# THE MAGNETIC SCORE: SOMATOSENSORY INSCRIPTIONS AND RELATIONAL DESIGN IN THE INSTRUMENT-SCORE

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## ABSTRACT

With the changes occurring in the dialectics between the composer and the interpreter during the second half of the twentieth century, the traditional concept of the musical score has undergone an ontological change. As composers began exploring unconventional notational practices and offering to the interpreter a higher autonomy, the locus of the musical information became less defined, at times merging with that of the instrument. In this paper we explore the dual nature of notation both as score and as instrument from the point of view of non-visual methods of representation. We do this by presenting the Magnetic Score, a system for the inscription and generation of sound that relies on permanent magnetic fields. In magnetic scores, the performative gestures emerge out of the interpreter's embodied interaction with the magnetic fields, and the relational design of the inscriptions together with the interdependence of the symbolic and somatosensory layers offer original insights on the role and situatedness of the musical score in contemporary practices.

## 1. INTRODUCTION

In his seminal work *Opera Aperta*, Eco describes the changes that characterise the emerging artistic poetics of the 1950s and 60s [1]. If classical musical works consisted of organised sets of information reproducing an enclosed structure as imagined by the author, the practices of composers such as Stockhausen, Berio and Pousseur offered to the interpreter a higher degree of autonomy in relating with the musical material.

With this change in the dialectics between the composer and the interpreter, some composers began approaching music notation as a description of gestural information for the performer rather than as pitch organised in time [2], and the mapping of such relations became a crucial element in designing musical interactions [3]. As a consequence, the acquired freedom in defining and representing the inscribed musical parameters has led to the emergence of a plethora of compositional approaches [4]. Among such, an increasing number redefine the composer's and performer's traditional roles and attributed agencies [5], explore the relational aspects of the inscription [6], or explicitly suggest a dynamic and open idea of the score's situatedness in relation to the instrument [7].

The overlapping of the musical expression with the score is rooted in the very nature of musical instruments, as they inherently embed theoretical models that define the interaction and the musical practices that have developed around them [8]. In the domain of electronic music this becomes particularly evident, with the compositional processes and their technological substrate overlapping with unprecedented fluidity. As a consequence, the *notational space*, within the indeterminacy of the current artistic poetics, escapes the physical constraints of the score and coincides with that of the *dispositif*: an extension of the instrument-score, incorporating all the structural, tangible and virtual components that support the inscription [9].

In this paper we explore the dual nature of music notation both as score and as instrument. We also explore approaches that do not solely rely on visual representation, investigating how the embodiment that characterises contemporary compositional practices favours a holistic and sensuous experience of the inscription. We do this by introducing the *magnetic score*, a system for embodied notation in which the inscription is encoded via permanent magnets, and can be subjectively experienced through somatosensory feedback. As we will observe, magnetic scores combine the tangible features of instrument-scores with the relational and situational qualities of event scores, since, rather than being unilaterally inscribed, the information emerges through the interaction of the components that define the dispositif.

## 2. BACKGROUND

The use of graphic signs and symbols has been the prominent approach in inscribing music both in the tradition and within the avant-garde movements in the second half of the twentieth century. Works such as Cornelius Cardew's *Treatise* [10] and Earle Brown's *December* [11] adopt graphic notation to convey musical ideas, oftentimes endowing the performer with a high degree of interpretative freedom. In this sense, graphic notation has been a way for composers to develop personal systems of representation and elude the expressive constraints of traditional compositional praxis. Nonetheless, with the change in the artistic poetics that characterises the second half of the twentieth

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century, approaches that do not necessarily rely on visual notation have emerged, such as the implementation of tangible interfaces and the adoption of haptics [12].

In this section, we explore the relationship between instruments, scores and performers via the notion of non-visual inscriptions. In order to establish a theoretical framework, we look into inherent scores, tangible scores and event scores. We also describe the recent adoption of magnets in music performances and instrument-scores, as it provides a technical context for this work.

### 2.1 Instruments-Scores and Non-visual Inscriptions

Tomás and Kaltenbrunner propose the concept of *inherent scores* to describe the progressive embedding of inscriptions within the instrument [3], and trace its origin back to Alvin Lucier, who, in describing the practices of the Sonic Art Union, stated that the scores were inherent to the circuits developed by the members of the collective [13]. This approach is not isolated to a single, although particularly influential, group of artists, as it overarches the practices of a large group of composers, such as Pauline Oliveros [14], Gordon Mumma [15] and David Tudor [7], as well as sound artists such as Peter Vogel [16] or Gerhard Trimpin [17].

Among inherent scores, *tangible scores* are a particular subgroup that relies on the tactile interaction with the instrument for the generation of sound as well as for the interpretation of the sign [18]. Tangible scores certainly hold a visual dimension in that they suggest specific gestures through the graphic inscriptions embedded in the instrument, but they complement it with a strong orientation toward tactility. Signs are engraved rather than printed on top of the surface: this adds a tangible layer that informs the performance as well as the generation of sound.

Similarly to that of tangible scores, the concept of *composed instruments* provides a non-visual take on the navigation of the inscription. At the basis of this type of instrument-score is often the decoupling of the sound-producing component with the gestural one [19]. As a consequence, the score is incorporated in multiple, modular mappings, whose features define the interaction between a controller and an arbitrary synthesis engine. In composed instruments, the score is encoded inside the dispositif in the form of a defined set of mappings and constraints, and is navigated through embodiment within the performative act.

Non-visual inscriptions are also particularly effective in contexts in which the interpreters are free to explore the performative space and can not rely on physical supports, or in the cases of "comprovisational" practices in which the instruction is situational [20]. In such cases, cues provided by haptic devices embedded within garments have granted the needed flexibility and at the same time preserved the situational character of the compositions [21]. Haptics is indeed a promising domain, as it allows to dynamically inform the performance without interfering with the interpreter's interaction with the instrument and with the space. Furthermore, it offers compositional and performative control over multiple parameters at the same time, such as frequency, intensity and duration, as well as spectral content and spatial position [22].

Finally, other systems explore non-visual notation with the specific aim of easing the learning of a piece by the visually-impaired [23, 24]. Even though they are relevant as non-visual scoring methodologies, for the most part these approaches are substantially different from the one proposed in this paper, in that they focus on the re-encoding of traditional notation rather than in the exploration of alternative ways to inform the performance.

### 2.2 Event Scores and Non-visual Inscriptions

Instead of encoding the information in the instrument, other methods of non-visual inscription explore the notational possibilities offered by the performers' embodied knowledge and reciprocal interactions.

*Event scores* are brief sets of verbal instructions defining rules to follow, actions to take and concepts to be aware of in the act of performing [25]. Among such, Pauline Oliveros' *text scores* [14] focus on the listening experience that emerges in the performance. Even though text scores hold a visual component that is functional to their transmission, in Oliveros' works a different informational layer emerges and unfolds within the relation of the interpreters with each other and with the environment. The practice of *deep listening* becomes the space where information is produced, and sound the domain in which the process operates. Through this, the score acquires a relational dimension, as the musical intake of an agent informs the action of another.

The aural quality that characterises event scores is also a feature of *audio scores*, in which information is presented during the performance through recorded or live-generated sound. Different types of audio scores have been proposed, some providing precise and repeatable sets of instructions [26], others inviting the performers to interact with a set of live generated sounds [27]. In *Pricked and Away* [28], Elisabeth Schimana interestingly explores memory itself as a medium for the inscription and for the re-elaboration of musical ideas: the sound excerpts are presented to the performers long before the performance, and the musicians are required to remember and play them during the concert following a specific timeline.

The practices and conventions that characterise musical performances always implicitly involve notions of embodiment and interaction. Nonetheless, in the aforementioned works the score incorporated in the performers' embodied knowledge and interacting subjectivities is amplified, formalised and defined within the system's setup. The relational nature of these compositional approaches, detectable in the situational stance of the performative instructions as well as in the emergent character of the work, underpins a direct involvement of the performers in the compositional process. In describing the intersubjectivity characterising relational aesthetics in the modern work of art, Bourriaud states that "the sense of the work issues from the movement that links up the signs transmitted by the artists, as well as from the collaboration between people in the exhibition space" [29].

As we will see, the system we propose embraces the embodied, relational nature that characterises some event scores and combines it with the tangible materiality of the instrument-score. This is achieved through a set of permanent magnets embedded and creatively displaced on the different components of the dispositif, and whose magnetic fields interact in order to generate the inscription as somatosensory manifestation and sound.

### 2.3 Permanent Magnets

Permanent magnets constitute a key component of most audio electronics and in the building of all kinds of actuators, and are extensively incorporated in the design of modern musical instruments and amplification technologies. As musicians, we operate with magnets on a daily basis, from pickups to speaker cones. However, the application of magnets as structural elements in a score's interaction design, as gestural control or for the generation of sound, has not been extensively explored as of yet.

Neodymium magnets have been introduced in musical scores quite recently. Michelle Agnes Magalhaes' *Mobile* [1] first explores their use on the piano strings in order to obtain bouncing and glissando effects. Because of the unique sounds they produce, magnets have since then been incorporated in the works of other composers such as Elena Rykova in *Bat Jamming* and *Cositas Diminutas*, [2] and Gustavo Díaz-Jerez in *Metaludios*. [3]

A notable example of the use of magnets as key components in the interaction design of an instrument-score is the *Chowndolo* [4] by Giacomo Lepri: a pendulum whose movement is dynamically controlled through a set of permanent magnets on its base. A different approach is instead explored by David Griffith in the *Pattern Matrix*, [5] a tangible AR live coding environment controlled through the orientation of permanent magnets on a tangible 5x5 matrix.

In the *Marble Machine* [6] the merging of the score with the instrument becomes particularly apparent. In this system, the instrument's sounds are generated through the interactions of ferromagnetic marbles with different surfaces, membranes or strings, and their timing is controlled by a tangible step sequencer made of small magnetic cylinders attracting and repositioning the marbles.

Finally, in NIME's proceedings from 2001 to present we identified three papers describing the application of small magnetic tags for position sensing [30, 31, 24]. The advantages of this approach are the precise representation of the tag's position and the granular control that can be achieved within a circumscribed space. In such cases the sound is defined by the dynamic repositioning of the passive elements in relation to a sensor. As we will describe in the next section, in magnetic scores the paradigm is flipped, and the performer interacts with the passive elements by moving the sensors in space.

[1] https://www.youtube.com/watch?v=xLLctkt14qs
[2] https://www.elenarykova.rocks/
[3] https://www.metaludios.com/
[4] http://www.giacomolepri.com/chowndolo
[5] https://penelope.hypotheses.org/category/pattern-matrix
[6] https://en.wikipedia.org/wiki/Wintergatan

## 3. THE MAGNETIC SCORE

Magnetic scores (Fig.1) enable the composition of haptic scores within the functionality of the instrument itself, as a specific instance of inherent scores. They comprises a board and a pair of controllers, both embedded with magnets. As the performer navigates the board with the controllers, the magnets attract and repel each other, thus suggesting the performative gesture.

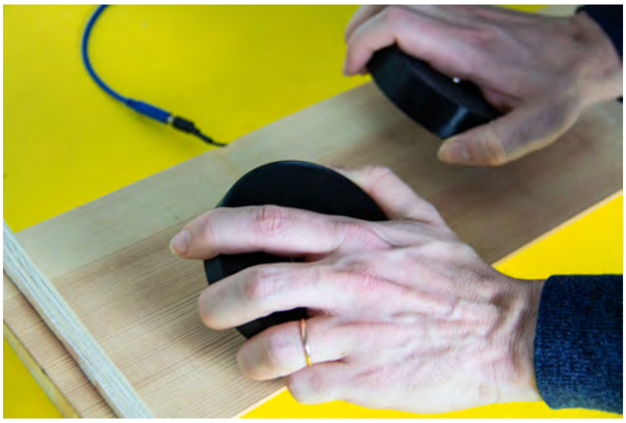

**Figure 1**. The Magnetic Score.

### 3.1 Magnetic Board

Magnetic scores encode performative instructions through magnets mounted underneath two-dimensional or tri-dimensional surfaces of variable dimensions and shape, named *magnetic boards*. The performer holds two controllers containing a series of sensors and a permanent magnet each, as described in 3.2. The interaction between the magnets within the board and the ones mounted on the controllers provides somatosensory feedback in the form of points of attraction and repulsion whose strength depends on the dimension of the magnets and their reciprocal distance. With the controllers, the performer dynamically explores the magnetic board as organised by the composer in the strength, spatial distribution and orientation of the magnetic fields.

The primary function of the magnets is to generate the score's information through their interaction, but in order to further investigate the boundaries between scores and instruments, in the particular instance of the Magnetic Score described in this paper, we turned a number of magnets into sound sources. This feature was easily achieved by selecting magnets and ferromagnetic material of different shapes, and placing them inside wooden tracks and 3D printed boxes mounted underneath the magnetic board. Upon interaction with the controllers, the magnets move against the board, producing sounds that are captured by two piezoelectric sensors. The sound is then routed to a laptop for processing in combination with the data generated by the magnetic discs.

For this first iteration of the Magnetic Score we designed a 50 x 15cm bi-dimensional wooden board (Fig 2). No visual information is inscribed, and the performer relies on somatosensory feedback and sound in exploring the surface. For the sound generation we included two flat, rounded neodymium magnets for punctual, sharp sounds, a series of ferromagnetic spheres of different dimensions for drones of variable pitch, and two sets of small screws for high-pitch, dense clusters of sound.

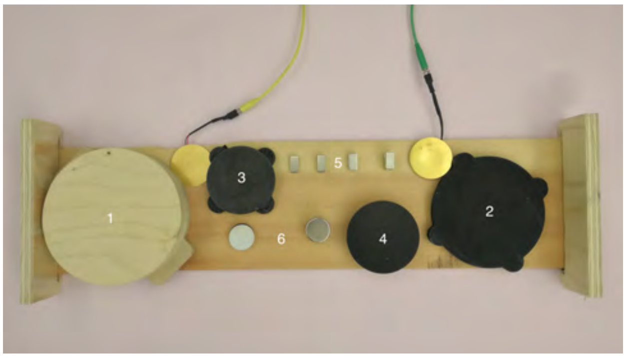


**Figure 2**. Magnetic Board's underside. 1-2 Ferromagnetic Marbles; 3-4 Ferromagnetic Screws and Marbles; 5-6 Magnets with Alternating Polarities.

### 3.2 Magnetic Discs

The *magnetic discs* (Fig. 3) are two 3D-printed, PLA cylindrical boxes. With a diameter of 10 cm and thickness of 2 cm, they mount a three-dimensional gyroscope and accelerometer, a three-dimensional magnetic sensor, one ESP32 microcontroller and a 1000 mAh battery. At the centre of the discs, a cavity hosts cylindrical magnets with a diameter of 3 cm. The magnets are loose within the discs, and are held in place by the performer's hand while holding the controller. When the magnet on a disc is approached to an external magnet with identical polarity, it moves and pushes on the performer's palm thus providing a proportional haptic response. At the same time, the resistance of the palm transfers the force of the magnet to the whole arm, thus influencing the performer's proprioceptive perception.

**Figure 3**. The Magnetic Discs.

Each disc wirelessly forwards to a laptop two data points: one relative to the xyz orientation of the device and one to the xyz strength of the magnetic field it is exposed to. Since the position of the disc and the orientation of the magnetic field are interrelated, the shape and orientation of the magnetic board allow to sensibly change the sound processing parameters. Interacting with a vertical score becomes therefore a very different experience than that of exploring a horizontal one, and curved surfaces allow to smoothly modulate in-between musical parameters.

As a consequence, further implementation of magnetic scores will extend the interaction design to larger and more articulated three dimensional artefacts, or even wider architectonic structures. This may be facilitated by the long-range wireless communication capabilities of the discs: through the *ESP-NOW* protocol, a dedicated wireless network is instantiated between the ESP32 microcontrollers mounted on the discs and a third ESP32 connected to the laptop's serial input and acting as a server. In an open space, the client devices can reach the server within a distance of 320 metres.[7] In addition, the flexibility of this protocol allows to add any number of client devices and even to instantiate parallel communication between them. This feature further expands the possible applications of the magnetic scores to large group performances and to different interaction modes.

Because the sensors transmit position-related data and no switches are embedded in the discs, the activation of specific behaviours at will is not easily achieved by the performer. We consider this as a feature of the system, which partially limits the performer's control and favours the emerging of the composer's intention. Nonetheless, in order to offer to the performer some agency over the individual dimensions, we leveraged the design features of the embedded magnetic sensor[8], whose axes individually saturate when the magnetic field is too close. The magnet's cavity is placed on the disc's lid two millimetres above the back of the sensor. Because of this, when the magnet is entirely inside the disc (i.e. no magnetic field of identical polarity is encountered or resisted) the z axis saturates, returning the maximum value regardless of the presence of an external magnetic field. When the performer encounters a magnet on the board with identical polarity and releases the palm's pressure on the disc, the disc's magnet moves away from the sensor, and the z axis starts reporting correct values. Through this, it becomes possible to momentarily activate the reading of at least two parameters (one for each of the discs) at will.

In this iteration of the Magnetic Score, the sound is provided by the magnets mounted on the board through piezoelectric sensors, and the data resulting from the interaction between the magnets, the performer and the space, is provided by the discs. The visualisation of the data and the sound processing are performed on a laptop. A Max/MSP patch (Fig. 5) returns visual feedback on the orientation of the two controllers, on the presence and position of a nearby magnetic field and on the magnetic sensor's z axis activation and measurements. Even though in performative scenarios we imagine the interaction with magnetic scores mainly as a somatosensory experience, the availability of a

[7] https://www.espressif.com/en/news/ESP-NOW
[8] https://www.adafruit.com/product/4022

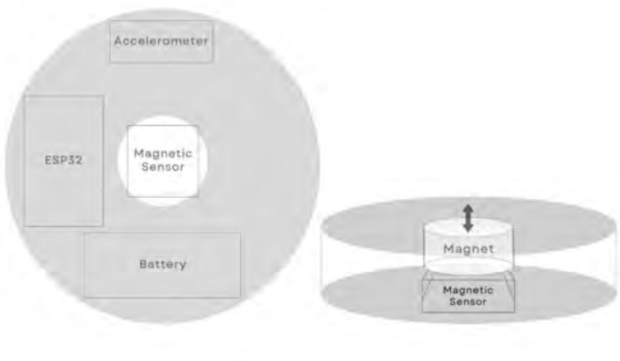


**Figure 4**. Magnetic Disc's Design.

real-time, three dimensional representation of the data has proven useful in calibrating the sensors and in describing the system to an audience, and might facilitate in the future the training of a performer or the application of machine learning algorithms for gesture recognition.

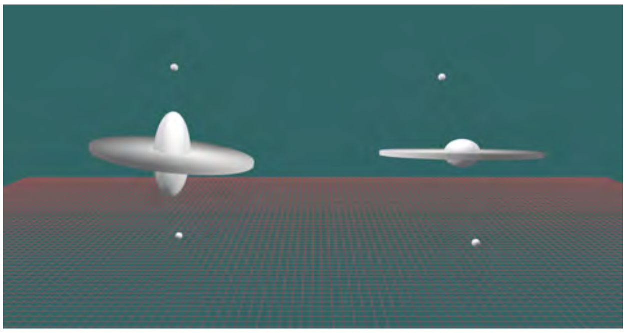

**Figure 5**. Magnetic Discs' Visualisation.

### 3.3 Sound Processing

In the occasion of the demo sessions described in section 5, we built a Max/MSP patch with a series of resonant filters, delay effects, and FM (with audio input as carrier) applied to the board's sounds conveyed through the two piezoelectric sensors in stereo configuration. The data forwarded to the laptop from the disc on the left and right hands is used to process respectively the left and right channels. The x and y values from the accelerometers define the centre frequency of the resonant filters and the x and y values from the magnetic sensors the amount of delay that is applied. Finally, the z value of the magnetic sensor, whose readings can be activated by approaching a field of identical polarity and releasing the pressure of the palm, activates and controls the amount of the frequency modulation. Future versions of the Magnetic Score will instead make use of Neural Synthesis [32]. By incorporating all of the sounds of the magnetic board within an AI synthesis model, thus separating the sound generation from the inscription layer, the encoding possibilities offered by the board's design will be highly extended, and new performative and compositional possibilities will become accessible.

## 4. PRESENTING THE MAGNETIC SCORE

We presented the Magnetic Score on two different occasions: a lecture with master's students in music composition and a discussion with a group of artists and researchers. During both events a demonstrative piece was performed.

In the first presentation, a prototype of the system was introduced to the participants and played by three of them, and a discussion followed. The initial comments centred around the possibility of designing different sound interactions: if the current version makes use of screws, spheres and magnets as sound sources, other designs might include boxes containing loose magnets and strings, or membranes and springs. The participants also suggested using multiple boards at once, each with a particular character defined by shape and interaction design, and to consider the possibility of extending the score to the whole room by embedding magnets inside double walls. The main limitation that emerged was the absence of a visual representation of the discs' position in space and in relation to nearby magnetic fields that could facilitate the initial understanding of the system. In response to this problem, we developed the Max/MSP patch described in 3.1, and presented it together with a more refined version of the Magnetic Score at the successive open event.

In the second session, the visual feedback was overall appreciated and helped clarify the relation between the discs and the surface. One participant noted that the magnetic discs could be separated from the rest of the system and independently explored as a musical instrument in their own right. The design of the discs is indeed articulated enough to generate complex interactions, and even though they do not unilaterally generate sound, the discs may be used to control a synthesis engine. Furthermore, mastering the control of the removable magnets inside each of them requires a good amount of practice, which makes them akin to traditional musical instruments.

During the discussion, a participant noted that when the element that generates the notation is the one that produces the sound, differentiating between the instrument and the score becomes a complex task. Even though the two concepts overlap in contemporary practices, a differentiation could still be observed in the amount of prescriptions that a system provides and in how they change in time. An instrument-score might be more akin to a score if it prescribes specific actions whose effects evolve in time, and more similar to a musical instrument if it provides a set of constraints for the performer to explore.

This final consideration is particularly useful in order to frame a reflection on the specificities of the Magnetic Score. In what ways this system may be seen as a score rather than a musical instrument? What is the experience of relating with magnetic fields as carriers of performative information? In the next chapter we explore magnetic scores as compositional system, focus on the somatosensory experience of the interaction, and frame them as a particular type of inherent score in which the inscription is relationally generated by the interaction of the magnetic fields.

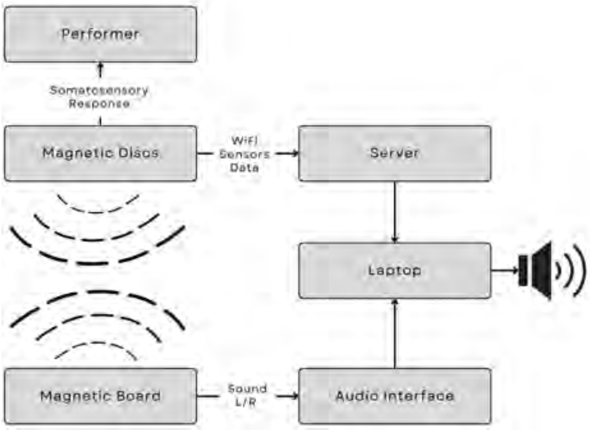


**Figure 6**. The Magnetic Score System.

## 5. DISCUSSION

As noted during the second public encounter, the overlapping of the instrument and the score is an apparent feature of this system. Because of the physical decoupling between the board and the two magnetic discs, it may be possible to interpret the Magnetic Score as an instrument (the board) being played with a device that excites it (the disc), similarly to a violin and a bow, a guitar and a pick, or a drum set and a drumstick interact. This is a useful metaphor in describing the generation of the sound in this particular instance of the system, but it does not take into account the variability of the mapping between the discs and the board and above all the articulated information that is possible to encode through the deliberate displacement of the magnets.

As explained above, the Magnetic Score is a compositional environment in which each board and mapping of the disc's parameters functions as an autonomous composition. By organising the invisible, attractive and repulsive forces embedded within, the composer guides the performer along the board. Similarly, by defining the mappings between the discs and the processing of the sound, it becomes possible to design the acoustic environment in which the interaction unfolds.

### 5.1 Magnetic Inscriptions

Composing a magnetic score appears as a very different experience than that of writing music on paper or other visual supports, as it requires to consider the performer's interactive, sensuous experience with the inscription. It also differs from engraving a tangible score in that, rather than focusing on fine tactility, it entails a more holistic interaction: the performer experiences the score as a force that dynamically pushes and pulls the arms, that unbalances the body, and through this produces specific gestures rather than suggesting them. By rehearsing the score, a performer learns to oppose the strength of the magnets, to follow them on the board, and internalises an abstract representation of the magnets' position and strength.

Through the size and positioning of the magnets, the composer can suggest specific gestures to the interpreter. In performing with the Magnetic Score, we realised that patterns of magnets with alternating polarities (such as in Fig. 2.3) suggest rapid movements over the board, as it becomes complex for the performer to operate with the discs. On the contrary, large magnets (see Fig. 2.7) are better suited for slow, vertical motions, as the magnetic fields interact with each other in a more predictable way. Loose magnets underneath the board are instead easier to control, and the performer's gestures tend to focus on the sound rather than on navigating the magnetic field.

We also realised that the granularity in the perception of the magnetic inscriptions is considerably lower than the one achievable through vision or direct tactility. As a consequence, in order to facilitate the recognition of magnetic patterns and avoid undesired interactions between the magnets, it is advised to use large surfaces as boards. By distancing the magnetic fields, the composer's intention can be interpreted more clearly, and it becomes possible to combine the magnets in order to inscribe simple shapes or symbols.

### 5.2 The Magnetic Score as Inherent Score

Because inherent scores combine inscriptions suggesting performative gestures with a device that generates the sound, we consider magnetic scores as an instance of this category. Nonetheless, the described system displays notable differences with other typologies of inherent scores, such as tangible scores and composed instruments, as well as similarities with situational practices such as event scores.

Typical tangible scores embed visual information on the surface of the instrument, and despite the overlapping of the score with the instrument in the act of performing, it is still possible to observe the sign from a distance, without interacting with it. Because no visual representation of the magnets is provided, and more broadly no information (except for the board's dimensions) is visually accessible to the performer, in the current version of the Magnetic Score the notation and the instrument further combine into an inextricable unity: in order to be read, the score has to be experienced as a holistic and sensuous encounter within the performative act.

Alternatively, the system may be observed from the perspective of composed instruments (as defined in 3.1). In magnetic scores, because of the interdependence between the controllers and the surface in generating the inscription, the mapping is not completely arbitrary as it would be expected on a composed instrument. Furthermore, even though we do not intend to generalise this feature to all magnetic scores, in this specific instance the gestural component is not decoupled from the sound generation, as the discs directly excite the loose magnets in order to generate the sounds. Nonetheless, through the processing techniques applied to the sound, the composer is capable of architecting time, which is a critical aspect of most music notation.

### 5.3 Relational Inscriptions

Magnetic scores also mutuate some of their features from event scores. As we have seen in 3.2, in numerous event scores the inscription is dynamically generated through the performers' interactions inside (and sometimes with) the performative space. The idea of the artwork as situationally emerging within the social context in which it is experienced, and out of the complexity of the relations between the people involved in its production and fruition, is at the centre of Bourriaud's relational aesthetics. From this stance, the aesthetic experience becomes a participative process that discursively generates the artwork.

This relational take is a key feature of the magnetic score's design. Rather than functioning one as an encoding and the other as a decoding component, both the board and the controllers have magnets embedded within. As a consequence, the readings of the magnetic fields that carry the inscription are the emergent result of their reciprocal interactions. Because of this, the score could not be considered as inscribed on the board alone, nor is it the unilateral result of the performer's action: it rather dynamically emerges as a series of events, or encounters, between the composer's ideas as inscribed through the displacement of the magnets, and the performer's exploration of the board with the magnetic discs.

Through this, the magnetic score invites the performer to become an active participant in the compositional process, and it does so at the inscription level, by translating the composer's and performer's intentions into a common somatosensory and sonic manifestation. This is a critical aspect to take into account during the compositional process: in designing the magnetic board, it becomes necessary to consider how the magnets' positioning suggests particular gestures to the performer, and how such gestures are affected by the shape, material and orientation of the board.

In this first iteration, we developed a rectangular board whose width is much greater than the height. This suggests a longitudinal exploration of the inscription and allows to operate symmetrically with each disc on one end. The mappings of the discs and the sound processing reflect this symmetry, as they control identical parameters, one on the left, and the other one on the right channel. Other pieces might instead explore asymmetrical mappings, in which one disc influences the parameters of the other. In such cases, the magnet's position and the board's shape might change accordingly, suggesting a whole different set of interactions.

## 6. FUTURE WORK

As observed by the participants in the evaluation sessions, the Magnetic Score may be further articulated in a variety of ways. In future pieces, it is our intention to increase the physical dimensions of the magnetic surface in order to embed more magnets and extend their distancing. By leveraging the portability and long communication range of the magnetic discs, we envisage to experiment with extended three dimensional surfaces as well as with architectural spaces such as entire rooms and buildings. In such situations, we wish to dig into the diffused character acquired by the musical score, and into the different subjectivities emerging out of the performers' embodied interaction with differently informed spaces.

We also envisage experimenting with additional inscription layers. Through transparent surface revealing the position of the magnets, or through symbols written on the magnetic board, the composer may be able to suggest more articulated interactions and to build upon the incidental relations emerging between the haptic and the visual domains. Additional inscriptions may be also generated by introducing materials that interact with the magnetic fields, such as ferromagnetic powder or ferrofluids. Through this, a dynamic representation layer would be introduced, thus combining the prescriptive nature of the magnetic score with a descriptive one and changing the grounding of the audience and of the performers in relation to the score.

Finally, we anticipate to further develop this system by coupling the permanent magnets embedded on the surface with a series of electromagnets whose polarities and strength are digitally controlled. This would allow to dynamically change the notation, and to introduce new agents in the form of generative algorithms. The information generated by the discs through the interaction with the electromagnets would in turn influence the system, thus instantiating a communication loop between the human performer and the computer. By introducing elements capable of exerting agency such as AI tools [33, 34] or artificial life simulations [35] as in Fig.7, and by exploring their embodied navigation, the roles of the performer and of the composer, the concepts of authorship and creativity and ultimately the cultural function of the musical score may be subject to further change.

**Figure 7**. *Ferroneural*, Jack Armitage and Nicola Privato.

## 7. CONCLUSIONS

In this paper we have presented the Magnetic Score, a system consisting of a surface with magnets mounted underneath, and two magnetic discs held by the performer. At the core of the Magnetic Score's compositional approach is the interaction between the magnetic fields of the discs with those of the magnets mounted on the board. Through this interaction, the score's inscriptions are generated as somatosensory feedback and interpreted as data for the processing of the sound.

We explored magnetic scores with the aim of reflecting upon the merger between score and instrument in contemporary musical practices from the perspective of systems that do not solely rely on graphic signs. We argued that magnetic scores are a subcategory of inherent scores that further merges information, sound generation and representation into an inextricable whole: in order to be read, the score has to be experienced.

We also argued that in magnetic scores the nature of the inscription is relational, in that it emerges from the interaction between the controllers held by the performer with the surface as designed by the composer, rather than being unilaterally inscribed. Because of this, the creative intention of the composer inextricably merges and overlaps with that of the performer, supporting the indeterminacy and openness of the modern artistic poetics as postulated by Eco, as well as the transitivity of the aesthetic experience as described by Bourriaud.

We believe that the magnetic score adds to the already pluralistic and heterogeneous nature of contemporary scores and notational practices, in that it explores them from the perspective of the embodied experience, by suggesting performative gestures through the reciprocal attraction and repulsion of the magnetic fields. In this paper we have presented a generalised overview of this system, and defined it as the combination of a bi-dimensional or tri-dimensional surface with embedded magnets, and two magnetic discs that decode the information. Nonetheless, specific instances can be as deterministic and prescribed as the composer desires.

By performing and presenting this system to an audience new research questions have arised: what new performative practices does the embodied, somatosensory manifestation of the score suggest? What types of information is it possible to convey through magnetic inscriptions? What other forms could magnetic scores take? Our intention is to release the hardware and software specifications of the system such that other people can build their own and contribute to the exploration of these questions.

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