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Chapter 24: Ecooperatic Music Game Theory

David Kanaga

dkanagamusic@gmail.com

ABSTRACT

Computer games can be approached as musical forms. Considered in this light, they operate at a number of scales that are typically considered hierarchically distinct, functioning at once as instrument, composition, notation, robotic musician(s), and ecosystem or 'total music space'. The totalizing image is central, as the marriage of musics with games presents us with the possibility of composing works as 'total artworks', *operatic toys* assembled from a diverse set of interactive and deterministic algorithmic components. This understanding of games is grounded in the concept of affordances as drawn from ecological psychology and explicitly contrasted with the totalizing psycho-social economism implied by game theory's rational agents. The purpose of this chapter is to attempt a description of computer games in such a way as to aid in conceptualizing a pluralistic ecological 'totality' vis-a-vis the computer game medium's essential musicality.

Keywords: computer games, opera, ecological psychology, game theory, computer game music

INTRODUCTION

The word ‘game’ is used in a very broad sense throughout this chapter, having as much to do with the intuitive free play of improvising musicians as with the strict rule-abiding and goal-bound rational play associated with the optimal strategy-functions, winners and losers of mathematical game theory. The word is used to mean “formalized play” of any sort. The chapter’s focus is on computer games as algorithmic musical forms, and the broad meaning of ‘game’ is adopted because computer games are not games in the game theorist’s formal sense; they are interactive objects of a much less specific sort, but nonetheless strictly formalized playspaces. When musical games are created without first recognizing that the economism of the goal-pursuing rational agent is not a necessary component of a game’s structure, the forms which emerge tend to limit the potential for player improvisation in overly controlling ways. An example is Rock Band, one of the most commercially successful musical computer games ever released. Despite its robust modular sampling system which allows multi-track stems of studio recordings to be re-combined piecemeal at run-time, the flexible improvisatory potential of this form is completely ignored. Every ‘off-note’ that otherwise could function as a ‘creative misreading’ of the original song and a goad to the expansion of the improvisatory imagination via strange material re-configurations, is instead reduced to a boolean ‘mistake.‘ The game imposes an economistic attitude on the player; instead of responding to off-note or off-time input by triggering sample-playback at the wrong time, or the wrong pitch, which would afford the player with a wide variety of spatio-temporal freedoms, it instead plays a scratchy ‘mistake’ sound effect, thus treating the player as a creature who needs to be told what to do-- an insubordinate laborer, or one of Pavlov's dogs-- this, as opposed to a musician with an individual voice and unquantifiable creative potential.

The breadth of computer games must not be thought to be limited in any way by game theoretical formalisms and definitions of games. The medium has the capacity to encompass and integrate *all playable forms*-- all interactive algorithms-- which computers are able to embody. This is a totalizing effect which requires different metaphors. The best may be the image of games as opera, following George Lewis' theorization of interactive computer music, writing that "interactivity suggests a new model for the gesamtkunstwerk, one which is wary of hubris and disinclined to overweening centralization strategies" (Lewis 2009). A musical approach to computer games, which deals not only with the sound of game, but with the totality of its form including the organic-mechanical conversation between human and machine, proceeds from an understanding of this sort. An opera achieves an integral synthesis of parts and wholes. The word is the plural of opus; it is translated from the Latin as works. Operatic form can be considered essentially pluralistic, the 'multi' in multi-media. This book you are holding contains descriptions of many algorithmic forms, and it is possible for one game to implement a synthetic ecosystem composed of just as many such diverse algorithms. "The many become one and are increased by one" (Whitehead 1978). Algorithms are combined freely in a game, like notes or themes in a piece of music. The many components which are combined to create a musical game can be explicitly musical or ostensibly 'non-musical.' They may be overtly playful (Sicart 2011), or apparently boring and utilitarian (Bogost 2007). One computer game might be synthesized from a Frankenstein-like patchwork of many instrumental "tool" mechanics borrowed from the likes of Ableton, Photoshop, Excel, Facebook, and so on; mixed in with "toy" mechanics modeled on bouncing balls, silly putty, and finger paints; situated in architectural spaces informed by cities, parks, wilderness; propelled forward by "narrative" mechanics modeled on chat-room bots, AI agents, artificial organisms, and so on. And such 'non-musical' texture in a game may be interwoven with musical algorithms which create playable form resembling the formal patterning and affordances of instruments like keyboards and flutes; or which resemble musical abstractions, such as serial twelve-tone rows and the circle of fifths; or which imitate structural invariances of compositional forms like Sonata-Allegro, fugue, and so on. These diverse forms may be combined into strange new hybrids, such as a keyboard that is cyclically transposed through the circle of fifths every time a note is played, and which automatically plays an orchestral accompaniment in a nightmarish Sonata-Allegro style, allowing for any note to be played from keyboard, instrumentation changing as time goes by, according to the proportions of that form, tempo determined in a constant flux by the relative density or sparseness of the keys pressed by the player. All of these forms and many more can be freely combined. With computer games, there are no strict lines between instruments, compositions, embodied theories, artificial musicians. Nor is there is a strict line between musical and non-musical games. Musical games simply magnify latent rhythmical-structural-harmonic-- and crucially, improvisatory-- tendencies existing in the temporal flows of 'non-musical' interactive forms at large. Much of the musical potential of games is to be found in a marriage of explicit musical form with supposed non-musical activity.

The remainder of this chapter is organized into two block sections which attempt to draw various connections between algorithmic patterning of musical and non-musical form in games. The first deals with particular practical and speculative strategies for composing interactive game music, dealing with a variety of specific situations in turn. The second is attempts to encapsulate games and music into a formal generalization which includes both as instances of a broader class of shifting possibility spaces, such that music and game forms may be studied as formal isomorphisms of one another, as played forms; it considers the ways in which this chapter's formalized musical approach to games contrasts with that of game theory, which has inspired composers such as Xenakis to regard games as essentially rule-bound, goal-pursuing structures; game theory's abstract economic approach is contrasted with a broader musical analysis' concrete ecological approach.

1. Music As A Tangible Process

In his book Audio-Vision, Michel Chion distinguishes between three modes of listening, one of which is intimately related to the experience of agency afforded by music games. He calls this mode causal listening, and defines it as "listening for the the purpose of gaining information about the sound's cause" (Chion 1994). A bouncing ball drops, bounces, rises, and repeats, and we hear the gradual accelerando of successive bounces speeding up to a buzz, illustrating the loss of potential energy and corresponding diminution of vertical height caused by each bounce. The Earth's gravity plays this piece with the material of the ball. Play is causal influence. Chion's account of causal listening allows listeners to identify players, as it were, but music games emphasize the first-person experience of a player's direct participation with a cause, implicating themselves as a listener+player in a cascading chain of causality-- music games allow players to kick the bouncing ball.

The process of composing music games is one of mapping musical parameters either directly or indirectly to free variables controlled by inputs, with which the player may tangibly affect the outcome of the music, in a fully real instance of causal influence. There are obviously many possible approaches to designing music games. The possibilities suggested by the choice of inputs alone (microphone, qwerty keyboard, mouse, MIDI keyboard, MIDI control change knobs, etc) is enough to fill many books. I would like to narrow the focus, then, and highlight two approaches to compositional form, where the first presupposes a "non-musical" game-space which becomes musical by way of its dynamic soundtrack, and where the second speculates as to the possibility of 'adapting' existing musical objects into games, in a process conceptually analogous to that of adapting books to screen, though mechanically very different.

1.1. Designing Soundtracks & Composing Games

For the first approach, we begin by assuming the existence of a game which is nearly complete but as yet has no sound added to it. This is our blank slate. Any sounds whatsoever can be added, and it is the job of composer and sound designer to decide how this is to be done. Composing a soundtrack, and designing its interactions to a degree, is the kind of work that a musician is most likely to be hired for in a collaborative game development setting. This topic is the subject of books such as Karen Collins' Game Sound (Collins 2013), and Winifred Phillips' A Composer's Guide to Game Music (Phillips 2014), which cover orthodox scoring and sound design practices in some detail, from those shared with film scoring to those simple dynamic processes which are native to the games medium.

The process of soundtracking can be as simple as putting a piece or sequence of background music in the game, but this will do little to make the music and activity of play feel causally related to one another. It will do little to take advantage of Chion's *synchresis*. The music can become more integrated with the nature of the game-play, however, if the composer first tunes into causal relations and rhythmic events existing in the algorithmic movements of the game as a visual and physical-tangible thing, and then treats these events as triggers in a musical space resembling a vast musical instrument which is performed in part by the player. In this latter approach, many of the grounding algorithms for composition, rhythmic and structural, can be understood to be provided by the game as ready-made. The game functions as a metric scaffolding upon which an open form musical composition is built.

For instance, in a game where the player is given the power to jump, a variable can be defined that measures the player's distance from the ground. This variable can, in theory, be attached to any musical parameter whatsoever, and its range scaled to map neatly onto the desired range of a musical effects. It could control the pitch of a simple oscillator or speed of an audio-file, mapped such as to create a loopy bend up and down when the player jumps and lands. Or, it could be attached to 2 (or more) virtual volume sliders, a and b, controlling several different looping audio files, such that when the player is 'on the ground,' file a, thick with bass tone, plays at 100%, and as the player approaches the top of the jump, a fades out to 0% as b, with a light floating texture, fades to 100%.

Alternately, in developing a score for this same jump, the distance from the ground could be ignored. The press which triggers the jump could at the same time trigger a single sounding event, with the ground collision of the landing yet triggering another, the way sound effects work. This event-triggering method could be made richer, and less repetitive, by triggering one event from an array of possible events, where the selected event is determined by the position of the player, or by the previous event played, or any number of other parameters. The event triggered need not be a single sound file. It might be a change in state of some more global aspect of the soundtrack. Consider, a map of harmonic interrelations like those explored in A Geometry of Music (Tymoczko 2011), could be used as a graph which the game moves through in a step-wise fashion, such that every time the player jumps, the accompanying music modulates around a rich harmonic space.

This approach can be thought of as a kind of ‘musical mimesis’, in that it mimics how objects in the physical world behave, making some amount of sound when interfered with. The traditionally differentiated tasks of ‘sound design’, the job of which is to mimic, and ‘composition’, with the job of making music-- are dissolved into a whole. In film scoring, this approach is called ‘mickey-mousing’, and it is often derided as a ludicrous over-scoring of the obvious. In a chapter on the bad habits of film composition, Adorno & Eisler deem musical mimicry an “unfortunate duplication” of what’s already obvious (Eisler & Adorno 1994). But this critique of mickey-mousing in the movies does not apply as sensibly to games, because games are tangle forms unlike movies. They are not wholly illusory in a causal sense, as with musical sound design, but indeed partially exemplify fully real causal relations between human and machine and have thus a tendency to become musical instruments, to a degree, the affective power of which musical mimesis greatly amplifies. Only when game events, both direct and indirect, are ‘mickey-moused’ do they actualize this innate tendency; otherwise they remain as ‘silent instruments’, akin to MIDI controllers which are not yet hooked up to control anything.

As a subset of the imitative musical space, we notice a fundamental distinction between game events which are directly caused by the player, such as the pressing of a button to jump, and those which the player only indirectly influences, such as vertical positioning after a jump. The latter indirect event is enabled by the player but is not directly caused by the player alone; it is just as much caused by the game's code which defines how high the jump reaches at its apex, and how long it takes to get there (how strong is gravity in relation to the player-object's 'weight'). The press resembles the directness of a musical instrument, while the partial autonomy of the rising and then falling y-position begins to resemble the mechanical determination of a linear composition. And then, there is yet another class of event that can drive musical change, that which is wholly uncaused and uninfluenced by the player. For instance, imagine our jumping player is set next to a jumping non-player-character (NPC), controlled by a simple random-walk style algorithm, who pays no need whatsoever to the player's activity. This NPC's jumps can be scored in any of the ways we have already discussed, triggering individual hits or driving continuous changes. This kind of event most resembles the mickey-mousing of movies, in that the player does not affect its outcome.

Now, each of methods discussed may be used on their own, or they may be combined. Combination may be accomplished simultaneously or sequentially. When used simultaneously, a jump would both trigger a one-off instantaneous musical event and also continuously trigger changes to the the musical parameter affected by the player's y-position. This has the effect of thickening the musical texture, or vertical aspect, of this compositional moment. When used sequentially, a jump might trigger instant sound effects in one room with no continuous recognition of jump height, and in a different room, silence this causal response, instead tracing a melodic line, with its frequency determined by the player's vertical y-position. This has the effect of adding to the variation of the game's horizontal musical structure. In this way, a composer can begin to think about games in terms of their musical texture and form.

Given the immensity of moving parts in many existing games, a visit from the spirit of Laplace's Demon may incline composers to try and attach musical parameters to all moving variables in a game, in order to fashion an ambitious mimicry of the causal richness of the real world. It is a sublime thought in its own way, but serious pursuit of this thankless task seems to me somewhat misguided. The goal of the composer may more profitably be directed toward emphasizing the musical effects of certain meaningful, relevant, or interesting activities at the expense of others, and creating a texture which approaches simplicity amidst the complexity of the total situation.

Rez and Electroplankton are two games which have been widely celebrated for their embrace of a musical approach to game design. Each emphasizes certain activities and musical forms at the expense of others.

Rez takes a familiar genre, the 'rail shooter', and quantizes its potential for rhythmic input and environmental movement to a 16th-note grid. The method of quantizing events to a grid has become a very common tactic for making something musical, having since been employed in the Bit.Trip games, the 'rhythm violence game' Thumper, and others. These grids are often static in the scale of quantization they use, settling for the 16th note, rarely venturing into triplet time, let alone polyrhythms, mixed meters, or changing tempos. There is much exciting room for the development of grid-based games which explore more varied and nuanced rhythmic palettes in addition to means of moving between palettes. An example of a more varied game-form in germ can be experienced by playing with a free variable attached to a knob controlling an arpeggiator which moves between quantization values of 1/4, 1/6, 1/8, 1/12, 1/16, 1/24, and so on, affording easy movement through a rich line of duple and triple time relationships. Such a 1-dimensional form could be made into a space with 2 dimensions by affording the player 1 further degree of freedom that would move by doubling or halving within duple time or triple time exclusively, such that at position [1/8], the player could move to [1/4] or [1/16] along this new axis, and at position [1/12], the player could move to [1/6] or [1/24]. Further dimensions of control could be added which allow a player to change tempos by relations such as [1/12 = 1/4], where the time in milliseconds of an eighth-note triplet in tempoA would be used as the time in quarter notes of tempoB. Creating a variety of relationships in this way, and mapping them to further dimensions of control could create a highly dynamic and intuitive rhythm-modulator. Such a space could be controlled using n knobs, where n is the number of dimensions of control available; or instead, these 'knobs' could exist in the background, not given immediate direct control to the player, but instead functioning as a compositional map which play could freely move through by way of influence rather than direct cause.

Electroplankton takes a different approach by modeling itself as a kind of 'album' of 10 mini-games, each a unique composition exploring a different algorithmic space. One of the more hypnotic games allows for the re-configuration of the leaves of a plant on which 'plankton' are being shot at and bounced off of, the spatial orientation of leaves changing the angle of the bounce and thus the speed of the plankton and the rhythm of the resulting music. Other mini-games are playful explorations of signal flow, DSP and other topics in computer music. This album format allows for a diversity of algorithmic processes, each compartmentalized so as to avoid interfering with others. But it is also possible to weave wildly disparate algorithms together into a new whole. Such is one interpretation of an ‘operatic’ approach to composing with algorithms, in the sense of opera’s combinatorial pluralism. Computer games which are not designed with a specific musical objective in mind are often structured in this way. An action-adventure game like those in the Zelda series combine a wide variety of processes: open-world spatial exploration with its varied psychogeographical moods; the rhythmic ballet of combat with its varied articulations according to which weapons are being used with which enemies; the mini-games which are playable in the towns; the structured side-quests that a player can take as an interruption of her main journey; the boss fights structured like ABACAD song-forms; and so on. Each of these components is not accessible from the main menu, as in an album of games, but is rather nested within a very complex topology which describes the connectedness of game forms, the ways one is able to move between mini-games. Such a topology serves as a map of the high-dimensional musical space, much like the meter of conventionally notated music, but existing in many potential dimensions with elastic temporalities instead of the merely one always-forward-moving time dimension of the classical score. Composers of musical games may eschew the narrative form of games like Zelda while still employing the kinds of labyrinthine topologies which a narrative world demands, and which affords interesting spatial relations and dependencies between musical forms. A global game form might be structured such that a certain musical mini-game is accessible only by playing a different mini-game up to a certain point, and then transitioning from this point into the new one. There might be games which are neighbors of one another, such that the player can move from one to the other rapidly and at will. The opening “Shrovetide Fair” scene of Stravinsky’s Petrushka is a simple example of how such a form might sound, hopping from one modular set of blocks to another, returning to the first for a shorter stint, and back to the other which has changed in the interim, and repeating this process with dozens of games in the neighborhood forming with one another a rhythmic mesh of patterned spatial relations.

The means of achieving interactive musical effects in computer games are readily available using many tools. Common ones include development engines such as Unity or Unreal, and interactive music 'middleware' engines such as Wwise and FMOD. These platforms allow for additional scripting, and some can be hacked so as to allow for integration of existing music programming languages which some computer musicians are already familiar with. In Unity, for instance, it is possible to integrate Pure Data patches into a game environment using open sound control such that any algorithms designed in Pd can imported into the game's codebase, 'attached' to game parameters, and played by the player. This effect was achieved by Henk Boom and Richard Flanagan in the game FRACT OSC. Possible approaches to the ambitious mode of 'Laplacian' sound design using Pd are richly illustrated by the myriad examples and theory of Andy Farnell's book Designing Sound (Farnell 2010), which focuses on procedural synthesis of natural processes, many ideas from which could be reapplied for more explicitly musical purposes.

1.2. Adapting Musics

Not only can game forms be treated as musical forms, but so too the roles can be reversed, and existing pieces of music can be studied as games. There are at least two ways in which any piece of music can be formally deconstructed in search of its play aspect. In the first, any composition (or otherwise fixed form) is studied as an imaginary play-through of a game which could have turned out differently. In the second, a performer is considered as the player of game, the rules of which are the instructions of the composition. The first privileges non-temporal or 'eternal' relations in the music, its informational content. A possibility space or game is inferred by imagining the formal-material conditions which gave rise, or theoretically could have given rise, to this particular state of affairs. The second privileges the various real-time contingencies which compositions afford a player by way of the incompleteness of their instructions, whether intentional or accidental. These two approaches identify, in turn, two different operant levels of freedom within a music space, which we can call composed freedom and performative freedom.

The first sort, composed freedom, is associated with the free play of fixed materials or 'constants' in a linear piece of music. Melodies dance, harmonies drift, rhythms shift, textures expand and contract, etc. These are all qualities which can be represented quantitatively. We find play in the variability of numbers. The pattern "1298887342346662727" *plays* more than the pattern "22222222." What is moving or varying in a piece of music is 'playing'-- these moments of variation are perhaps related to what James Tenney calls 'structural entropies' in his *META Meta-Hodos* (Tenney 2000). These do not represent the freedoms of actual time in its present-flow, but rather freedoms which have been expressed in the past and fixed in place. For instance, when I typed the two strings of numbers above, with the second string, I was determined to repeat the digit '2', the only freedom I allowed myself being how many times to repeat it; whereas, with the first string, I was not sure what I would type, and was free to bang out something quite randomly. But an account of my particular subjective experience is not required to qualify the first as more free; the freedom is embodied in the pattern. Composed freedoms are 'memories' of the past which have been frozen or fossilized into place. They are the material repercussions of events which have solidified into *objective* forms. Works of art are objective manifestations of past freedoms in this way. It is not possible to recover the exact ‘game’ which produced these artworks, but projects such as David Cope’s *Experiments in Musical Intelligence* attempt a kind of reverse-engineering of this sort, recreating from an ensemble of fixed objects, a more generalized possibility space which, when *played*, either by a human operator or a random number generator, is capable of triggering events such that not only the original object might be created, but also any number of other ‘sibling’ objects, seeded by the same genes, but having played and grown up differently (Cope 2001). Cope’s EMI does not allow for real-time play with the games which have been ‘inferred’, but we can see that they could be. For instance, imagine a computer game hooked up to a MIDI keyboard that affords a simple freedom to that player. Any key can be pressed, and this note will immediately be harmonized in the style of the composer-module being used and in the context of what has already been played, and this event will trigger a cascade of automatic material composed in the appropriate style, and in appropriate response to the player’s disturbance. This interaction could be afforded at the down-beat of every measure, with the automatic play of the game holding a fermata on the final notes of each measure until the player triggered the next harmonic space. Or, more interestingly, the game could perform continuously and automatically all while listening for interruptions from the player, who is free to provide monophonic input at any point. This game would resemble some chimeric hybrid of the original composer’s style with the patterns offered by the player. It would surely be ugly by some standards, but this ugliness would be worth trying to understand and love. It is likely only by pushing through such barriers of ugliness and apparently profane re-interpretations of fixed masterworks that a new kind of beauty might be discovered in this form of adaptation.

The second sort, performative freedom, rather more resembles the kind we have been discussing, concerning the free play of 'free variables', those values which the composition does not fix, and which are left indeterminate up to the moment of performance, being decided by a player of some sort. It is impossible that everything in a composition be made constant. Even a strictly notated piece by Bach might not specify tempo or dynamics, or instrumentation, and the performer can play freely with these variables. The guidelines of a collective improvisation offer a looser example. Even if the 'rules' have not been written down as a score that we can study, the invariant form of such a game can be intuited by listening to two different takes of an recording of loose compositional form, like "Enter, Evening" by Cecil Taylor or "Ascension" by John Coltrane, and analyzing what remains constant between the two performances amidst the flux of the improvisation. This *constancy* is the game, whereas the performance variability is the *play*. All music is played to one degree or another. Even a recording, supposedly as fixed as an Platonic Form, can *in performance* be played on cheap computer speakers at a low volume or on a massive car stereo, and the listener can choose which and where. Further, the listener, can treat the recording itself as playspace, clicking around on an mp3 player's track-timeline in order to remix it freely on the spot, or, if it is being played on a vinyl record, slowing and speeding up and reversing playback to turn it into a raw material for 'scratching.' This kind of relation in which the variability of music is dominant is described in Bruce Benson's musical phenomenology, which considers all engagement with music to be essentially improvisatory (Benson 2003), in Christopher Small's concept of 'musicking' (Small 1998), which likewise describes music as always an active process, and others. It is an approach which takes on utopian musickal hues in Adam Harper's imagining the next millenium of musicking (Harper 2011), and in Jacques Attali's 'age of composition' (Attali 1985).

Composers such as Iannis Xenakis and John Zorn are notable for having worked with free forms which they consciously regarded as games, as with Xenakis' Duel and Strategie, and Zorn's Cobra and others from his series of game pieces from the late 1970s. These works afford performative freedoms at the same time that they embody composed freedoms which performances are constrained by. And, though they may not call their works 'games', a much broader spectrum of composers, too, can be understood to already work with the properties of game forms we are concerned with, and indeed computer games in particular, without calling them such. George Lewis describes a game-like composition of his as follows: "In Voyager, improvisors engage in dialogue with a computer-driven, interactive 'virtual improvising orchestra.' A computer program analyzes aspects of a human improvisor's performance in real time, using that analysis to guide an automatic composition (or, if you will, improvisation) program that generates both complex responses to the musician's playing and independent behavior that arises from its own internal processes" (Lewis 2000).

Improvised musics performed with computers such as *Voyager* are, taking a broad view of things, *already* computer games which are simply not mass-distributed, which are only playable by one or several musicians who have access to the software. An alternate history of computer games is awaiting articulation by way of the 20th century's musical history, specifically in the interplay of its improvised musics and algorithmic techniques. In light of this, it would seem that the attention paid to widespread *distribution* and *accessibility* are as important as any in determining the popular conception of a piece of software as being a musical game. It may be that the process of ‘composing computer games’ is simply to compose music in ways similar to how it’s already being composed, but to distribute it in such a way as to make clear that it is not a *recording* or a *performance* which is considered the final relation between composer and listener, but rather it is the *game* which is the final relation between composer and listener, or, what is more accurate, composer and player. A major aid in establishing this relation is providing the listener with software that ‘just works’, that does not require expertise of any sort to set up, as is the case with, say, a pure data patch; playing a game should be as accessible as reading a book or putting on a record. In seeking such accessibility, there is an implied aesthetic turn away from the demand for professionalism from a performer in interpreting a composition, in favor of celebrating musical amateurism-- this, in both the negative sense signifying a somewhat lazy dilettantism as well as the positive sense of its etymology, meaning lover. Both laziness and love affirmed.

In this embrace of the listener-cum-amateur-player, computer games propose a solution to what is not quite a *problem* in computer music, but which can nevertheless be a persistent source of tension and occasional angst-- a problem which we might call *process opacity,* which is characterized by the *causal listener* (in Chion’s sense) becoming alienated by way of not being able to identify a sound’s cause. Non-electronic folk musics, as a counterexample, have an appealing transparency of process. Most listeners are at least loosely familiar with the means of producing vocal song, and many are familiar with the means of producing percussive music and guitar strums, such that listening causally to these forms naturally evokes an imaginary environment in which the listener is virtually *playing them*. But computer music’s tapestries of pinched sounds, impulse pops, stochastic clouds, granular storms and FFT freakouts are often perceived merely as special effects to non-acclimated ears, sometimes enjoyed, and ever moreso when there is visible body-movement of some sort connected to the sound-making process, but not yet fully appreciated as the embodied, down-to-earth folksy, haptic constructions that they can be from the first-person point of view of the musicians involved in creating them, in tweaking the knobs or otherwise engaging the interface that translates bodily movement into these strange sounds. For an experience of transparency with computer music, there must be some intimacy with the material cause of the sounds. Process-centric computer music is all-too-often felt to be impenetrable from the perspective of mainstream audiences, who have not spent time patching worlds together in Max/MSP or even cutting sounds up in a simple audio editor. Many listeners become dismayed to find themselves at a laptop concert, if there is not some visual ornamentation of some sort happening, or ideally a body moving in such a way as to demonstrate causal influence over the sounds. Understanding the means by which a given sound is created is a key to feelinng meaning in that sound, and most people today are not familiar with computer musics' varied and intricate means of production.

Working directly with computer games as a musical medium offers the composer the possibility of designing forms in such a way that a direct causal experience play or *touch* is established as the default relation between the 'audience' and the piece. Critically, this approach aims to distribute such compositions to listeners (players) on a mass scale, serving a potentially (though by no means necessarily) democratizing purpose for interactive algorithmic music which is analogous to the purpose that recordings or take-home piano scores serve for a piece of linear music.

2. Formalized Games

2.1. Shifting Possibility Spaces

The analog of the timeline form of a linear composition (embodied equally in recordings and classical scores) is the general structure of an n-dimensional possibility space, the sort of form in which indeterminate activity happens. The rules of a game and the rules of correct voice-leading over a cantus firmus and the material constraints of a saxophone are all equally exemplary of the sorts of mechanical-algorithmic atoms that give rise to this generalized concept.

The notion of a possibility space is one which is by no means native to music or game thinking. An inkling of the form is intuitively entertained in the most mundane circumstances of everyday life whenever we are confronted with a decision point, a branching pathway, physical or mental. It is felt in a more hazy sense when we look at a distant landscape, for instance, and imagine ourselves there, or imagine the lives of whomever is presently there. The sense of possibility is poetic and vague before it becomes formal and narrow. Its formal conceptualization can be described using mathematics.

The formal idea of a possibility space is already present in the simplest instance of a logical-mathematical variable. An algebraic expression is an example of a highly formalized and very simple possibility space. If we write $3 < x < 6$, then we know that x lies somewhere between 3 and 6, but we do not know where. This simple expression describes a 1-dimensional possibility space, having only 1 free variable. An algebraic equation like $x + y + z = 10$ relates three variables to one another, but does not determine their value, it only determines the relational space of possible values. The number of variables are called the 'degrees of freedom' of the space, and the number of degrees of freedom in a given space establishes its dimensionality. Considered as a totality, the possibility space is an N-dimensional geometrical form, or manifold, but a space with its dimensions 'extending' into abstract dimensions of logico-mathematical possibility as opposed to the 3 spatial dimensions of our physical spacetime. The applications which bridge the continuum between logical-metaphysical form and the materialism of everyday life is filled in by the natural sciences, and to this end, Manuel DeLanda catalogs and describes a series of natural possibility spaces in his book Philosophy and Simulation (DeLanda 2011).

Game designers often speak in this way about the totalizing 'possibility space' of a game, in the same way a music theorist might speak of a piece's Form (e.g. Sonata-Allegro, fugue), but what is lost in this global analysis, especially in the case of musical games, is an acknowledgment of the temporal flux of shifting possibilities, based on the contingent value of what is possible for a player at a given moment. *Playing* is a process of moving through possibility spaces. Considered locally, the experience of a possibility space is not that of a solid object but rather of a morphing form, with shifting presences and absences of free variables corresponding to shifts of local dimensionality.

The complexity theorist Stuart Kauffman uses the concept of 'adjacent possibility' to describe the movement organisms in their environments (Kauffman 2000). This is a useful approach to thinking about game play in general, which opposes the universalizing tendency to think of a possibility space zoomed all the way out, as an object. The adjacent possible is simply the set of whatever is within the immediate sphere of possible moves afforded to the player. To return to our algebraic example, $3 < x < 6$, a player might be afforded the capacity to determine the precise value of x, first by selecting a value between 3 and 6, and second by adding or subtracting 0.1 to this value. Thus, if the player starts at $x = 3.5$, there are two adjacent possible values which could be moved to next, 3.4 and 3.6. If, on the other hand, the player were allowed to move by intervals of 0.1, 0.5 or 1, then the set of adjacent possibles would triple accordingly. Notice that in these examples, the infinite holding capacity of the real number line is now off limits, because the player is not afforded the means of determining a value with infinite precision.

The dimensionality of a local adjacent possible is characterized by its degrees of freedom, the value of which shifts with time. These can be controlled by players operating at a variety of hierarchical levels. One player can control many degrees of freedom, like one body controlling ten fingers dancing across a piano's keyboard, or one player might only control a single degree of freedom, such as a determining the value of a single x variable by way of a MIDI control change slider. We can think of our body as one player, or we can think of it as many players (joints, muscles, nutrition, hydration, etc.). A piano can be played by one player or by a rotating cast of many players. A player with a piano can become one with the instrument by way of her intimacy with it. The process of individuating a 'player' is a matter of chunking several or many parts together at different scales and counting them as units with freedom. In perhaps the most abstract sense, a logical free variable itself can be thought to represent an atomic 'player' of a metaphysical sort.

The 'dimensionality' of freedoms in our everyday lives is incomprehensible, approaching and perhaps actualizing some kind of infinity, or at least indefinable largeness. The human skeleton alone has several hundred joints and these are only scratching the surface of the freedoms of the human experience. Besides, it is not the singular body alone that accounts for our freedoms. A human body tied to a tree or otherwise disabled does not benefit from those several hundred freedoms. Our freedoms are always afforded by our body's relation to other bodies, other humans, non-human animals, plants, inorganic materials -- houses, neighborhoods, social groups, musical instruments, games and so on.

2.2. Formalized Computer Games

When software is run on a computer, the activity of the whole functions as a body, which is strictly determinate in some sense, always following the rules according to its algorithmic form. However, when a computer listens for input from a player, even though it has been instructed to do so, it thus invites indeterminism into its body. Computer games are distinct from non-interactive algorithmic forms in that they are composed both of modules which are deterministic (as is the exclusive case of non-game algorithms) as well as those which are non-deterministic, affording varying degrees of freedom to a player.

The precise dual form of determined versus free algorithms was defined by Alan Turing at the advent of modern computing as follows:

> If at each stage the motion of a machine [...] is completely determined by the configuration, we shall call the machine an "automatic machine" (or a-machine). For some purposes we might use machines (choice machines or c-machines) whose motion is only partially determined by the configuration [...]. When such a machine reaches one of these ambiguous configurations, it cannot go on until some arbitrary choice has been made by an external operator." (Turing 1936)

A computer game is formally built of both a-machines and c-machines, with the a-machines forming the deterministic boundaries which enclose the playing field, and the c-machines opening up the space of possibilities which allow for play enclosed by these boundaries.

A player's freedoms ripple throughout the formal space of the game's logic by way of the presence of at least one free variable x attached to a formal c-machine on one end and a physical input device such as a MIDI controller or keyboard or mouse or microphone on the another. A c-machine's x value may be controlled or "played" by another algorithm, such as a random number generator, thus producing a generative artwork, as in the stochastic process music of Cage, Xenakis, et. al, but an x variable means something very different in the hands of a human operator than it does in the hands of a random number generator. Meaning emerges from the process of touching the x-variable, and this process is fundamentally a bodily one which is not reducible to an algorithmic form in the way a machine's processes are. The human is an organic component of the indefinably complex biosphere, an animal in her environment, before she is a 'computing mind' or, as game theorists and neoclassical economists would insist, a 'rational agent.' The relationship formed between human and computer allows for filtered echoes of the biosphere to enter into the x values of the machine's indeterminate configurations. As Marc Leman describes it: "If the human body and mediation technology are hooked into each other, then it is possible to conceive the digital domain as a natural extension of the physical domain. The human mind will then extend its activity range to this digital environment in a natural way" (Leman 2008).

A computer game is not just a hunk of dead formal code. When it is running, it is a half-living thing, a material-energetic creature with sense organs and conceptual movements and expressions analogous to those of an organism. Its sensory inputs-- buttons, knobs, joysticks-- correspond to an animal's eyes, ears, mouth. Its expressive outputs-- flashing lights, vibrations, pulsing sounds-- correspond to organic song, dance, speech. And its internal algorithmic architecture in general corresponding to a creature's guts, skeleton, musculature, nervous system, and so on. When we play a computer game, we become the 'environment' which this machine-organism lives 'within.' The output of our play provides the inputs or sense-data for the game, what it 'knows' of its external world, a bizarre inversion of the classical human-centric empiricism in which sensory experience inscribes ideas onto our mental tabula rasa. We become the machine's environment. This, at the same time that we 'immerse' ourselves in the software, allowing it to become our own environment. The relation of organism to environment is parallel to that of the relation between player and playspace.

2.3. Ecological and Economic Games

Such an image of games evokes a theoretical approach to the medium which is radically different from that of game theory, with its reductive psychological economism assuming that players improvise in efficiency-obsessed, rational, ways, and whose founders described it as "the proper instrument with which to develop a theory of economic behavior" (Von Neumann & Morgenstern 1953). Thus, whereas musical works like Xenakis' game theory-inspired compositions Duel and Strategie are characterized by payoff functions resembling those of goal-oriented competitions amenable to game theoretical analysis like chess or basketball, computer games have a more general relation to algorithms, one which does not ask of them whether they are more or less optimal or efficient, which rather accepts all algorithms for what they are, as raw materials, musical players rhythmically churning their patterned textures forward through time.

In Xenakis' language, a game of this sort is called a "false" or degenerate game, "one in which the parties play arbitrarily following a more or less improvised route, without any conditioning for conflict, and therefore without any new compositional argument" (Xenakis 1971). For Xenakis, a "true" game is one in which the players, too, become algorithmic, submitting themselves to a "compositional argument" and performing optimally in its defense, like a cook following the dictates of a recipe, hoping to make it exactly as advertised. But this chapter has mostly concerned the "degenerate" game form which has no expectations as to what the player should be doing. In a computer game, the deterministic content is provided by the machine, there is no need to employ the player with a given job.

The relation of the player to the machine and the machine's algorithms in relation to one another as parts and in relation to their collective environmental totality is the subject matter of a non-game-theoretical 'theory of games' which has a musical quality and which is rather more ecological than economical. In the sense that the human player is never truly beholden to any particular task by the machine, an ecological approach to games is better suited than the economism of game theory to deal with the particular materiality of computer game form.

This contrast of economic and ecological form can perhaps begin to differentiate the properties of an apparent dualism at the heart of all game form, computer and otherwise, and including musical works in general. This is that there are two distinctly different sorts of constraints on player movement which establish the boundaries of a game-- (1) Rules, which are abstract, immaterial, non-actual instructions for operating on material things; and (2) Forces, which are concrete, material-energetic, actual, the things themselves.We can call the first sort of constraint ‘economic’ and the second sort of constraint ‘ecological’. Computer games are manifestations of economical rules being transmuted into ecological force.

The root of both “eco-” words, οἶκος, is Greek for ‘household’, where economy can be translated to ‘rule of the household’, and where ecology can be translated to ‘ground of the household’. If, for the sake of example, all games are considered as a kind of ‘playing house’, then economics deals with the abstract legal guidelines managing the expected and allowable behaviors in this house such as chores and regulations and optimizations of dishwashing, and ecology deals with the concrete energetic actualities which are impossible to change without forcing a radical transformation of material conditions, actualities such as water temperature, gravity holding furniture to the ground, musculature which allows house-members to stand and walk, lightness or darkness of rooms, and so on.

Musically speaking, instruments function as ‘ecological games’, or energetic forces, in that they do not insist on a particular mode of interfacing with them, even if professionalization does demand such rule-based interfacing, or economizing. Performative compositions, on the other hand, function as ‘economic games’, being as they are a set of notated or otherwise pre-stated rules that the laboring duo of musician+instrument must subject themselves to in order to work in accordance with the composer’s intentions and in harmony with the trajectory of the musical ensemble as a whole. While game theory provides a robust analytical tool kit for for interrogating economic forms of the relation between a rational player and games like chess and warfare, the ecological aspect of games, the raw energetic relations of influence and resonance between organism and playspace/environment, is much less studied in the context of games.

Throughout this essay, the word 'afford' has been often used, in the sense of 'makes possible.' The theory of affordances, borrowed from the aptly-named discipline of ecological psychology and popularized in many design communities, can serve to bridge the patterns of physical energies to their fluxes and invariances as experienced from the first-person perspective of the organism, serving as a grounding for an ecological theory of games. James Gibson describes the concept thus: "The *affordances* of the environment are what it *offers* the animal, what it *provides* or *furnishes,* either for good or for ill. The verb *to afford* is found in the dictionary, but the noun *affordance* is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complimentarily of the animal and the environment" (Gibson 2014). When an animal touches anything in its environment, for instance a squirrel holding an acorn, or a dog swimming in a lake, the relations of between toucher and touched such as 'holding' or 'swimming' are illustrative of the what it means for an environment to afford some activity, to open up a space of possibilities. In the case of computer games, all mechanical interactivity within the game space is afforded, as described in the previous section, by Turing c-machine modules connected to input devices. The concept of affordance can help us treat these inputs and choice-machines in a way that does justice both the objectivity of the space of possibilities and the player, and crucially, to the relationship between the two.

2.4. Operaism

One of the most compelling aspects of Gibson's ecological psychology is its dissolution of subjectivity and objectivity: "an affordance is neither an objective property or a subjective property; or it is both if you like. An affordance cuts across the dichotomy of subjective-objective and helps us to understand its inadequacy [...] It is both physical and psychical, yet neither" (ibid.). Following from this subject-object dissolution, ecological psychology points toward, if it does not explictly adopt, a speculative panexperiential or panpsychist cosmology (Whitehead 1978), the hypothesis that everything has an experience or 'mentality.' Regardless of the legitimacy of this perspective, it seems to me to offer a pragmatic stance for creative work, affording more potently strange and enchanted mindset from which to engage with computational materials than that of the game theorist's ceaseless striving for efficiency and its associated positivist metaphysic which views computer algorithms as just rules. For the panpsychist, the computational material is allowed to live in its own inorganic way, as 'vibrant matter' (Bennett 2010), becoming a half-living collaborator in our work and play. The algorithm is not reduced to its abstract rules, but is regarded as a concrete creature participating in the world amongst other creatures-- playing, working.

Returning to the concept of opera-- works-- it takes on the hues of a natural philosophy. In an apparent inversion of Vedanta Hinduism's concept of lila, the divine play-aspect of the world, we begin to regard everything as aesthetic work. The world is an opera, or many operas; opera is what happens. The laborer works, the musician looks for a job. "Because energy can move we may harness and channel it to do work [...] Work is a change of energy, also measured in Joules. So, another definition of energy is the ability to do work. It can cause things to get hotter, or move things, or emit light and radio waves. One way it can move is as sound, so sound can be thought of as changing energy" (Farnell 2010). Sokal and Bricmont would scoff predictably at any fuzziness of scalar reference which treated labor and thermodynamic work and opera within one breath as all of a kind, but other sources such as Darwin, Marx, Wagner (Barzun 1958) are correct to identify a field of relations shared between ecological, economic, and musical thought. Indeed, as described in Georgescu-Roegen's work on ecological economics (Georgescu-Roegen 1971), the physicist's conception of work itself is a product of its economic times -- the steam engine and its objectification of what had prior been the province of labor-power, horse-power. And so, too, computer game theories exert an economic influence in relation to work. This is seen in both the spheres of "gamification" (McGonigal 2011, Eyal and Hoover 2014), which attempts to convince laborers to happily perform otherwise boring tasks by couching them in addictive game mechanics, as well as that of automation, which attempts to dispense with the laborer altogether, by converting an already-mechanical task which once required organic labor-power into pure mechanism, in a process analogous to the way in which a chess computer game automates the upholding of the rules such that what were contingent on an implicit contract between players agreeing to play by a shared value-system has become enforced by way of the ecological affordances which resist any change to this contract.

It should be emphasized that 'ecological' form cannot by any means be equated with 'good', and 'economic' with 'bad.' Ecological form resists freedoms at the same time as it affords them. Crucially, economies of music, the directed jobs/goals of players, ought not be ignored to the degree which I've largely been guilty of throughout this essay, supposing as I have that the player has been free to do as she pleases. Though I disagree with Xenakis' description of un-directed playforms as "degenerate games", there is admittedly a sense in which the ostensible apolitical stance of free play-- no goals-- meshes with the 'anything goes' philosophy of the anarcho-capitalist/libertarian corporatism which has risen to ideological prominence during the same years as those which compose the history of computer games. Free play, free markets:

“There is no alternative.” There is something degenerate indeed about the freedom implied by this perspective! It ought to be asked in what ways a musical “compositional argument” in Xenakis’ language could help aid in conceptualizing and implementing in musical microcosm a good economy. Algorithmic automation used to allow economists to dream of a future with no work. Keynes speculated in 1930 as to the character of life once ‘the economic problem’ had been solved: “for the first time since his creation man will be faced with his real, his permanent problem-how to use his freedom from pressing economic cares, how to occupy the leisure, which science and compound interest will have won for him, to live wisely and agreeably and well.” Though a contemporary dream may not look just like Keynes’, it seems that this quest for leisure, for the positive freedom which arises from being able to work as a choice and not forced by necessity, is one with continued relevance, and one intimately related to games and the question of whether we are playing the game or working it as a “playborer” (Biggs 2010). In the face of all of this, a musical approach to games considers an alternative way to conceptualize what it means to be a game. It is a small gesture, but one which may have something to contribute by way of dealing explicitly with many of the materials and concepts which must be engaged with in even the larger questions-- economies, ecologies, freedoms, possibilities, necessities, work, play, and so on.

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