only using the PWM modulation[17] of the air pump could not meet the fine, fast, cross pitch, pressure step demands.

PWM control also suffers from mechanical lag and air compressibility, making it difficult to achieve fast, narrow, linear pressure micro adjustments.

By contrast, the dual channel “pump + vent hole” solution is more stable: the pump handles coarse adjustment which I call it a baseline flow, the vent hole fine adjustment which is the transient pressure, and the servo clamp provides a secondary control layer for reed pressure.

Together they form a hierarchical control structure that improves both responsiveness and stability.

3.6 Calibration Strategy and Repeatability

Due to the reed manufacturing variance and reeds wearing out over time (life cycle about 2–4 weeks), the target air pressure and clamping force under the same mechanical settings are not constant.

Currently I perform quick manual calibration after each reed replacement: for every new reed I spend up to ten minutes tuning parameters required for stable vibration.

Experiments show that plastic reeds are superior to bamboo reeds in long term stability and repeatability.

Bamboo reeds deform with temperature and humidity changes, making airflow and pressure distribution unstable, while plastic reeds are largely unaffected and maintain consistent response after repeated installation.

4. Key Execution and Mechanical Structure

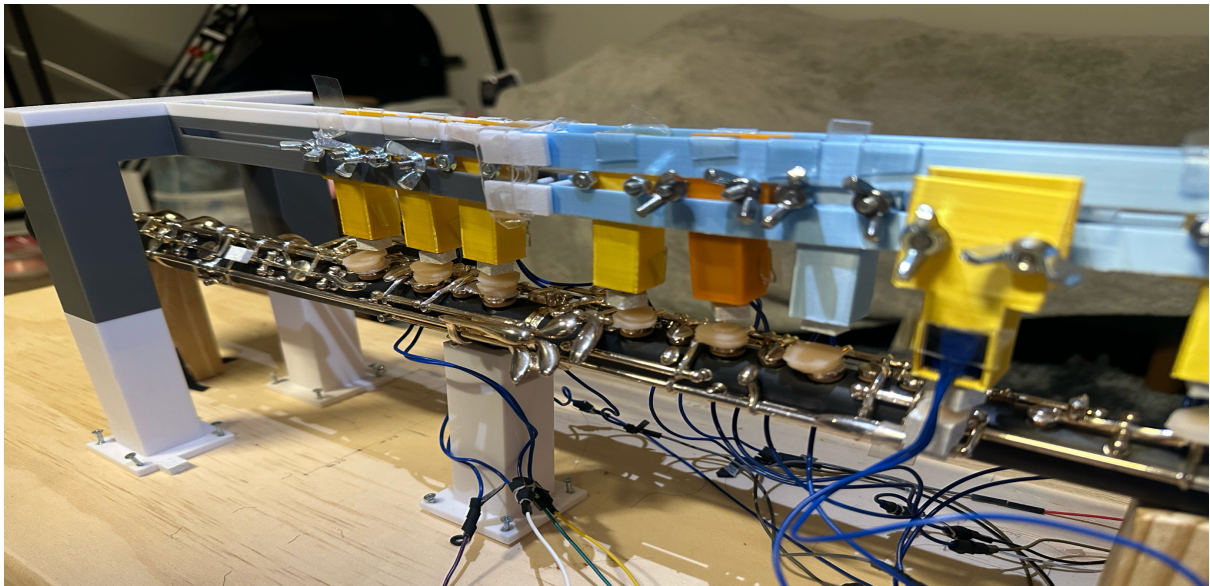


Figure 3: The key control part of the OBOT

4.1 Why Solenoids over Servos

In actuator selection, 180° servos offer angle control but insufficient force and slower speed; 360° servos provide both but are bulky and less precise.

To achieve a millisecond level response with linear motion, solenoids were chosen as key actuators.

4.2 3D Printed “Bridge” and Sliding Alignment

The six main oboe keys align longitudinally.

A parallel 3D printed bridge was designed directly above them:

- Solenoid housing: 3D printed with screw holes on top.
- The bridge’s internal width matches the housing width.
- Housings can slide laterally on the bridge and lock with screws for precise alignment.
- The bridge is supported by wooden columns at both ends and suspended above the instrument.

4.3 Eight Key Coverage and Sealing

After the prototype, I made that including six keys, the system expanded to eight keys. Metal-to-metal contact tended to slip, and some keys had small leakage holes, so silicone pads were added at contact points to increase friction and seal minor leaks, improving stability.

4.4 Key Surface and Travel Correction

For unstable tones such as D5, the solenoid tip was reshaped to a square area roughly equal to the key surface.

Thicker silicone pads were added to enlarge contact area and distribute force evenly, and the solenoid stroke was mechanically limited to reduce incomplete presses.

These modifications significantly improved D5 reliability and pitch transitions.

4.5 Heat and Power Management

Continuous current causes solenoids to heat up and lose thrust.

The system uses the time division pulse triggering, with each press energized for only about 15–20 ms.

Independent MOSFET drivers and a shared ground reduce voltage drop and crosstalk, balancing speed and thermal stability.

4.6 Circuit Layout

An Arduino Uno[18] serves as the control core.

Each solenoid is driven by an independent digital pin through a MOSFET module.

The pump and servos use different systems to avoid interference.

Wiring is arranged for maintainability and easy replacement, with spare connectors for future side key expansion.

4.7 Code Structure and Musical Organization

Software revolves around an event queue[19], each note is defined by a timestamp and an eight key Boolean vector[19], optionally with pump/vent/clamp presets.
This enables unified timing for rhythm, duration, and legato, while reserving clear interfaces for MIDI[20] input.

5. Results and Evaluation

5.1 Playable Range and Stability

Oboe Range (Bb3–G6)	Obot Available Notes	Obot Stable Notes
Bb3	–	–
B3	–	–
C4	–	–
C#4 / Db4	–	–
D4	✓	–
D#4 / Eb4	–	–
E4	✓	–
F4	✓	–
F#4 / Gb4	✓	–
G4	✓	✓
G#4 / Ab4	–	–

A4	✓	✓
A#4 / Bb4	✓	✓
B4	✓	✓
C5	✓	✓
C#5 / Db5	—	—
D5	✓	—
D#5 / Eb5	—	—
E5	✓	✓
F5	✓	✓
F#5 / Gb5	✓	✓
G5	✓	✓
G#5 / Ab5	—	—
A5	✓	✓
A#5 / Bb5	✓	✓
B5	✓	✓
C6	✓	✓
C#6 / Db6	✓	—
D6	✓	—
D#6 / Eb6	—	—
E6	—	—
F6	—	—
F#6 / Gb6	—	—
G6	—	—

5.2 Difficult Notes and Transitions

D5 is the most challenging note, it requires a narrow and precise pressure window.

In the C5 → D5 → E5 transition, internal pressure differences are large, and D5 fingering needs five keys pressed simultaneously with high synchronization.

With the modified tip, thicker pad, and travel limiter discussed in section 5.3, D5 success rate improved markedly and transitions became controllable.

5.3 Tuning Efficiency

After adopting the dual channel “pump and vent” scheme and reinforced clamp rigidity, tuning time dropped from around ten minutes to one to three minutes, crucial for live demos or classes, reducing interruptions and failure rate.

6. Future Work

6.1 Automated Pitch Calibration

Small manufacturing differences between reeds and clamps cause each reed to require slightly different airflow.

To minimize manual adjustments after replacements, I plan to develop an automatic tuning and calibration system.

It will use a tuner to measure pitch deviation in real time and coordinate the servo clamp and vent servo within set step sizes to search for the optimal airflow and pressure combination until pitch meets the target.

The system will then store these parameters as presets for each note.

This will drastically reduce manual tuning time while tracking reed and pressure variation over time, maintaining pitch stability even after multiple reed changes.

6.2 Side Holes and Full Range Coverage

Three tone holes remain uncovered for full oboe range.

The lowest three keys actually act on only two holes, so adding solenoids to those two positions can reproduce three key functions.

Because the holes are on the side rather than the top, I plan to 3D print angled brackets to mount solenoids at a tilted orientation above the holes, keeping alignment parallel to upper keys.

This layout maintains uniform structure while minimizing body modification; some original supports will be repositioned or removed to make space.

6.3 Dynamics and Expression

The current system can produce high volume but lacks continuous dynamic control.

Future integration will combine:

- low frequency PWM pump envelope (dynamics);
 - fast vent micro adjustment (transient detail);
 - clamp preload control (tone and attack zone).
- Together they can realize crescendo/decrescendo, accent, and even vibrato control possibilities.

6.4 Code and Interaction Expansion

Within the existing event queue logic, Obot's control runs on timer interrupts coordinating the pump, servos, and solenoids.

At present, all presets must be manually coded.

The next goal is to generate parameter curves automatically and provide a visual editor, allowing airflow, clamp angle, and note triggers to be adjusted intuitively on a timeline.

The system will also add MIDI and OSC interfaces, enabling standard playback and real time control from external devices.

Future versions will include a self learning parameter optimization module that records each note's success rate, pitch deviation, and volume fluctuation, statistically refining presets over time.

This will gradually evolve Obot from a "fixed setting mechanical performer" into a "self adapting learning performance system."

7. Conclusion

This study designed and implemented Obot, a robotic system capable of autonomously performing the oboe.

Unlike conventional automatic instruments, Obot's key challenge lies in recreating the coordination of airflow, reed pressure, and fingering found in human playing.

In airflow control, the three layer scheme (pump, vent servo and clamp servo) achieved dynamic balance between pressure and reed vibration, avoiding the lag of air pump speed control and improving tuning efficiency.

Mechanically, the 3D printed bridge and solenoid array accurately covered eight main and octave keys, forming a reliable and detachable actuation system.

On the circuit and code level, the use of MOSFET and Pulse Triggering System design provided high responsiveness with low heat.

Experiments showed that Obot can stably perform *Swan Lake* themes, covering D4–C6 and most stable from G4–C6.

From a research perspective, Obot's value lies beyond engineering, it explores the mapping between mechanical systems and human performance behavior.

Through layered control, highly adjustable hardware, and parameter tuning, Obot offers a methodological framework for automating double reed instruments.

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