Housework Commons: Rheostat Rotary Rack

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ABSTRACT
This paper describes the creation of a NIME, *Rheostat Rotary Rack* (*RRR*), based on a rotary drying rack. Part of the *Women's Labor* feminist project that creates Embedded Acoustic Instruments using old domestic tools, *RRR* is anchored by a base that acts as resonator for the system and includes sensors—potentiometers (rheostats) and a rotary encoder—embedded into its physical architecture. *RRR* detects the weight of hanging clothes and velocity of rotation by hand or wind. Motivated by the feminist concept of reproductive commons, we invite the public to do and witness communal housework in interactive installation and musical performance, in order to challenge gender inequality in domestic work division. A composition written for *RRR*, *A Body of Resistance*, draws upon quotes by rheostat inventor Mary Hallock-Greenewalt to address women's struggles for equal treatment. The sound designs for *RRR* and *A Body of Resistance* take inspiration from the drying rack's original wind-powered utility, using aerophone sounds and vibrational modelling of pipes and bars. By reimagining domestic tools with embedded technologies, we envision a musical housework commons that can act as a catalyst for social change.

Author Keywords
NIME, feminist, Embedded Acoustic Instrument, gesture, domestic

CCS Concepts
• **Applied computing → Arts and Humanities → Sound and music computing**; **Applied computing → Arts and Humanities → Performing Arts** • Human-centered computing → Human computer interaction (HCI) → Interaction devices → Sound-based input /output

1. INTRODUCTION
Rheostat Rotary Rack (*RRR*) is the second instrument of *Women's Labor,* a feminist project conceptualized and directed by Ho that repurposes old domestic tools with embedded technologies to make new Embedded Acoustic Instruments (EADs) [19]. Catapulting domestic tools that belong to the private sphere into public spotlight, *Women's Labor* challenges the global gender inequality in unpaid housework division [20]. The domestic-tool-turned musical instruments are featured in installations, new compositions by women composers [8], [9], [12], [18], and performances. While Schedel has been part of *Women's Labor* since its inception to design, compose, and perform with the instruments, Jacobs was approached to help with engineering and fabricating the *RRR*. This paper focuses on the design and construction of *RRR* (Figure 1) that is based on the Australian Hills Hoist Dryer, an outdoor drying rack with an in-built rotating mechanism that spins by hand and in the wind.

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1.1 MOTIVATION
Housework, often performed in isolation within the confines of one's home, remains largely invisible to the public eye. From a socialist-feminist perspective, the isolation and invisibility of unpaid "reproductive labor" (including caregiving and domestic work) perpetuates women's oppression in a capitalist framework [3]. In parts of Latin America, women have formed non-capitalist modes of production by turning public spaces into grassroots organised hubs called "reproductive commons," communally doing reproductive work such as cooking, caring for children, playing music, and running political education events [4]. These acts of political and social resistance build solidarity and strength, reorganizing and socializing domestic work and thereby the home and neighbourhood to counter the capitalist "atomisation" of singular family units.

Expanding upon this practice of reproductive commons, we use the Hills Hoist Dryer, an exemplary household tool within Ho's social setting in contemporary suburban Australia. The Hills Hoist Dryer captures the friction between the public and the domestic, and the individual and the communal. Listed as a National Treasure in the National Library of Australia [15] and featured in the 2000 Sydney Olympics opening ceremony, it is a national, public icon of an idealized, suburban domestic life [11]. Within the community, the dryer is found ubiquitously in backyards of not only individual household units, but also in communal living settings in Australia, including social housing units in Ho's neighborhood. *RRR* repurposes the Hills Hoist Dryer to be used in a "housework commons," challenging its symbolized ideal of suburban bliss that conceals the exploitation of women's unpaid labor behind gender-normative roles. The Hills Hoist Dryer has been featured in film [10],[13], sculpture [17], and photography [1]; departing from its artistic use as visual text, *RRR* is an expressive, gestural instrument, taking a new approach by augmenting the human actions of hanging laundry with sound. In interactive installation of *RRR,* the public participates in house-working in which all genders and ages are invited to sonically meditate on the act of hang their own and others' clothes. Their sound performance becomes a social performance, in which laundering becomes a de-gendered activity for all. *RRR* also defies the traditional gendering of technology as masculine [16] by foregrounding a domestic, traditionally feminized technological innovation. By reimagining domestic technologies with new technologies, we shed light on them as undervalued technological inventions and question the feminization of housework.

2. RHEOSTAT ROTARY RACK
Ho has conceptualized the performativity of the EADs in *Women's Labor* to complement each other, such that they can become a suite of instruments for which theatrically-oriented compositions interrogating gendered inequality can be commissioned. While the performative gestures of the first

Figure 1. *Rheostat Rotary Rack* Installation, Governors Island, NYC

instrument, *Embedded Iron*, are downward and two-dimensional on the ironing board [19], those of *RRR*—hanging clothes onto its strings and rotating it either by hand or by wind—are upward and three-dimensional.

The two instruments are also designed to have contrasting sound concepts. Whereas *Embedded Iron*'s noisy, electric guitar pedal effects in its audio synthesis evoke the original, searing hot working conditions, *RRR's* sound design alludes to wind drying, referencing the sounds of aeolian harps by using samples of aerophones: rubbing the rims of wine glasses and spinning whirly tubes. Both *RRR* and *Embedded Iron* are designed to contain resonators within their instrument bodies. *Embedded Iron* is fitted with a transducer and a speaker on the underside of the ironing board as resonator. While panning is two-dimensional on the ironing board, *RRR* has a base that serves as a resonator for 8 channels of audio diffused through all six sides of the box (Figure 2). Two channels are connected to low frequency transducers facing down, four go to mid-range speakers facing out, and two are directed up through high-frequency tweeters, allowing for 360-degree spatialization.

2.1 Physical Construction and Sensing

RRR is constructed to evoke the architecture of the original Hills Hoist Dryer. The anatomy of *RRR* consists of three main segments: the branches, the trunk, and the base, constructed using 3D printed parts, PVC pipes and steel couplers, and a custom-made wooden box (see Figure 1). In total, Jacobs designed twelve custom 3D-printed structural components. The four branches create four quadrants; each quadrant supports one inner and one outer string on which fabric can be hung by the performer or public participant. Each branch is supported by an arm that connects it to the top of the trunk. This stability reinforcement taken from the Hills Hoist Dryer's structural design minimizes undesired displacement that could result in unwanted noise in the sensor signals. While the Hills Hoist Dryer is conventionally set into the ground using concrete mix, the light-weight materials anchored by the wooden box allows *RRR* to be easily transportable so that Housework Commons can be installed at different sites.

Our choice of sensors is informed by Ho's aesthetic vision of correlating the instrumental affordances of the *Women's Labor* EADs with the domestic tools' original affordances. The quotidian actions that one makes with the Hills Hoist Dryer—hanging clothes and spinning the rack to access other quadrants—become precisely the instrumental gestures of *RRR*, such that these natural actions of domestic work become the site of interrogation through augmenting them with sound. For this purpose, we selected two types of sensors—potentiometers and a rotary encoder—to fit into the physical construction. A potentiometer measures the weight applied to each string when a performer or public participant hangs a piece of fabric. Two custom, 3D-printed parts were required for this weight-sensing mechanism— one to mount the potentiometer to the branch, and another to attach the string to the potentiometer. A spring is used to return the potentiometer to its original position once the weight applied to the string is removed.

Signals from the potentiometers are sent down the trunk to the base and interpreted by a Teensy 3.2 microcontroller (Figure 3). These signals are ultimately used to modify audio synthesis generated in Pure Data, running on a Raspberry Pi. Connecting the potentiometers to the Pi is complicated by the rotational motion of the trunk through an opening in the base. This motion would ordinarily result in wires becoming tangled; however we used an ESP8266 microcontroller to transmit potentiometer data to the Pi wirelessly. This allows for free spinning of *RRR*, without limitation on the number of rotations. Jacobs created a custom circuit board to facilitate the connection of the potentiometers through the Teensy to the ESP8266.

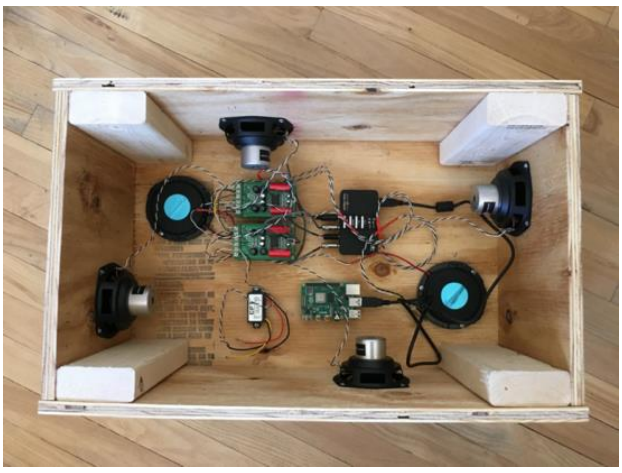

Figure 2. Interior of speaker box base with mounted speakers

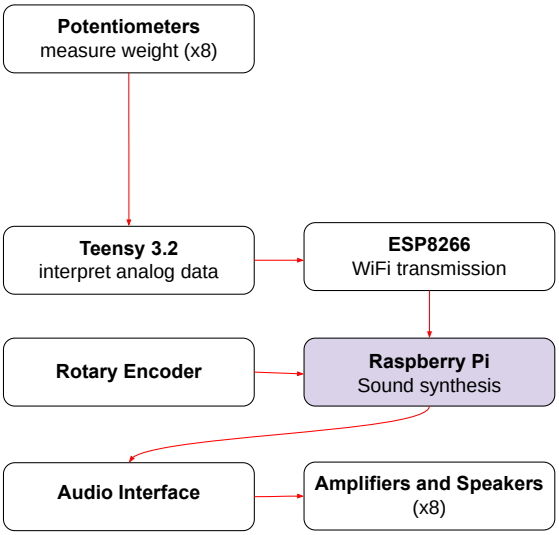

Figure 3. Architecture diagram for *Rheostat Rotary Rack*

The second instrumental gesture of spinning the branches of *RRR* is implemented through a high-resolution rotary encoder that measures the rotational motion of the trunk. A 3D-printed component was created to mount the encoder to the base, allowing the encoder's shaft to couple with the trunk when inserted through an opening in the top of the base. Five 3D-printed components were needed to stabilize the trunk, mount bearings, secure the encoder, and mount the Teensy/ESP8266 board and accompanying power supply.

The majority of the electrical components are housed in the base that also acts as a resonator. *RRR* was designed to conceal the electrical components in order to direct attention away from the technical intricacies, and towards the performative and sculptural capabilities of the instrument.

2.2 Adaptable Sound-Gesture Mapping

RRR's overarching mapping concept can be summarized as follows: 1) hanging clothes on a string triggers wine glass sounds, with the pitch and timbre determined by the clothing's weight and specific string activated; and 2) rotating *RRR* triggers whirly tube sounds that change pitch based on rotational velocity. The mapping of gesture to pitch is designed to be easily adaptable from composition to composition so that composers are not limited by pre-chosen pitch class sets. A simple 6x17 grid of frequencies populates the synthesis engine in Pure Data, shown in Table 1. Given the wine glass and whirly tube samples (Column 2), the composer dictates the pitches they desire by altering the "Fundamental" frequency (Column 3) and the three "Overtones" (Columns 4-6). The rows indicate the strings, in which the first number denotes the quadrant of the instrument. Letter 'a' denotes the outside string in the quadrant and letter 'b', the inside string. Each string has two sets of frequencies that are mapped to lighter and heavier weights of the material hung on the line, denoted by .1 or .2 respectively. For example, the outside string of the first quadrant has two frequency sets, listed in rows 1a.1 and 1a.2. Using this grid, the PD patch calculates the transposition from the sample frequencies. Once the composer has selected their pitch design, it is simple to load these settings in a CSV file with a thumb drive and a small screen inside the base of the instrument.

When the performer hangs a fabric on a string, one of the two Fundamentals will sound (depending on its weight). Rotating *RRR* creates sustained audio; Overtones 1–3 are then activated by spinning the structure faster and faster, as it reaches three threshold velocities.

Table 1. Chart of Frequencies for *A Body of Resistance*

String	Sample	Fundamental	Overtone 1	Overtone 2	Overtone 3
Whirly	146.859375	293.71875	440.578125	587.4375	734.296875
1a.1	511	511	1533	1277.5	3577
1a.2	511	255.5	766.5	638.75	894.25
1b.1	2590	2590	7770	6475	9065
1b.2	2590	863	2589	2157.5	3020.5
2a.1	552	552	276	690	1380
2a.2	552	184	92	230	460
2b.1	3032	3032	1516	3790	7580
2b.2	3032	758	379	947.5	1895
3a.1	1942	1942	2679.96	3495.6	4335.515
3a.2	1942	1699.25	2344.965	3058.65	3793.575625
3b.1	346	346	477.48	622.8	772.445
3b.2	346	288.3333	397.899954	518.99994	643.70409225
4a.1	854	854	1338.645	2497.95	2669.91454545455
4a.2	854	569.333	892.4294775	1665.299025	1779.941988182
4b.1	1443	1443	2261.9025	4220.775	4511.342727273
4b.2	1443	901.875	1413.6890625	2637.984375	2819.589204545

3. ORIGINAL COMPOSITION

Ho commissioned Schedel to write the first commissioned composition for *RRR, A Body of Resistance.* The piece uses quotes by British/Syrian musician and inventor Mary Hallock-Greenewalt (1871-1950), from her writings and patent application [5] for a sensitive, non-linear rheostat that she invented for her audio/visual performances with piano. Before Hallock-Greenewalt's invention, rheostats were highly stepped; with her innovation light could "be increased or decreased at will by the least perceptible increments" [6]. She holds eleven patents; for this composition quotes from her patent simply titled "Rheostat" were used. Impressively, she successfully defended her patent against General Electric, who contended that a woman could not possibly devise such a sophisticated invention [2]. The title of the composition alludes to the continuous acts of resistance women must perform to achieve equality.

Schedel's aunt, Kathleen Kadis, embroidered seventeen banners with the titles of the instrument and project, piece name, and quotes from Hallock-Greenewalt onto multi-colored banners (Figure 4). She made each banner from a different fabric, with distinct lengths and widths. Because the banners were too close in weight to be readable by the potentiometers when added cumulatively to a string, Schedel sewed fishing weights into some of the banners. This modification ensures that sound is

triggered for each banner when a succession of them are added to a string.

In the performance, the performer hangs the banners and rotates *RRR* in different sequences. Each banner contains a name or phrase, one of four quadrant numbers, and instructions for how fast to spin or stop the rotation. The first four 'reference' banners are pre-determined and their placement dictates the quadrant numbers. Each of the 'reference' banners becomes an indication point—the '*Women's Labor'* banner becomes quadrant one. Each of the 'reference' banners has a distinct color, making it easy to place subsequent fabrics in the right position. The performer has the choice of hanging the 'reference' banners on the inside or outside string. After these, a random number generator dictates the order with which the rest of the banners should be hung.

The performer adopts a meditative demeanor, playing *A Body of Resistance* at a markedly slow pace. At the outset of the performance, all banners are pinned with numbered safety pins to a large brass shield, originally used in the military for sorting laundry. The performer selects a banner based on a randomizer, detaches it from the shield, and positions it on the designated quadrant before either spinning or halting the *RRR* rotation. Schedel herself premiered *A Body of Resistance* in an outdoor venue on New York City's Governors Island [7]. Excitingly, during the performance, the wind was strong enough to rotate the rack and serve as an unpredictable duet partner.

3.1 Compositional Sound Design

Extending *RRR's* wind-powered sound concept, the sound design of *A Body of Resistance* is inspired by vibrations of pipes and bars. Table 1 shows the frequencies chosen by Schedel for the piece. The secondary set of pitches associated with heavier fabrics are higher, inspired by the jump in pitch when a pipe is overblown. The pitches are not random; Schedel chose the fundamental frequencies for the eight strings to create two contrasting chords: one chord for all lightweight fabrics, and another for heavier fabrics. In the performance, as the performer adds fabrics, the sound slowly moves from one chord to another.

The timbre for the sound is determined by the fundamental frequency and its overtones. Schedel chose each quadrant to correlate to a different kind of physical model—from an open pipe to a clamped bar. An open pipe is a musical instrument that is open at both ends, such as a flute or an organ pipe. When an open pipe is played, it resonates at its fundamental frequency and at whole-number multiples of that fundamental frequency. On the other hand, a clamped bar is a bar fixed at one end, such as tuning fork. When struck, it also vibrates and produces a fundamental frequency along with its overtones. However, the overtone series for a clamped bar is more complex than that of an open pipe. The overtone frequencies are not whole-number multiples of the fundamental frequency; instead, they occur at frequencies that are irregular, fractional multiples of the fundamental frequency [14]. While the tuning fork's timbre is similar to that of a simple sine wave because of its sparse and muted overtones, the amplified overtones of the clamped-bar model on *RRR* leads to a more dissonant sound.

4. FUTURE DIRECTIONS

To expand upon *RRR's* wind-powered concept, employing physical modeling synthesis to simulate the acoustics of an open tube may allow for a more nuanced translation from sensors to sound generation. We will add more percussive, plucking timbres of bending the corrugated ridges and furrows of whirly tubes to complement the current drone-like sound design. We have begun mapping different velocities and durations of whirly-tube bending to hanging fabrics of different weights. Mapping a decisive, plucking sound gesture to hanging clothes accentuates and foregrounds this unremarkable action of laundering.

The next stage of the physical construction of *RRR* will involve further refinement of its aesthetics and extension of its playability. Extending the branches to allow for five strings per quadrant, mimicking the Hills Hoist Dryer, will allow us to create more pitch, timbral, and textural possibilities. Adding an option to adjust the height of *RRR* will enable the inclusion of players of different heights and abilities. The structural rigidity and durability of some physical components could be reexamined should the project budget expand in the future. Material such as aluminum, while more expensive to manufacture, may prove to be a better choice than 3D-printed PLA parts for connecting joints.

Figure 4. Selected embroidered Banners for *A Body of Resistance*

5. CONCLUSION

Rheostat Rotary Rack invites the public to participate in and witness housework as public performance, thereby reimagining and revaluing domestic work as communal labor. Apart from creating individual compositions for these NIMEs, we encourage composers to write music for small chamber ensembles that blends these NIMEs with acoustic instruments and theatrical components. Through the public's participation in interactive installation, it is our vision that a musical housework commons will lead to future socially-engaged collaborations that can inspire social and political action.

6. ACKNOWLEDGMENTS

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7. ETHICAL STANDARDS

RRR was funded by Harvestworks and UCLA. No conflicts of interest were identified. All researchers and audience participants took part consensually in the activities outlined in this paper. Audiences participants were free to participate or not participate in the installation.

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