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VR Open Scores: Scores as Inspiration for VR Scenarios

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ABSTRACT

In this paper, we introduce the concept of VR Open Scores: aleatoric score-based virtual scenarios where an aleatoric score is embedded in a virtual environment. This idea builds upon the notion of graphic scores and composed instrument, and apply them in a new context. Our proposal also explores possible parallels between open meaning in interaction design, and aleatoric score, conceptualized as Open Work by the Italian philosopher Umberto Eco. Our approach has two aims. The first aim is to create an environment where users can immerse themselves in the visual elements of a score while listening to the corresponding music. The second aim is to facilitate users to develop a personal relationship with both the system and the score. To achieve those aims, as a practical implementation of our proposed concept, we developed two immersive scenarios: a 360° video and an interactive space. We conclude presenting how our design aims were accomplished in the two scenarios, and describing positive and negative elements of our implementations.

Author Keywords

NIME, Musical Score, Virtual Reality

CCS Concepts

•**Applied computing** → **Sound and music computing;** •**Human-centered computing** → *HCI theory, concepts and models;*

1. INTRODUCTION

Scores have been a central element in the evolution of western music and their role has greatly evolved in the last century. Aleatoric scores, whose graphic and non-standard notations require to be interpreted and grant the performer(s) with a high degree of freedom in the interpretation, are a particularly relevant example of the evolution of scores that occurred in the last century. The aleatoric repertoire introduced a significant level of indeterminacy in the compositions, whose aesthetic and sonic features resulted to be open, and not clearly defined or determined in the notation itself [15]. Building on these characteristics, the Italian philosopher Umberto Eco proposed the term Open Work, highlighting that these compositions have an "ambiguous" notation that is subject to the free interpretation of the performer [8]. This conceptualization proposed by Eco, share similarities with some strategies adapted to interaction design to foster multiple and personal relationships with a digital artefact. For instance, "ambiguity" and "open interpretation" [22] in interaction design can be a resource to facilitate "personal engagement with systems" [9]. Open Works changed the traditional distinction of roles between composers and performers, providing the latest with much more agency as compared with traditional repertoire.

With the development of electronic music systems and Digital Musical Instruments (DMIs), the role of the score was, in some cases, subsumed in the design of the instrument itself, as the instrument embedded the characteristics of a piece of music [21, 14]. To play the piece, the performer can freely explore the "affordances of the instrument" [28] that, therefore, might play a role similar to the graphic notation in the aleatoric score. The distinction often blurred between instruments and musical pieces [14], as the instrument embodies the characteristics of the piece, and the notion of score becomes inherent to the system itself [28].

The relationship between music technology and score has mainly been investigated in performative scenarios with musicians as main users. We detect two opportunities for interactive technology and scores, to engage non-musicians. Firstly, the openness of aleatoric scores have the potential to engage non-musicians with avant-garde music, giving them more agency on a musical experience, and supporting the development of a personal meaning and interpretation. Secondly, the visual element of aleatoric scores has a potential for multi-sensory engagement in an interactive experience. Thirdly, the inherent relation that score can have with a piece of music technology could be translated to an entire environment to facilitate the first two possibilities. Virtual Reality (VR) appears to be a fruitful arena to explore these possibilities as it allows to "immerse" [25] the user in a multi

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sensorial experience and offers navigational possibilities that have been relatively unexplored in terms of scores.

In this paper, to explore the above mentioned possibilities, we propose the VR Open Score, a concept theorised by the first author: VR scenarios based on aleatoric scores. This proposal applies the identified inherent relation between scores and music technology to the design of a Virtual Reality (VR) scenario, to allow non-musicians to explore an aleatoric score. The aim of our proposed approach is twofold. The first aim is to create an environment where users can experience in the first person a score both in its acoustic and graphic features, by immersing themselves in the visual elements of the score and listen to the corresponding music. The second aim is to enable the users to develop a personal relation with the system and the piece, relying on the openness of the score. An important aspect of our proposal is that users of such a system can be non-musicians. As a practical example of our proposed concept we describe the implementation of two VR Open Score scenarios based on the score of Serenata Per Un Satellite (1970) by Bruno Maderna. We also present an initial user evaluation which aimed to assess the experience from the perspective of our two design aims, and to collect feedback about possible improvements.

The work presented in this paper contributes to the debate among the NIME community on the relation between score and technology, targeting non-musicians as possible users, as well as proposing a new paradigm to develop musical experiences in VR. This work also reflects on the relation between aleatoric score and ambiguity in design.

2. BACKGROUND

In this section, we begin by tracing the evolution of music notations, then we present new relationships that emerged between scores and new instruments, and discuss parallels between the indeterminacy of aleatoric scores and open interpretation in interaction design. We conclude by presenting related works that adopted VR for musical purposes.

2.1 From Traditional to Graphic Notation

Scores have played a central role in the development of the western musical tradition. For instance, Taruskin decided to begin his "History of Western Music" with the early forms of notation [26]. With the establishment of music printing during the Renaissance and the enhanced diffusion of musical scores, scores consolidated the social role of composers as authors [29]. Composers encoded a piece of music by using a music notation system that was quite standardised. Consequently, the piece could be re-performed at any time as its form was concluded and defined by the written score, which provided the performer with a quite detailed description of the final result of the music.

Among the avant-garde experimentations that emerged in the last century, aleatoric music composers developed a different use and function of scores, which no longer encoded the pieces in their final form, rather defined a set of possibilities among which the performer can choose. The performer was consequently required to have a high degree of invention, interpretation, and improvisation. This indeterminacy of form, typical of the aleatoric score, often relied on graphical elements fostering a "new and imaginative way of interpretation" [28]. Graphic notations had an impact on music technology practitioners and electroacoustic composers. In the digital domain, graphical notation have been used for screen scores as a form of "new media manuscript" [12]: a score whose graphical elements are changing in real-time, displayed on a screen.

2.2 Scores and Music Technology

With the development of new technology in the last century, the act of composing, in many cases, overlapped with the act of creating new technology. This tendency has been articulated by the composer and performer Gordon Mumma when he said: "I consider that my designing and building of circuits is really composing" (Mumma in [20], chapter 5). This approach had a primary role in transforming the conception and role of scores within the music technology practice. The composer Alvin Lucier, describing his work with the collective of composers/makers/performers Sonic Art Unions, wrote that "the scores were inherent to the circuits" [13]. These musicians extensively explored the musical and compositional potential of electronic circuits, and progressively abandoned musical notation. Performers explored the affordances of musical technological artefacts, rather than following the prescription notated on a piece of paper. Later, in the digital age, Schnell and Battier proposed the concept of Composed Instrument [21]: a musical artefact that embodies the notion of the score. Building on the idea of the composed instrument and inherent scores, Tomas developed Tangible Scores, that are a "physical representation of a musical piece" modified as an extra "layer" embedded in digital musical instrument [28]. Discussing his work, Tomas also refers to Cook's guideline, it is better to "make a piece, not an instrument" [5]. This guideline reinforces the idea that the score (as a representation of a piece) is inherent to an instrument, and the need of compositional thinking while designing a new musical artefact. Tomas further develops this approach with the idea of *musical instruments as scores*, as a hybrid approach between composing and designing [27]. Analyzing this trend, Magnusson proposed the idea that those DMIs that carry the notion of a score as well of an instrument are epistemic tools, as they are assemblages of software and hardware components, resulting in artefacts that carry the vision on how a specific piece of music could be thought and expressed [15].

2.3 Open Interpretation: Parallels Between HCI and Avant-Garde Music

Open Work (Opera Aperta) was a term proposed by Eco to describe art pieces whose final form is not entirely determined by the decision process of their creators [8]. In these art pieces, artists leave the arrangement of a number of the constituents of the piece itself open either to a performer, audience, or chance; thus not giving to the artwork a single definitive order but a multiplicity of possibilities. Eco included aleatoric music and graphic scores in this category, in particular, he analyses the work by many composers mainly operating at the Studio di Fonologia Di Milano (this includes Berio, Maderna, Boulez, Pousseur, Stockhausen). The author also explains that the openness of Open Works is due to their characteristic of being "ambiguous" and subjected to the interpretation of the performer, who is free to give his own meaning to the score [8].

In the last two decades, in what has been defined as third-wave HCI [3], computing started to spread from the workplace to various aspects of human life, including art and culture. One of the consequences of this change is that digital artefacts started to be designed with multiple possible purposes outside task-based interactions necessary in the workplace. Coincidentally, HCI literature adopted terms similar to those used to describe aleatoric music. For instance, Sengers and Gavers published a paper titled "Staying Open to Interpretation" proposing "that multiple, potentially competing interpretations [of interactive digital artefacts] can fruitfully co-exist" [22]. Appropriation of technology by

users, defined by Dix as "improvisations [...] around technology" [6], also started to be proposed as valuable aspects that could be considered to design interactive technology. Dourish proposed that, to foster appropriation, a designer should aim to support multiple perspectives on information [7] echoing the idea of ambiguity. Ambiguity was extensively studied from a design perspective by Gaver [9], who proposed three different categories of ambiguity: *ambiguity of information* if the information is presented ambiguously; *ambiguity of context*, different contexts give different meanings to technology; *ambiguity of relationship*, each user has a different relationship with a piece of technology. Comparing the terms and concepts, we argue that Open Work and open interpretation in interaction design might have several overlapping characteristics. As Bin and colleagues have pointed out [2], electronic music, and we add, experimental music in general, have adopted the concept of ambiguity and appropriation for a far more extended period than HCI.

Recently, a few studies in the domain of musical interfaces borrowed HCI concepts related to open interpretation. For instance, the work by Zappi and McPherson [31] proposed that multiple mapping dimensions is a good characteristic to achieve exploration and appropriation. Another example is that of Beatfield, an audio-visual installation using multimodal approaches where audio and visual elements have only a subtle and non-overexposed relation, to facilitate multiple interpretations of the artefact itself [18].

2.4 Music and Virtual Reality

Virtual Reality (VR) has been defined as "an immersive artificial environment experienced through technologically simulated sensory stimuli" [23]. In the last few years, VR has been explored as a design space for musical experiences. Specifically, a fruitful domain is represented by a new form of instruments: the Virtual Reality Musical Instruments (see [23, 24] for an extensive literature review). In other cases, VR is used to generate immersive visuals from sounds. For instance, Carey used spectral analysis to extract information from music and used the data to trigger the generation of objects in a virtual world, that could be experienced through Head Mounted Displays (HMDs) [4]. Another example is EAVE, an installation where the audio-visual content reproduced through an HMD is mediated by the data gathered through a brain-computer-interface [19]. To conclude, Zappi and colleagues relied on Mixed Reality to develop a performance where virtual objects and performers share the same stage and create audio-visual choreographies [30]. VR environments have emerged as a fruitful arena for experimentation, where a user can experience in a new immersive way audiovisual elements embedded in the surrounding environment. We support that aleatoric score can play the role of visuals in such a context.

3. VR OPEN SCORES

Based on the literature presented above, and following previous research by the first author about score and technology, this paper proposes the idea of VR Open Scores [16, 17]: aleatoric score-based virtual scenarios where the score is inherent to the virtual environment. This approach has two main aims: 1) allow the users to immerse themselves in the score, having the possibility to experience the visual graphic feature of the score directly, and 2) support the user to develop a personal relationship with, or interpretation of, both the score and the system.

By expanding the inherent score from the instrument to the environment, this research extends the work done with graphic scores (described in section 2.1) as it relies on a new type of technology to display a score, and furthers the debate on the relation between score and technology (described in section 2.2). Our approach also offers a new reflection on ambiguity in interaction design (described in section 2.3), as we explicitly aim to foster multiple interpretations in our user relying on the ambiguity of an existing Open Work. To conclude, this paper introduces a novel musical use of VR scenarios (section 2.4), and it constitutes a new paradigm to design musical experience in VR. The idea of VR Open Scores is also inspired by a recent proposal by Gurevich who suggests designing new music technology based on existing scores [10] and build upon the idea that one of the "implied goals of NIME is to place its practice in the trajectory of Western European music history" [11].

4. TWO VR OPEN SCORE SCENARIOS

In order to test our proposal, we designed and developed two VR Open Score scenarios. For both scenarios, we used the score of "Serenata Per Un Satellite" (1970) by Bruno Maderna, one of the composers operating at the Studio di Fonologia, whose practice was studied by Eco, leading to his proposed notion of Open Work. This score consists of only one page, with a number of concise musical elements notated on almost traditional pentagrams in different positions of the page. The composer indicates that the performer can reorganise the different elements in the order that she prefers, "improvising" but using the notes written on the page, without a prescribed length. Previously, this score has been discussed through the lenses of the design concepts of affordances and constraints. It has been discussed that visual affordances of the score facilitate free (gaze) exploration that is not bounded to linear prescriptions [17]. For these reasons, we decided to use this score for the design of our scenarios.

The two scenarios we developed are: a 360° video whose visual components are a frame with the score and visual cues that highlight the position of the element that is currently playing; and an interactive environment where the user can explore the different elements notated on the score, by choosing which one is playing. The two scenarios represent two different uses of VR technology and provide the user with different levels of agency. In the video the user can only decide where to look at, but this does not introduce changes in the system, while in the interactive scenario the user can select which part of the score is playing. We decided to design and develop two different scenarios with the same score, to 1) provide examples of how the same score could be adapted to more than one implementation, 2) test the same score with different level of agency. Moreover, the two scenarios are connected to the two design aims we propose with VR Open Score. The 360° video mainly reflects our first design aim, while the interactive scenario reflects both first and second aims.

4.1 VR Open Score - Scenario 1: 360° Video

In order to embed the graphical score in the video, we placed the visual score on a virtual sphere, resulting in an equirectangular image where the virtual sphere is unfolded (Figure 1). We created an audio file with a possible version of the score (4 minutes length); this audio was a solo version of the piece, with no overlapping of different elements of the score, rendered realised with a marimba sound by the first author of this paper, who has performed this piece in ensemble before. By merging the visual score with the audio, the different sound elements of the file were spatialized according to the position of the corresponding notated element in the score. To map the audio in the 3D space of the score, we used Cue Control [1], a tool that allows sound designers to

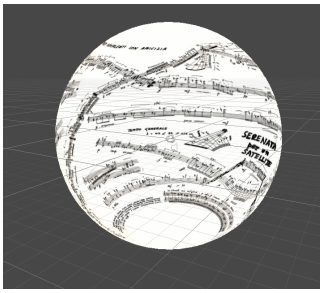

Figure 1: The score on the virtual sphere

spatially locate audio sources in a specific point. To create a connection between the score and the sound, we added a particle system that moves around following the location of the music and highlighting the notation of the different elements that are playing at each time. The resulting scenario was implemented in Unity 2018.2 and was experienced using a Samsung Galaxy S6 with a Gear VR as HMD.

4.2 VR Open Score - Scenario 2: Virtual Interactive Room

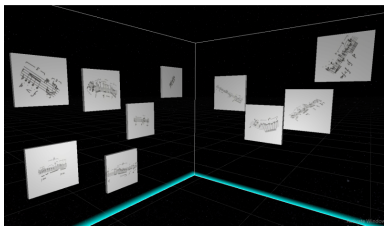

Figure 2: The virtual scenario from the user perspective

For the interactive scenario, we decomposed the original score separating each musical fragment. As criteria for separation of the musical fragments, we decided to cut a sample when 1) the pentagram ends, or 2) the direction of the pentagram changes. To organize these musical fragments, we adopted the paradigm of the art gallery, where the virtual environment would be represented by a room where the different elements are represented as paintings located on the walls, on the ceiling and on the floor. In terms of the implementation, the walls of this room were invisible and the musical fragments were planes textured with the original score, the position in the room was based on the original placement of the fragments on the page (Figure 2).

Users can interact with the elements of the systems by looking at the different objects (by raycasting the head direction to trigger the playback of the audio corresponding to the element whose score is textured on the plane). The music element corresponding to the targeted object will loop as long as the user is looking at it. When the user would stop looking at it, the file would play until it reached the end and stop. This allows for overlapping different fragments if the user moves fast from one to the other. This scenario was implemented in Unity 2019.2 and was experienced using a HTC Vive HMD.

5. EVALUATION

We evaluated the two scenarios with ten participants (7 female, 3 male), all non-musicians. The objective of this study was to evaluate if our implementation met the two design aims that we identified with the conceptualization of the VR Open Score: 1) create an environment where the user can experience a score both in its acoustic and graphic features in the first person by being immersed in the visual elements of the score and listening to the music, and 2) to help users developing a personal interpretation of the system while interacting with the score.

Participation was voluntary, and each participant signed a consent form. The evaluation took place in a room in our research lab. Before the test, participants were informed about the original piece and about the main functioning of the two environments. Each participant experienced both scenarios in a random order. The video lasted for four minutes, while the interactive scenario had no fixed length. At the end of both experiences, participants were interviewed. We adopted a semi-structured interview (e.g. *What is your impression about your experience? How did you approach the virtual space? What did you try to do? What was the aspect that you liked the more, or less? What would you improve?*). Interviews were recorded and analysed using a deductive approach, thereby coded according to three main themes: "Immersivity", "User Behaviour", "Design Suggestions". The first two themes relate to our two design aims, while the last theme aimed to understand positive and negative aspects highlighted by our participants, that could be useful for future implementations. Results are reported in the next section, direct quotes from participants have been anonymized (P.1-P.10).

5.1 Findings

Overall, our participants reported having a positive experience. Nine out of ten enjoyed both the video and the interactive scenario, seven preferred the interactive version, while two preferred the video. The tenth participant declared that she does not like VR in general, and felt discomfort wearing the HMD.

5.1.1 Immersivity

In general, our participants felt immersed in the score and appreciated the experience. For instance, P.8 referring to the video: "it was like the music is in the score and I was in the score", and P.4 referring to the interactive scenario: "I generally don't like this kind of music, but in this environment I liked it, the fact that I was immersed in the notation [...] was important". Based on this, we can speculate that the immersivity provided by VR has a fundamental and positive impact on the experience, and allowed the user to have a sense of being inside the score. This is related to our first design aim.

5.1.2 Behavioural Patterns

To test our second design aim, we clustered participant statements about how they approached and what they did in the scenarios. This analysis is inspired by the study by Morreale and colleagues about ambiguity in design [18]. We related different behavioural patterns to different interpretation of the system.

360° video: Our participants approached the 360° video in a quite homogeneous way. They aimed at following the "position" of the particle/music on the score, P.6: "I was following the sparkle on the notation and see how it matched the audio", P.1: "I was trying to follow the lights", P.3. "I liked following the notes".

Interactive Scenario: In the interactive scenario, we identified three main interpretations of the system that correspond to four different behavioural patterns.

The scenario as an instrument: participants used the scenario to **make music**. Two different approaches were based on the musical features of the fragments. *Mixing the*

fragments: a few participants wanted to create texture by overlapping different fragments (e.g. "[...] I was trying to mix them" P.1, "I tried to see if I could mix them" P.3. "I was trying to move fast to listen to all of them together" P.7) *Combining the fragments*: after a first exploration, two participants relied upon the sonic features to combine fragments that have similar or opposed musical features. P.1: "Toward the end I did try to check the different melodies, trying to see if by combining them it emerged something interesting". P.9 was aiming to play "the one that I found more interesting, probably the opposite like calm and then strong".

The scenario as an explorative environment: participants **explored the space**. Few participants explored the space by playing with the objects that were physically nearby, relying on the spatial location to explore the different objects P.1: "initially I tried to mix the objects that were nearby, randomly", P. 5 "have a few in front of me, and try to see if I can make them sound nice together". P.9: "I was trying to experience all things...I kind of started in one corner and pretty much circulated around".

The scenario as a memory game: participants used the scenario to **self-challenging their memory**. Users were exploring the scenario, trying to remember and recall the different samples. P.6: "it was more linked to the actual space, where they were located, I think that the shortest snippets were the easiest to memorise [...] I remembered more or less the sound of that square over there (indicating with his hand a position)". P3: "I was trying to [remember and] choose those that I liked the most".

5.1.3 Design Suggestions

To conclude, based on the evaluation of both scenarios, we propose the following refinements to the system.

360° video - For the 360° video: 1) **Increase the contrast** of the particle system or use a stronger colour to better highlight what is playing. (e.g. "It was not completely clear, it was a bit blurred" P.3). 2) **Reduce fast movements** changes in the "position" of the particle system (> 180°) to facilitate the visual tracking. 3) **Add a visual cue**, indicating the "position" of the particle/music on the score, when is outside of the current field of view. "It would need to have something that tells you where to turn your head" P.1. 4) Either decrease the length (around 3 minutes) or add more variety, in terms of different scores.

Interactive Scenario - For the Interactive Scenario: 1) Play with the **association of the object spatial positioning**, for instance, one participant particularly appreciated the fact that the sample on the floor had different musical characteristics. "At the end I discovered the one on the bottom, that sounded like I discovered the Bonus Track [...] it was a good idea put it there" P.1. 2) Add a **visual cue** to better provide feedback about where the viewpoint is or what is playing. "If there was small feedback about [...]this is playing, could be interesting" P.4. In terms of implementation this could be a marker showing the current gaze, or a halo around the square that is playing. 3) Add a **visual counter** showing the time remaining to the different sound samples "I would have like to have some kind of counter, that displays the length of each piece" P.1 "some kind of animation progressing with the sound" P.7.

6. DISCUSSION AND CONLUSION

In this paper, we presented VR Open Score: an aleatoric score-based VR environment. The idea of VR Open Score builds upon the literature about the relation between music technology and score [13, 21, 27], and extends it from a conceptual point of view and with a practical design study.

Our work builds upon recent literature that investigates the **relationship between score and music technology**, in particular on the idea that scores can be inherent to a piece of technology. This idea has emerged and was used to discuss the compositional nature of technology designed for performative contexts, with musicians as main users [13]. We applied this idea with a different technology, VR, that is currently unexplored from this perspective. Moreover, we shifted the target users: from musicians to non-musicians. As a "composed instrument" [21] incorporates the notion of a music piece, VR Open Score is a composed environment that represents and renders an aleatoric score on a virtual layer. Tomas discussed his Tangible Score as a "physical layer" of the instrument that embodies the notion of a score [27]. In VR Open Scores, the score is a virtual layer of the digital world, that plays both the role of being a graphical representation of the music and visually engaging the users. This work also expands the technological domains that have been explored with the screen scores [12], as it proposes VR as a new media to display graphic scores.

This paper also offers a practical example of how **Open Work** [8], and **open interpretation** [22, 6, 7, 9] can fruitfully coexist and how a digital artefact can exploit elements extrapolated from an aleatoric piece. In the interactive scenario, we observed a number of different behavioural patterns in our participants that correspond to different interpretations of the system. Comparing VR Open Scores to similar studies in the domain of musical interfaces [31, 18], our work introduces the idea of open interpretation in a digital artefact, borrowing directly from the intrinsic openness of an aleatoric score. Thus, our work offers a theoretical grounding and practical implementation to a precise exploration of the similarities between Open Works and open interpretation in interaction design. We argue that this parallel might pave the way toward more studies both in the area of musical VR applications and of musical instruments.

A contribution of this paper that can have a direct impact on the **design of VR scenarios**, is the proposal of VR Open Score as a novel design paradigm. As compared to other audiovisual experiences in VR [4, 19], our approach allows to incorporate existing aleatoric scores in the VR environment and therefore develop scenarios that are more connected to western music tradition [11]. The study we described, can be useful to researchers or practitioners who might want to develop similar scenarios.

From the implementation of the two scenarios and their evaluation, we learned two main lessons. Firstly, VR, in general, can facilitate users' immersion in a score, as users reported experiencing immersivity in both the video and in the interactive scenario. This finding supports our first design aim: to design an interactive artefact where a user can experience both the graphic elements of a score and the sound in a single immersive experience. We can, therefore, speculate that VR can be used to immerse a user in a score both in linear and interactive scenarios. Secondly, interactivity is required to foster multiple interpretations and behaviour in the users. This finding relates to our second aim: to facilitate users to develop a personal relationship with the system and the piece. Our findings highlight that different approaches emerged only in the interactive scenario, and not in the 360° video. Based on this finding, we suggest that some interaction is necessary to foster independent exploration and stimulate multiple meanings of the scenario for the users.

Future work might include the use of different aleatoric scores belonging to the avant-garde repertoire. We also envision to invite composers to create new pieces and environments using this approach. In the latter case, it would

be interesting to run through participatory design activities combining ideas generated by interaction designers and composers to redesign the interactive features of the environment, based on the need of the different pieces. This could lead to a fresh consideration of VR both as a design and as a compositional space.

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