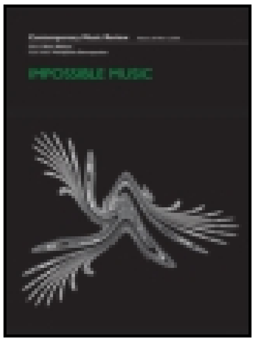

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# The Suitability of Genetic Algorithms for Musical Composition

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# The Suitability of Genetic Algorithms for Musical Composition

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This article is concerned with investigating some aspects of the usefulness of using genetic algorithms (GAs) for musical composition and to highlight some of their limitations. It also demonstrates the limited amount of work done so far in examining the output of GAs used in creative applications, rather than simply describing the architecture and functionality of such an algorithm, and the limited scope of work that has been undertaken. The article examines some approaches in musicology and composition that may help us to understand further how GAs could be applied to creative music tasks, and presents the *IndagoSonus* system as one possible application.

KEYWORDS: evolutionary musicology, musical composition, generative music, genetic algorithms, composition

## I. Introduction

This article does not attempt to present a survey of previous work concerning composition and GAs (see Burton and Vladimirova 1999 for a good overview). Nor do we cover what a GA is or how it works; any number of publications will cover this basic material (e.g. Mitchell 1996). We are concerned with investigating some aspects of the usefulness and difficulties of using GAs for musical composition, and to look to musical and musicological examples to help us understand this.

GAs are part of a larger group of algorithms in artificial intelligence (AI) research concerned with search processes. So, before we investigate any particular features of GAs that make them more or less useful in creative exploration, it makes sense to start off with a discussion of what part *search* plays in *human* creative processes, and particularly, given the title of this article, musical composition.

## II. Creative Search Processes

A commonly used compositional process, perhaps the most fundamental compositional process of all, may be described as taking an existing musical idea and changing it in some way to produce a new, but related, idea. Musicians in various styles and genres may follow the process differently, some through improvisation, others through pencil and paper. Indeed, the form the overall piece takes may itself be a reflection and revelation of this organic process of change, or it may be constructed with quite different structural notions. Nevertheless, suggesting that

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– the shaping of musical ideas from an existing starting point by a process of incremental directed change may be seen as a common low-level compositional activity – is likely to be an uncontroversial assertion.

This process of musical shaping and exploration may further be seen as a process of *searching* a musical space containing all potential options, as described by Biles:

> As with most problem solving activities, musical tasks like composition, arranging and improvisation involve a great deal of search . . . Certainly, the notion of 'right' is individual, but a typical musician 'knows what she likes', and the aesthetic sense guides the search through the various problem spaces of notes, chords, or voicings. (Biles 1994)

But as suggested above, and highlighted by Cohen, such a search process is not a random series of events: ". . . creativity is not a random walk in a space of interesting possibilities, but . . . directed" (Cohen 2002: 59).

So, we now have a concept of a key compositional process being to some degree analogous with *searching* for solutions, and that this search is somehow *directed*.

## III. Types of Computer Search and the Potential of Genetic Algorithms

### *III.i. Traditional Search Mechanisms*

Search processes have been a core part of AI research since the subject's foundation, both as a lower-level cognition process and an activity in its own right.

Many different mechanisms have been developed, but traditional search processes explore a problem or search spaces viewed as a tree structure, and are broadly split into depth-first and breadth-first approaches. Whereas a depth-first search searches down to the end of a single pathway before trying an alternative starting point, a breadth-first approach follows all available options until the next decision point is reached. If a solution exists, depth-first is sure to find it, but may not be the best solution. Breadth-first is generally better at finding the solution with the least number of steps.

Heuristics may be added to search mechanisms to improve the likelihood of finding an appropriate solution. The role of the heuristic is to *limit* the size of the search space being charted by the algorithm. The better the heuristic the more likely the search is to find a good solution. But it is important to realize that the nature of the search process is very determined by the heuristics used and can result in an over restricted space.

Even with the restrictions of heuristic search it is still possible to see how such a tool may benefit a human creative in finding points in a search space that may otherwise be missed, even by the designer of the heuristics used. Human search processes may be influenced not just by desired heuristics, or by exploring an insightful new direction, but also by unconscious habit and other patterns of behaviour. A heuristic search mechanism may help break free of such constraints and find new acceptable solutions. But heuristics are limiting; that is what they are designed to do. Too broad a heuristic and the search space can become too large to traverse; too small and the chance of finding a new, unexpected but acceptable, solution is severely reduced.

There is another problem with traditional computer search techniques.

Generally a search process in AI is akin to optimization. So, even if creative exploration has a similarity of process to searching, can the aims of composers, who as a group are not usually happy to accept the most efficient solution over the most interesting, be met by mechanisms primarily devised for optimization?

As the discussion of heuristics suggests, the key here is how the direction of the search is controlled. We have previously seen the search as a series of related incremental steps, which reflect a directed pathway through a musical space. If interesting pathways and solutions are to be found, the key is likely to be the way in which the search is directed.

This is where the power of a GA over other more traditional searches becomes apparent.

### *III.ii. The Advantages and Challenges of GAs*

*III.ii.1. GAs Map Human Exploration Processes*. Goldberg, a prominent figure in the development of GAs and their applications, proposes that the two key processes of GAs, mutation and recombination (or crossover) together with selection, form a basis for innovation that closely reflects the way in which human innovation takes place: "Selection + Mutation = Continual Improvement. Selection + Recombination = Innovation" (Goldberg 2002).

The notion of *continual improvement* does seem to find resonance with the search for a satisfactory creative solution, and *innovation* has an obvious role. Karl Sims is well known for his images produced by repeatedly selecting the best members from an evolved population, to the point where a satisfactory image is reached (Sims 1991). It is certainly easy to see this as *continually improving* the images by guiding the evolution to successful conclusion. So GAs are looking promising, at least in terms of overcoming the restriction of heuristics. But *continually improving* also creates a resonance that reveals GAs origins in optimization.

Bentley (2000) points out that a creative search activity is more akin to *exploration*, and regards optimization and exploration as fundamentally different activities, largely rejecting or at least severely limiting, the potential usefulness of optimization in creative activity.

> Optimisation: . . . The goal is to find a global or near global optimum with minimal computation. Exploration: The goal is to identify new and interesting solutions – normally more than one is desirable - and these solutions must be good. However, finding global optima may be undesirable, impractical or even impossible. (Bentley 2000)

This distinction is useful, and reflects my previous comments on the problem of optimization processes and creative search. But is it as clearly separated as Bentley suggests? A number of composers seem to believe that although they may be exploring a space, they are gradually improving an idea to the point that it is *correct*. By *correct*, we do not mean merely interesting or satisfactory, but in a musical sense *optimal*. So perhaps optimization may have a place in the toolbox of composer.

In any case, Bentley regards GAs as a useful tool for creative *exploration* as well as *optimization*, for many reasons, not least the fact that they are less fussy about direction than a heuristic search. So it seems that whether optimization is a useful creative process or not, GAs provide an advantage over previous search mechanisms.

A composer is certainly able to use a GA to help shape a musical idea in the same manner as Sims, whether we take the model of continual improvement, or exploration. Another possibility, and the primary focus of the remainder of this article, is to view the pathway travelled between two musical points as significant in its own right. This model is even less concerned with continual improvement and more about creating an interesting series of connected and related ideas.

*III.ii.2. The Fitness Function Problem.* A keyword in this article is directed with regard to search processes. GAs do appear to be more useful than traditional search techniques in replicating selected aspects of creative tasks, but we still have not answered the question of *how* they are to be directed down pathways of interest.

In a GA, many factors effect this: the genotype (i.e. the representation, or code), phenotype (i.e. the phenomenon being coded) and mapping between the two; the mutation and crossover mechanisms; and parameters such as population size, etc. However, one GA aspect stands out as being the single most important consideration in directing GA exploration: *the fitness function*.

It is no surprise then to find that much of the literature concerning GAs and art/music applications has focused on how to define the fitness function: how do we select what is best from a population. In a musical application, how can we define what is good music?

Traditionally there are two ways of measuring fitness.

1. *Use a human critic to make the selection – an interactive genetic algorithm (IGA)*: this requires an individual to use all the real world knowledge they possess to make decisions as to which population members should be promoted into the next generation.
2. *Automatic fitness assessment (AFA)*: this means encoding sufficient knowledge into the system to make fitness assessment automatic after each mutation and crossover process.

The problem with using an IGA is the time taken to make assessments, first described by Biles (1994) as the *fitness bottleneck*. This describes the difficulty in trying to assess many possible musical solutions due to the temporal nature of the medium. The benefit, however, is that we are not required to develop a formal rules base. We escape the fitness bottleneck with AFA, but face the daunting task of encoding the essence of the music we want to encourage.

Although coded fitness measures of various types have been extensively used in creative GAs, they are generally relatively easier to define in a *design* context, such as engineering or architecture, and more difficult to determine in a pure aesthetic situation, such as creative musical composition. As Bentley (2000) points out, "Designers and architects still remain at the forefront of this area of research". This is very likely because such areas have a strong element of *function* in the assessment that makes fitness relatively easier to define.

Of course, even in design context functionality maybe malleable. We might start designing a lamp to find that we have evolved away the ability to illuminate, but instead developed a different function. The new function would probably be seen as a new measure of fitness, but is still, nevertheless, a function.

Bentley (2000) points out that, "To date there has been no significant research aimed at understanding the difference between exploration and optimization." We would agree, and the reliance on so few sources in this section of the article reflects this, but would add that even less work has been done on identifying the different *types* of exploration, and in what ways they differ. Simply relying on instinct concerning similarity or difference is not sufficient, and more work is necessary.

Music and art (depending on the type of music and art, of course) most often have different aims to design, and coded fitness functions generally work best here in two types of situation.

In the first situation. We might have a "code-able" new and original aesthetic in mind that we want to try. Tim Blackwell's *Swarm Music* is good example of finding new musical directions through algorithmic processes (Blackwell 2003); and Eduardo Miranda's *CAMUS* system is a successful model of music based on Cellular Automata (Miranda 2003). Here the creative act is in the codification of fitness, along with other aspects of the algorithm, and we are exploring new musical shores through a definable measure. GAs are certainly a good choice for this type of exploration, over and above heuristic search, for the reasons previously outlined. This avenue may of course lead to wonderful new pieces of artistic output, but it is important to be clear that the success or otherwise of the application becomes an aesthetic judgment, and is not measurably successful in terms meaningful to current computer or cognitive science. Bentley (2000) states that, "My own work in this area continues, as I use evolution to compose music that cannot be distinguished from human compositions." But we have to ask if this is an appropriate measure of success. If a piece of music is under investigation within the musical academic community it would be usual to explore it in some detail using analytical techniques or approaches, and to discuss its place within a wider musical and cultural setting. The work produced by computer code has to stand on its own musical feet, and be judged like any other. In short, in situations where we cannot define the success of a solution in a scientific manner the task ceases to be primarily one of computer science and shifts to the domain of the solution space. It is not enough for computer scientists to claim success in their work, and stop short of a valid explanation in terms of the relevant domain methods. Here we appeal for music analysts, aestheticians, and creativity researchers to take up the challenge.

In the second situation 2, we may be recreating an existing style where the rules and/or grammars are sufficiently known. Biles's *GenJam* is a good example of this (Biles 1994). It is clear that in many of the most successful attempts to compose using GAs, the details of the implemented algorithms are often made domain specific in an attempt to produce acceptable output by modelling human processes. Indeed, in the most recent incarnation of *GenJam*, the mutation operators are considered sufficiently musical to dispense with fitness measures entirely. In such cases, we may be looking to achieve objective validation of a given set of rules, as well as other aspects of the algorithm, by providing compositional output as a test, in effect asking: How good are my rules? Examples of this work include the work of Wiggins and colleagues where the output is designed to be assessable first-year undergraduate harmony exercises, an aim that may be seen as principally a musicological or music-analytical task (Wiggins *et al.* 1998).

For other approaches (which probably encompasses most art composers working today), pure coded fitness measures are likely to be restrictive or inappropriate. This leaves us with IGAs, and the fitness bottleneck.

> These applications raise numerous human–computer-interfacing issues . . . [such] software tools have been shown to aid imagination and creativity, but how best to let the user inform evolution of his/her preferences and how best for the computer to report the structure and contents of the space being explored? Clearly, further research is required to address these issues. (Bentley 2000)

At the end of this paper we briefly describe the *IndagoSonus* system, which is designed to address the problem of the fitness bottleneck.

*III.ii.3. Bottom-up and Top-Down.* Most musical applications of GAs tend to focus on evolving only small-scale short phrases. This is understandably an easier task than tackling larger-scale formal issues, in part due to the technical challenges, but also due to the musical knowledge and compositional experience necessary to tackle such tasks. In some ways this reflects the common early stage in the learning path of many undergraduate music composition students.

Often the overall piece becomes a collection of such small-scale phrases and may be considered a "bottom-up" way of composing larger-scale pieces. For a more complete description of bottom-up versus top-down composition methods and systems, see Miranda's (2001) book *Composing Music with Computers*. In many cases, especially music based on artificial life, this is exactly the compositional aesthetic, with large-scale form being seen as an outcome of the emergent behaviour of smaller elements. Sometimes it is simply a restriction of the system.

Composing with a top-down approach is less common, certainly with GAs, but it is clear that human composers will most often operate on many levels, top-down, bottom-up and shades in between, often simultaneously, when structuring a piece. Simulating this multi-view approach is a key challenge if GAs are to model human compositional processes.

Having discussed directed search processes we are now able to examine the usefulness and appropriateness of using GAs within a conventional musical context.

## IV. Inspiration and Hard Work: What Use Are Genetic Algorithms?

Two distinct modes in which composers create have been defined as *inspiration* (or genius) and *hard work*. The possibilities inherent in composition programs to replicate the two modes have been succinctly summarized by Jacob:

> In short, creativity comes in two flavors: genius and hard work. While the former may produce more "inspired" music, we do not fully understand it and therefore have a slim chance of reproducing it. The latter resembles an iterative algorithm that attempts to achieve some optimal function of merit, and is therefore more easily realizable as a computer program. (Jacob 1996: 158)

The hard work aspect of musical composition referred to by Jacob seems to resonate with the view of at least some aspects of composition as a search process. But is inspiration so different?

It is, at least, open to question the extent to which some types of compositional inspiration can also be replicated, given the possibility that the hard work too can lie behind the end product and is capable of being uncovered, even though its existence may have been confined to its creator's unconscious rather than in the form of notated sketches. Such a perspective would allow that inspiration might also be a process of directed search.

This was one of the premises that underpinned Hans Keller's *Functional Wordless Analysis*. From 1957 to 1978, Keller produced fourteen wordless analyses of musical works, in which analytical intermezzos were inserted between movements or sections of pieces, mostly from the classical repertoire, in order to demonstrate hidden unity or continuity lying behind apparently contrasting material. This was intended to produce a new kind of analysis free of technical jargon that so often impeded aural understanding, in order to reinstate the listening ear as the sole judge of the validity of what was uncovered (Keller 1994). The intention is to perform the analyses in conjunction with the complete works being analysed without a single word being uttered from the beginning to the end of the process. The techniques used by Keller on the original music in the composed analytical intermezzos are broadly similar to the following mutational operations described by Todd and Werner, discussing the work of Biles: "During the breeding phrase as well, Biles introduces more musical structure: He uses 'musically meaningful mutation' operators such as reverse, invert, transpose, and sort notes, rather than the usual blind random-replacement mutation of standard genetic algorithms" (Werner and Todd 1998: 322).

Keller performed similar operations on an opening musical idea in order to fill in the gaps by means of which the apparently contrasting second idea was linked. A simple example (figure 1), taken from *Music Analysis* (Wintle 1986) will illustrate one of the less complex types of thematic links uncovered by Keller (the note-enclosing boxes have been added by the authors).

A connection is made between the apparently contrasting first and second movements of Haydn's *Lark Quartet* (Op. 64, No. 5). The four notes that form bar 2 of the example are first transposed up an octave and then the first three of these notes are reduced to a quarter of their original durational value to become the up-beat to a phrase of the second movement, which starts with the fourth note. For reasons of space, we give the simplest possible example of Keller's work. More complex examples abound, but the basic transformational techniques remain the same, although applied in a more concentrated fashion, analogous to Horner and Goldberg's thematic bridging: ". . . if the thematic patterns are dissimilar and the bridge duration is short, relatively high-level operations may be needed to bring off the transformation" (Horner and Goldberg 1991).

This transformation of a motif in the example, probably unconscious in Haydn's case, may well be akin to inspiration, but there is no intrinsic reason why the process may not be replicated by hard work undertaken by a domain-knowledge-rich GA.

This has distinct but related implications both for musical analysis and composition. A GA dedicated to the uncovering of thematic, motivic, rhythmic or harmonic continuity would be trained in whatever compositional syntax lay behind the work to be analysed; the start and end points would be established and by a process of incremental change, the intermediary steps (or hard work) could be uncovered. Although a high degree of stylistic assimilation on the part of the program would be required this is by no means an impossible task.

Its possible applications for the composer would, of course, vary according to the individual creative character. As Jacob (1996: 160) comments: "The more closely we can model our creative processes, the more the computer becomes a simple tool for artistic creation, and less a replacement for inspiration."

First, let us examine the case of a motivically minded composer, whose aesthetic


**Figure 1**
**Musical example of Keller's functional analysis.**

demands that ideas, however superficially contrasted, must be in some audible fashion related. The capabilities of various GA-based systems for generating such material from an initial cell, or motif, have already been widely discussed (Horner and Goldberg 1991). Here, a slightly different scenario is proposed. The composer creates two contrasting ideas, satisfactory in themselves but with no apparent relationship. Placed at either end of a goal-directed GA cycle, the program could uncover any number of intermediary steps or routes by which the one could lead to the other. This may either suggest material that could be incorporated into the composition to link the two ideas, making connections that were previously only latent manifest, or that the program may simply serve to satisfy the composer's motivic conscience! The latter is by no means as fanciful a notion as it might first appear as the experience of Arnold Schoenberg with his *Chamber Symphony,* Opus 9 illustrates:

After I had completed the work I worried very much about the apparent absence of any relationship between the two themes. Directed only by my sense of form and the stream of ideas, I had not asked such questions while composing; but, as is usual with me, doubts arose as soon as I had finished. They went so far that I had already raised the sword for the kill, taken the red pencil of the censor to cross out the theme b. Fortunately, I stood by my inspiration and ignored these mental tortures. About twenty years later I saw the true relationship. It is of such a complicated nature that I doubt whether any composer would have cared deliberately to construct a theme in this way; but our subconscious does it involuntarily. (Schoenberg 1975: 222–223)

Application of a GA-based program could well have saved Schoenberg a mental torture or two had one been available to him! This type of motivic thinking is closely allied with a bottom-up approach, as discussed earlier, in that it is primarily concerned with developing musically related ideas. But what about using GAs for top-down composition?

Although the type of motivic thinking exemplified in the work of Haydn and Schoenberg was central to western art-music for most of the Baroque, Classical and Romantic periods, its supremacy became increasingly challenged as the twentieth century progressed. The next application must therefore concern itself with a composer operating with a diametrically opposed aesthetic. In a composing career that saw many apparently drastic changes in style and idiom, one constant trait pervades every stage in the creative life of Igor Stravinsky. After completing a traditional training under Rimsky Korsakov, at no point did he evince in his music the slightest interest in traditional organic development of musical ideas or motifs. Much of his work may be characterized as the juxtaposition of contrasting blocks of sound with no intimation that any one block "develops" from the other. Such a description is a gross simplification of a complex musical language but is enough to characterize an aesthetic far removed from organicism. The distinction between Schoenberg and Stravinsky might also be characterized in Boden's (1999) terms as T-creative (transformational creativity) and E-creative (exploratory creativity).

Of what use to such a creative type as Stravinsky could a computer program based on genetic mutation of an initial idea be? The problem is more apparent than real as the underlying assumption of the question is that the mutation of ideas represents a goal-directed narrative structure, albeit in embryonic form, rather than its alternative potentiality as a generator of possible ideas than could be selected and used in any order.

Stravinsky's juxtaposed but unconnected ideas as exemplified in a work such as Symphonies of Wind Instruments never reappear in an identical form in the course of the work. The processes by which Stravinsky changes them have been analysed by Joseph Straus as pattern completion, rather than traditional development: "Pattern-completion thus consists of two fundamental aspects: (a) establishment of a single collection-type or pattern as the normative structural unit for a composition and (b) exploitation of the listener's desire for the completion of that unit" (Straus 1982: 107).

The initial idea in the section of Symphonies of Wind Instruments discussed by Straus is a simple rising tetrachord, in this case, E♭-F-G-A♭. It is used both horizontally and vertically and may be inverted or transposed. More than one version of it may appear simultaneously. Because its use is so all-pervasive in the section, the presence of just three out of its four components creates an expectation of the fourth, analogous to the sense of closure achieved by a perfect cadence in tonal music. Stravinsky arrived at the many permutations of the tetrachord empirically but it would not be beyond the bounds of present possibility for a GA-based program to produce similar permutations, particularly if there were a facility for superimposing or "mixing and matching" the results. As Jacob (1996: 164) remarked: "The computer is far better suited to performing routine functions repeatedly than a human is so it is appropriate to assign the task of generating all possible variations to the computer."

If programmers were attempting to produce pastiche Stravinsky, fairly strict melodic, harmonic, rhythmic and timbral fitness functions would need to be imposed, but if they were simply exploring the potentialities of the tetrachord, with or without its full complement of members, the only restrictions need be the extent to which they might wish to limit the infinite permutations that would result.

This is perhaps the most challenging problem facing the designer of a GA-based composition program, whether for general use or tailored to one particular set of preferences. The past decade and more has shown that a GA has no difficulty in replicating a composer in hard-work mode but without the most stringently defined search space, an unmanageably large amount of potential material, mostly unusable, is apt to be produced. As discussed earlier, Biles (1994) has described this situation as the fitness bottleneck. However, if the search space is too strictly defined, the unexpected and interesting permutation, which is what all the hard work is supposed to uncover may not emerge at all: "More structure and knowledge built into the system means more reasonably structured musical output; less structure and knowledge in the system means more novel, unexpected output, but also more unstructured musical chaff" (Werner and Todd 1998: 315).

## V. The *IndagoSonus* System

The *IndagoSonus* system is designed to answer two key problems:

1. The fitness bottleneck problem, with its associated Human Computer Interaction (HCI) issues.
2. The need to limit the search space without over constraining potential new solutions.

The system uses blocks, which are combined together in a similar way to children's wooden building blocks to make physical structures (although currently it exists as a 3D graphical display only [figure 2]). Each block has the ability to both play and compose music; so building a physical structure also results in building a piece of music.

Imagine we have two blocks next to each other, both playing their respective musical phrase – each block has a *home musical phrase* that it holds on to throughout. Now press a button on block 1 labelled "send music". This causes block 1 to send its music to block 2. Block 2 then performs a composition activity, based on its own home music and the music it has just been passed by block 1. The compositional aim for the block is to produce a new musical section that has a thematic relationship with both its home music and the music it has just been passed. It does this by calling on a GA, which has its starting music as the home music, and the evolutionary target as the music passed to it. The path taken by the GA in evolving from start to target then reflects new fragments related to both supplied sections. Block 2 then starts playing its new music.

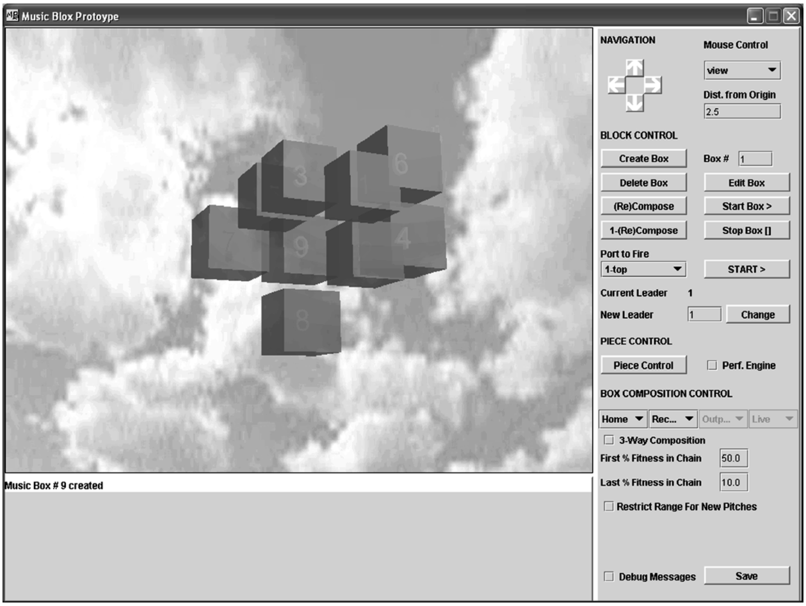


**Figure 2**
**A screenshot of the current *IndagoSonus* 3D graphical model.**

Any number of blocks may be chained or grouped in any 3D structure. If a block is passed some music from its neighbour, it first recomposes itself, and then passes its new music on to all of its neighbours, and so forth within a pre-specified range. It is important to clarify that each block holds on to its home music throughout, enabling any music composed by it to remain thematically related, despite the constant process of re-composition undertaken by each block. In this way the composer of the home music for all blocks maintains a compositional thumbprint on the evolving musical structure. In effect, the listener/performer is able to shape the overall music by choosing to send musical fragments from blocks they like to influence other blocks.

The system possesses significantly more functionality than this (please refer to a previous paper by Gartland-Jones (2003) for more detail). It is hoped that the description given is sufficient to show how it attempts to overcome the two problems outlined above.

## VI. Concluding Remarks

This paper has attempted to examine the usefulness of GAs in performing compositional tasks by demonstrating the benefit they offer over and above traditional search mechanisms, and to suggest ways in which they might perform a process that in some way matches established human compositional processes. It seems clear that GAs do offer significant advantages, but that they also come with inherent problems.

The *IndagoSonus* system tries to overcome some of these difficulties by evolving from a supplied musical starting point to a given musical target, a technique that has similarities to previous work on the use of GAs for thematic bridging by

Horner and Goldberg (1991). The aim, however, is not to play in sequence all the solutions found on the evolutionary path from starting to target music, in the manner of phase or minimalist music, but to generate a single point solution at a specified location between the two. Another key difference is that Horner and Goldberg see the nature of the path as one of optimization: "Thematic bridging bears a close resemblance to another GA application, job scheduling" (Horner and Goldberg 1991). In discussion of their results they describe developing, "An alternative approach . . . in an attempt to reduce the problem's non-linearities to a reasonable level and improve linkage" (Horner and Goldberg 1991). By contrast the evolutionary path in *IndagoSonus* aims to be as loose as possible, whilst still retaining forward motion between starting and target music. In essence, the function is to explore the space, and find musically interesting solutions, rather than to perform a linear morph.

Another related earlier work is that of Ralley (1995). Here the initial population of the GA was "seeded with melodies similar to the user's input melody" which has obvious similarities to the notion of starting music. There is also a similarity in goal, and Ralley states two aims: to develop a GA as a tool for searching melody space interactively; and to use the system to move towards an explicit goal.

The *IndagoSonus* system possesses particular advantages in relation to both the IGA/fitness assessment problem and the search space limitation problem. First, the user is able to direct the search in a similar manner to an IGA, but without having to make conscious choices after every generation. Second, the target music directs and limits the search and, therefore, "makes fitness assessment significantly easier". Third, as the aim is not "to play in sequence all the solutions found on the evolutionary path from starting to target music" (Gartland-Jones 2003: 496), not only are sudden (though related) T-creative leaps of the imagination possible, although defined by the search space, but also a manageable amount of potential material is uncovered for the E-creative.

In order to assess the usefulness of GAs in musically creative tasks however, more general discussion of the musical output needs to be conducted. It needs to be recognized that the task is not simply one of computer science, but must include discussion in the relevant domain. This will require the skills and engagement of the wider musical academic community, and an increased number of interdisciplinary research projects.

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