Part Three

Technology

Harnessing Ancillary Microgestures in Piano Technique

Abstract

The chapter presents a system allowing pianists to manipulate live audio processing of the piano through microgestural hand and finger control. The system avoids the need for pianists to learn new finger and hand movements, and instead utilizes movements already present in standard piano technique, thus enabling the performer to have a greater level of control over digital sound processing through intuitive gestures. By using radar millimeter waves to capture micromotions and microgestures, performers achieve high levels of expression without the need to modify their instrument or develop additional technique. This research builds upon existing instrumental technique and removes the steep learning curve typically found when performing digital or augmented musical instruments. We present a case study that enables pianists to retain and focus on technical control and musical freedom, resulting in a less disruptive experience.

Running Head Right-hand: Harnessing Ancillary Microgestures

Running Head Left-hand: Niccolò Granieri et al.

Harnessing Ancillary Microgestures in Piano Technique

Implementing Microgestural Control Into an Expressive Keyboard-Based Hyper-Instrument

Niccolò Granieri, James Dooley and Tychonas Michailidis

Introduction and Aims

Musicians spend a great deal of time practicing their instrument. As a result, they develop a unique set of microgestures that define their sound: their acoustic signature. We consider microgestures as small movements that are part of the pianistic technique, but not necessarily related to the sound production. These movements revolve around the sound-producing gestures and are also called ancillary movements (Cadoz and Wanderley, 2000).

This personal palette of gestures presents unique aspects of piano playing and varies from musician to musician, making a distinctive sound and enabling them to convey their music expressively. ~~This chapter presents a case study investigating an innovative way of extending keyboard interfaces, drawing upon pianists' existing instrumental technique. The goal of this research is to extend the creative possibilities available on keyboard-based interfaces, stimulating the creation of new approaches to build intuitive interfaces for musical expression, as well as exploring new ways of learning and playing digital instruments.~~

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Concert pianist Xenia Pestova suggests that "the ability to be creative with phrasing, articulation and stylistically acceptable breathing or flexibility are just some of the elements that make for an expressive performance and create a satisfying experience for both the performer and the audience" (Pestova, 2008, p. 68).

Focusing on user-centered and activity-centered interface design approach, we ~~aim~~ propose~~at creating~~ a system that interfaces and allows performers to express their creativity and extend it through greater engagement with this innate microgestures in the activity of piano performance. An interface that removes or reduces the steepness of the learning curve when approaching it for the first time can also remove the creative barrier posed by a system designed without the end user in mind (Bullock et al., 2016). The chapter presents a case study investigating an innovative way of extending keyboard interfaces, drawing upon pianists' existing instrumental technique. The goal of this research is to extend the creative possibilities available on keyboard-based interfaces, stimulating the creation of new approaches to build intuitive interfaces for musical expression, as well as exploring new ways of learning and playing digital instruments.

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Background

Since the introduction of aftertouch technology in the 1980s, a keyboard feature that allows control of ~~enables us to affect~~ sound parameters through the use of pressure-sensitive keys, there has been a great development in keyboard-based digital instruments. Through the available technology, creators have had the opportunity to enhance features of the instrument by adding several layers of expressive features~~,~~ making effects and modulations possible that are not available to their acoustic counterparts.

Both the *Haken Continuum Fingerboard* (Haken et al., 1992) and *The Rolky Asproyd* (Johnstone, 1985) approached the issue via two different methods. The first approach consisted of a continuous neoprene surface where a classical keyboard was drawn, and the independent tracking of the x-y-z coordinates of up to ten different fingers enabled single-note pitch and amplitude control. The second approach consisted of a transparent surface using light detection to determine the position of each finger and enable single-key pitch modulation. Both of these interfaces had a limited amount of tactile information regarding the location of the fingers and did not manage to provide an intuitive way to enable polyphonic pitch-bending capacity while also allowing effective tuned playing (Lamb and

Robertson, 2011). In addition, the Haken Continuum Fingerboard does not have moving keys, while the Rolky Asproyd is not specifically a keyboard-based instrument; instead, it is a touch controller. Both interfaces present the pianist with a level of unfamiliarity that requires adaptation or the learning of new skills.

More recently, the ROLI Seaboard (Lamb and Robertson, 2011) and Andrew McPherson's TouchKeys (McPherson, 2012) present two innovative keyboard interface developments. The common thread between these two interfaces is that they both require users to alter or adapt their technique to accommodate a new gestural vocabulary built to work with their systems.

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The ROLI Seaboard, as described by its creator Roland Lamb, "is a new musical instrument which enables real-time continuous polyphonic control of pitch, amplitude and timbral variation" (Lamb and Robertson, 2011, p. 503). A silicon membrane has been applied, following the traditional keyboard layout, transforming the keyboard into a continuous slate where the fingers' position, pressure and movement can be tracked and mapped to control individual parameters through the provided software.

Similarly, Andrew McPherson's TouchKeys coats a standard electronic keyboard, or acoustic piano, with a touch-capacitive sleeve that enables the individual detection of the fingers along the length of the keys, enabling the control of different parameters. Both interfaces take what is known as the pianistic technique and enhance it by implementing individual note pitch-bending capabilities and other sound modulations, all taking information from the pianist's fingers. However, these two interfaces dissemble a familiar pianistic technique into various time-dependent gestures. They extrapolate only the sound-producing gesture, the vertical movement of the finger when pressing a key and build a new set of gestures or technique to control the new sound modulation parameters. While we acknowledge the cutting-edge technology implemented in these innovative interfaces, our research aims to address the steep learning curve that is inherently proposed towards the 'classically' trained performer who already has mastered his or her piano technique.

Lower Degree of Invasiveness

Traditionally, instruments are built and designed to achieve a particular sound; the physical properties of their construction define their timbral identity. For example, the organ or the double bass need to be shaped in the way we know and occupy a certain amount of volume in order to produce their unique tonal qualities. The shape of the acoustic instrument determines the gestural interaction and technique required to play the instruments as well as determining the sonic characteristic and any haptic feedback. Musicians spend years working within these limitations refining their command of the instrument to achieve a desired sonic result, a specific acoustic signature (Chadefaux et al., 2010). The amount of time spent on the instrument itself refining its performative technique is justifiable through the well-established musical culture: one that charts a steady evolution in instrument design and technique. The combination of years of practice and technique development create a unique relationship between the instrumentalist and the instrument.

This concept could also be explained by Heidegger's concept of tools considered 'ready-to-hand' (Dourish, 2004). Acoustic instruments, being embedded into the musical culture, become an embodiment of the sound the performer wants to produce with them, thus falling into Heidegger's category of tool that can become *ready-to-hand*. A *ready-to-hand* tool is one that a user can act through: in this case, the musical instrument becomes an extension of the performer's hands and arms to play music. However, the morphing nature of the musical instrument considered as a tool does not usually apply to digital interfaces, which gestural interaction and timbral identity are not defined by their physical properties. On the contrary, digital instruments are versatile with no fixed properties on how they produce sound. Donald Norman, in a more pragmatic way, defines digital interfaces as problematic because of their nature: "The real problem with the interface is that it is an interface. Interfaces get in the way. I don't want to focus my energies on an interface. I want to focus on the job" (Norman, 1990, p. 210).

The problem with digital interfaces lies in the intrinsic fact that they are interfaces: they interface the user with something else. When we apply this concept to musicianship, an instrument is also an interface, but through years of practice the instrument/interface is no longer disruptive; it becomes a tool. However, a digital interface posed between the musician and the sound produced is an added step that is not present in its everyday practice, thus seen as disruptive, or with a higher degree of invasiveness. Interfacing between the performer-instrument relationship can often become invasive and disruptive from a performer's view. Grandhi et al. (2011) propose the significance of naturalness in interfaces. When we define an interface as unnatural, the definition usually is attributed to the system itself. Instead, we believe that the unnaturalness of a system, or the interaction with it, is the result of bad design and implementation.

A digital interface may be portrayed as poorly designed if it requires performers to relearn a familiar technique. When an interface is built around the designer's idea instead of the user's needs, it often results in fabricating a new type of hybrid performer that combines the creator of the interface, the composer and the performer (Michailidis, 2016). These design-centered, not user-centered, interfaces are not necessarily intuitive to performers other than the creator.

Utilizing a user-centered approach for the development of expressive digital interfaces, our system focuses on the importance of touch-free gesture recognition characterized by a low degree of invasiveness. It is inspired by the work of Dobrian and Koppelman (2006), who highlight the importance of developing systems that allow artists to reach the same level of sophistication achieved with traditional instruments (jazz, classical and so forth). We focus on developing strategies for better mapping and gesture recognition utilizing existing virtuosity and developing new repertoire for piano performances.

Radar-Based Detection

Here we provide an overview of the capabilities of Google's Soli Alpha Developer Kit (Soli hereafter) sensor, outlining our motives for choosing the device. A thorough technical description of the Soli examining its hardware, software and design is provided by Lien et al. (2016). Soli is capable of using millimeter-wave radar to detect fine-grain and microscopic gestures with modulated pulses emitted at frequencies between 1–10 kHz. The strength of a radar-based signal lies in its ability to offer a high temporal resolution, the ability to work through specific materials such as cloth and plastic and to perform independently of environmental lighting conditions (Arner et al., 2017). One significant feature is the highly optimized hardware and software devoted to the prioritization of motion over spatial or static poses. In addition, the compact size makes it an excellent choice for musical purposes that require a low degree of invasiveness from the system.

Other systems are also capable of identifying gestures. This includes color detection from 2D RGB cameras (Erol et al., 2007) to 3D sensing arrays of cameras, such as Microsoft's Kinect (Han et al., 2013). Researchers have developed other means of sensing gestures such as IR technology mainly represented by Leap Motion (Han and Gold, 2014). However, such technologies often lack in precision when aimed for fine-grain gesture detection. Other devices that enable gestural input using radar-like detection are the SideSwipe, which analyzes disturbances of GSM signals (Zhao et al., 2014), and the WiSee that analyzes existing Wi-Fi signals and their perturbances to recognize human gestures (Pu et al., 2013).

The devices mentioned here are unable to capture microgestures with a high level of accuracy. Current devices using radar waves or wireless signals similar to Soli work with lower-frequency bands typically under 5 GHz. Soli uses high-frequency radar of 60 GHz that considerably increases the device's level of accuracy, making it suitable for fine-grain gesture sensing (Wang et al., 2016).

The System

Figure 16.1 shows an overview of the system design and components. Software written in OpenFrameworks manages and visualizes data received from Soli. The Random Forests classification algorithm determines whether the gesture is performed or not. This binary outcome is then used as a gate to forward or block the actual data directly mapped to the pitch-shifting algorithm.

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Figure 16.1 Overview of the System Design and Components

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Google provides several existing wrappers and examples for Project Soli, including OpenFrameworks, a C++ wrapper specifically designed for creative applications. Nick Gillian's "Random Forests Classification Algorithm" from the GRT (Gillian and Paradiso, 2014) was chosen as the initial test algorithm, as it is already implemented as part of the Soli framework, and during the initial prototyping phase of this research, it proved to be a valuable tool due to its ease of use and implementation.

Two core features from the dataset were chosen to control the pitch-shifting algorithm: the energy and the velocity of the gesture analyzed. Through the Open Sound Control (OSC) protocol, the Pure Data (PD) programming environment receives and maps data directly to a pitch-shifting effect: gesture intensity controls the range and amplitude of the effect. The intensity of the effect is also affected by the amount of audio signal incoming from the acoustic instrument, thus giving complete control to the performer regarding the quantity of modulation and volume.

Testing—Initial Case Study

The first prototype of the system was used during a performance at the Beyond Borders conference, held at Birmingham City University in July 2017. The performance ~~in front of a live audience~~enbled us ~~was an excellent opportunity~~ to identify any limitations and constraints and examine potential applications of microgestures of the system before the formal usability test.

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Figure 16.2 The Lateral Swaying of the Hands After the Key Had Been Pressed. Sequential snapshot of the vibrato gesture.

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The prototype system presented recognized only one gesture: lateral swaying of the hands after the key had been pressed, as shown in Figure 16.2.

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We demonstrate the system through a simple piano piece composed in the key of D major exploring the soundscape of the tonal key itself through chords, voicings and different melodic lines superimposed upon one another. The use of the pedal was essential in this piece to create an extended and continuous bedrock of sound that would fill the room with harmonics. It was also aimed to give enough 'room' to the pitch-shifting effect to be heard and noticed. The composition and the performance were tailored to the audience without any musical background to get as much constructive feedback as possible. The piece was divided into three parts, to underline the differences of gestures and gestural nuances in piano playing. During the first part, the pianist used different sizes of wooden sticks, allowing the playing of chords that were otherwise impossible to play. This section underlines the non-expressive elements of performance, by limiting the abilities of the musician to a mechanic motion: note-on, note-off. By pressing the piano keys with a wooden board instead of the finger, it resulted in a 'binary' and mechanical playing that lacked expression and musicality.

The second part bridges the purely 'binary' playing of the first part, seeing the pianist slowly abandoning the wooden contraptions he had been using until that moment to play, and moving towards a hand-driven exploration of the keys. With the hands on the keyboard, but still performing a binary movement, the system did not activate, and the machine-learning algorithm was not able to recognize any ancillary movements revolving around the piano technique: the playing was still not expressive. This leads us to the third part of the piece, where the pianist makes extensive use of his pianistic technique enhanced by layers of sound modulation.

In the third part, the pianist explores chords, modulating sounds and playing with the sound effect driven by the sensor. The gesture recognition is tailored to the unique hand gestures of the performer. Naturally, the microgestural approach changes depending on the expressive articulations within the score. The piece finishes with a chord struck with one of the sticks from the first part.

The feedback from this initial performance was mostly positive. Mapping the gesture to a frequency-modulation effect gave the illusion to the performer that the acoustic piano could produce a vibrato effect on the notes played. The majority of the audience when asked felt that the gestures produced an organic sound modulation and could not distinguish the different sound sources of the acoustic and electronic textures, even though the speaker was placed directly under the piano. The recognized gesture by the system took place as if it was always there. The pianist mentioned that he was able to control and trigger the vibrato and that the interaction with the system felt natural and non-invasive (Granieri, 2017).[1]

The lateral swaying of the hand together with the vibrato effect turned out to be a really intuitive pair of gesture-modulation to implement.~~,~~ A~~a~~s confirmed later on, one of the pianists from the user testing said~~:~~ “It’s helpful to know what a vibrato is so you can try and fit a technique to what you’d imagine it. Or if you would imagine a string player doing vibrato and copy that shape that was kind of what was going through my head”. The lateral movement of a hand associated with slight pitch modulation is something that both musicians and audiences can easily relate to the gesture due to the familiarity that vibrato effect has with string instruments. The performer also found very interesting the control of sound modulations through microgestures, and said ~~and he also mentioned: “~~“it was very easy to connect with the audience and increase or decrease the amount of the modulation depending on the section of the piece that was being played. This was also due to the piece being very free in its form and composed to accommodate the modulation of the system and the gesture recognized”.

User Testing

We use an informal formative method for the user testing as described by Martens (2016) to test and assess interaction in a task-based scenario. This method was chosen due to the early stage of the research and the ongoing development of the prototype system. A formal user-testing method including error counting and timed tasks would have been less useful for the further development of the system. ~~Moreover, not having~~Without any previous ~~reference~~research as reference, a simple empirical test followed by an interview to gather experiences and impressions from the users on the system was the best approach.

Twelve piano students from the Royal Birmingham Conservatoire, Birmingham City University split equally by gender, -participated in the user testing. The tests included students from different stages in their studies ~~of becoming professional pianist~~ varying in age and experience~~s~~. The musical focus was equally split between classical and jazz trained pianists.

The user tests were conducted in a recording studio using a Yamaha upright piano at Royal Birmingham Conservatoire. An Audio Technica AT4040 cardioid microphone captured the sound, and the effects were emitted via a single Behringer B2031A Active Studio Monitor placed on the studio floor. The microgestures were analyzed using the Soli sensor as described earlier. The system detects the lateral swaying of the hands, as shown in Figure 16.2, and maps the movement to the pitch shifting, which is limited to a maximum of half a tone above and below the note played. The real-time audio analysis allows us to introduce a threshold to avoid unintentional triggering of the system.

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Each test lasted approximately 40 minutes per participant. Subjects were briefly interviewed about their pianistic background and current knowledge and experience with electronic music and digital instruments. After the interview and a brief explanation of the system, the users were given 10 minutes to try the system and get comfortable with the effected sound coming from the speaker. There was no dry piano signal coming from the speaker; this choice was made because of the loudness of the piano and the small size of the room. We took advantage of that time to calibrate the system, adjusting to the gesture technique of the pianist. Subjects were then asked to perform a series of simple tasks to assess the precision and reliability of the system. These tasks were the following: play a note, play a chord, play a scale. During the first run all tasks were performed twice and users were asked not to activate the system, while the second time to purposely try to activate it. This was done to make users aware of the threshold and how their gestures may trigger the audio processing. Furthermore, subjects were asked to either perform a piece we provided or perform one from their repertoire.[2] We then asked them to perform the pieces twice with and without the system as a mean of comparison. Two users chose to perform a piece from the provided repertoire, and both were coming from a classical background. The pieces chosen by these two performers were *September Chorale* by Gabriel Jackson and *Bells* by Simon Bainbridge. Finally, they were asked if they were willing to improvise, and then were asked to fill in a User Experience Questionnaire (UEQ) (Schrepp et al., 2017). The UEQ allow us to evaluate the system on its efficiency, perspicuity, dependability as well as aspects of the user experience such as originality and stimulation. Each subject took part in a brief final interview about the experience and the system.

Discussion

The musical background and level of the pianist appeared not to have a significant effect on the result of the test itself. Both classical and jazz pianists were able to perform with the system and commented that they would happily use the system in their performances. During the interview, one user said “this is very diverse, can be applied to classical, jazz, anybody who plays the piano. It can be for anyone”. He continued, “it was really interesting to play on a real piano, in its natural form being able to effect sound is not something that is possible without controls and effects” (referring to knobs and effects on his keyboard). The results from the questionnaire were all positive, with higher marks given to the system’s attractiveness and hedonic quality, and lower but still positive marks in the pragmatic section, as seen in Figure 16.3. This section concerned the responsiveness and reliability of the system. We anticipated such responses as the system was still in the prototyping stage. During the analysis of interviews, a connection emerged between the piece performed and the feedback given. When they performed one of the proposed pieces, the users tended to be more willing to adapt the composition to their

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imagination and freely interpret the tempo to accommodate sound modulation through the system. The listed pieces were chosen together with a piano teacher from the Royal Birmingham Conservatoire because of their temporal and rhythmic freedom and long ringing chords. We believe this is something that encourages the pianists to take advantage of the system. When users chose to play a piece from their repertoire, the comments were less encouraging. The users seemed to be less likely to feel the need to add this expressive layer on a consolidated piece that they already knew how to play expressively to convey a certain emotion. This can be related to McNutt's (2004) observations stating that performers need to have a reasonable idea of what sounds they will hear, and in this specific case, what sounds their hands will produce. This link between the pieces and the comments given was also confirmed by the most noticed comment on the system throughout the user testing. All users said that the system was eliminating or at least reducing the learning curve of typical interactive systems, but that the strain had shifted to the ability of predicting and expecting the sound of the instrument. Five users underlined that the hardest element to get accustomed to in the system was not the gestures it ~~involved, but~~involved but ~~was~~ the sound of it.

> In this case I heard something I wasn't expecting, before I played I knew how the sound (of the acoustic piano) should have been, and when I played now I was like "wow what is this" because it's something new, and I don't like the sound to be different to what I hear before. (Classical Pianist 5)

When asked if they had to change their piano technique to take advantage of the system, one user said, "The technique that's needed is the listening, as we say we pedal with our ears. It's really what it's about".

Three out of twelve users pointed out that they would have needed some time to practice the system, to learn what their pianistic gestures would correspond to from a sonic point of view. This is closely tied to the previous statements related to the piece performed during the testing: the fact that the user could not predict what the system would have sounded like meant that the system would have felt invasive from a sonic point of view in contrast to a performance of an already known piece.

The following section of the test was optional and consisted of a short improvisation with the system. This enabled us to assess if within the relatively short time of using the system subjects were able to improvise, and if so, to what extent. This section was aimed mainly towards jazz pianists; however, one classical pianist asked to try and improvise with it. The results had many similarities with the previous part. During the improvisation, users were keen to unexpected sounds and timbres, and were willing to explore the new sonic environment with their technique. When asked to compare the experiences of playing a repertoire piece or improvising, one user said:

> I'd say they were different, I wouldn't say one was better than the other. The theme was less spontaneous, so you knew what was coming up, so I was able to pre-empt. Whereas the improvisation is spontaneous, so I would have to be actively putting it and using it.

Another user said:

> I guess someone could be inspired, and write a piece for it, or someone could use it to aid a performance. Not so sure about pre-existing composition, I am sure that for me if I wrote something I wouldn't want to mess around and perform it in a manner that's adding something that's not in the original scripting of my writing.

~~Before the final interview process, the users were asked to complete a UEQ that enabled us to evaluate the system on its efficiency, perspicuity, dependability as well as aspects of the user experience such as originality and stimulation.~~

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With exceptionally high values of 2.4 and 2.17, attractiveness and hedonic quality were the categories that reached the highest score in the test. We believe that the high values were due to the non-invasive character of the system that gave users an additional sonic element with the minimum learning curve. Another less favorable feature of the system was identified in its pragmatic area. While nine users found the system to be innovative and exciting to play with, three users did not feel entirely in control of the system and felt that the system was not responsive enough, resulting in miss-triggering.

The users that felt in control of the system were able to control the triggering of the audio effects in an expressive way through their playing. One user said:

> Yeah I felt mostly in control at some points maybe I was worried I wasn't doing it right. But especially once I got used to it, it felt a lot easier to control. There were a couple of points where I really was thinking If I was performing the gesture correctly, but I don't see it as a long-term issue because I played for a total of 15 minutes.

The comments and feedback, as well as the results of the questionnaire, were expected at this stage of the research. During lab tests, the prototype system was sometimes lacking consistency in providing the data output.

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Figure 16.3 On the left, the average of each parameter on a scale from -3 to +3. On the right, the same parameters grouped under three macro categories.

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Conclusion

From our initial research, the approach we have adopted for developing new interfaces for musical expression has helped to elucidate many factors that musicians face when using digital instruments. By creating interfaces that are non-invasive and build on existing instrumental technique, we can move towards creating less disruptive experiences for performers using technology in performance. We have shown how musicians and pianists, in particular, may benefit from such interfaces. The choice of technologies we have used has allowed us to achieve this. The findings gathered from both the development of the prototype and the usability testing showed positive and encouraging outcomes. The user testing showed how users are keen to adapt and accept such a system which builds upon their existing technique.

With the development of new technologies and devices available, perhaps we need to think about a new communication protocol in instrumental performances that can further explore the potentials presented through microgestures and open new horizons to composers and musician alike.

Notes

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[1] The performance can be seen on Vimeo: https://vimeo.com/226180524.

[2] Piano pieces provided: *September Chorale* (Jackson, Gabriel), *Nocturne I* (Harrison, Sadie), *Nocturne II* (Harrison, Sadie), *Utrecht Chimes* (Lange, Elena), *Bells* (Bainbridge, Simon), *Yvaropera 5* (Finnissy, Michael).

Repertoire piano pieces: *Nocturne in C-sharp minor*, B.49 (Chopin, Frédéric), *Piano Sonata No. 8 in C minor, Op. 13, Adagio cantabile* (Beethoven, Ludwig van), *Paraphrase de concert sur Rigoletto, S.434* (Liszt, Franz), *Faschingsschwank aus Wien, Op. 26: I. Allegro* (Schumann, Robert), personal arrangement of *When You Wish Upon a Star* (Edwards, Cliff), *Nocturne, Op. 32, Andante sostenuto in B major* (Chopin, Frédéric), *Piano Sonata No. 10, Op. 14, No. 2* (Beethoven, Ludwig van), *Prelude in G-Sharp Minor, Op. 32, No. 12* (Rachmaninoff, Sergei).