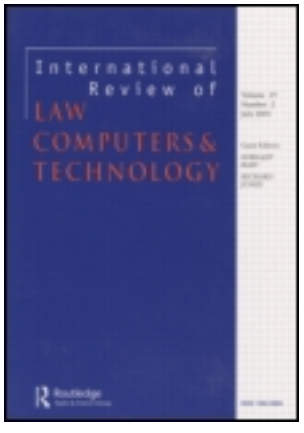

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Singing from the same sheet: computational melodic similarity measurement and copyright law

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Musical plagiarism is an area of law that is not only of interest to lawyers but captures the curiosity of the public, induces apprehension in the composer and now intrigues the computer scientist. Attention increases in the case of celebrated artists when the revenue is likely to be significant, and when the allegation is one of a perceived similarity between the infringing and infringed works. Despite the broad interest and frequently high commercial significance of this issue, there has been little systematic research into what constitutes musical plagiarism from either a technical or perceptual perspective. This article discusses some suggestions made to date for introducing a technical measurement of musical similarity in copyright disputes before presenting our own computational system. The novelty of our proposal arises from an interdisciplinary approach combining computational, musicological, and psychological perspectives to emulate legal principles, mimic the reasonable listener as well as copy the type of evidence often presented in these cases.

Keywords: musical plagiarism; similarity; computational modelling

Technology, Music and the Law

Technological advancements have played a key role within the music industry, ranging from the creation of new compositional tools and techniques (such as synthesisers, sampling and audio mixing software), digital storage and transfer (MP3, peer-to-peer file sharing), to search and recommender software to facilitate online music distribution. At the same time, such breakthroughs present new challenges for copyright law; in the UK, examples include digital sampling, which tested the limits of the substantial part doctrine, and the outdated intellectual property framework surrounding transfer and storage of music, addressed recently by the Hargreaves Review.[1] While new technology often calls into question existing laws, this paper examines the existing law and introduces a new computational system of similarity measurement designed for use in musical copyright disputes.

Although technology for music comparison is not a recent innovation, legal academia has rarely attempted to translate advancements in this field onto a juridical framework. In the same way, since the majority of this type of software is currently tailored towards the consumer market, it is often unsuitable for application in a legal framework. By contrast, the system presented in this paper, has been designed to measure the degree of similarity

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between musical works in disputes involving altered (or non-identical) reproduction of a protected work. Furthermore, the development of our system has been guided by an appreciation of copyright case law and legislation with a view to providing a technical system that closely reflects and is faithful to contemporary legal practice and principles.

Taking UK copyright law as our frame of reference, the first part of this paper examines the current legal treatment of altered copying in musical works and the arguments in favour of a complementary, objective and transparent test. This is followed by a critique of attempts made to date by legal and computational disciplines to implement a method of similarity measurement. The final part of this paper introduces our own system of similarity measurement which, unlike the alternatives just discussed, aims to reflect copyright law. The paper concludes by outlining some of the encouraging results our system has already produced.

Copyright infringement in altered copying

Currently our system is designed for use in copyright disputes that involve the altered copying of a section of musical work. That is, it is not intended for use in cases of identical copying (such as digital sampling), or in cases of adaptation (such as the transcription of music). Our system is also currently restricted to cases where a section rather than the whole of the copyright work has been reproduced.

In the UK, the relevant statutory provisions are contained in the Copyright Design and Patents Act 1988.[2] Section 16(1) of CDPA 1988 grants copyright holders reproduction rights; rental (or lending) rights; public performance rights; the right to communicate the work to the public; rights of adaption and the right to authorise others to carry out any of these activities. In altered copying disputes, the author's right of reproduction is allegedly infringed. In relation to musical works the CDPA states that copying includes 'reproducing the work in any material form' (s.17 (2)) extending copyright protection to non-identical copying. In such cases the level of similarity between the disputed works is essential to be able to demonstrate that the claimant's right of reproduction has been infringed.

A further important provision is s.16 (3)(a) of the CDPA 1988, which extends the copyright holder's statutory rights to the whole or a 'substantial part' of the protected work. Our technique therefore has ensured it takes into account both the degree of similarity needed to establish infringement as well as whether the disputed section represents a substantial part of that of the copyright work.

The legal degree of similarity

In cases of altered copying, the degree of similarity between the party's works is essential for demonstrating that infringement has taken place. In the UK a leading authority on musical infringement is *Francis Day Hunter v Bron*[3] where Lord Diplock states:

> There must be sufficient objective similarity between the infringing work and the copyright work, or a substantial part thereof, for the former to be properly described, not necessarily as identical with, but as a reproduction or adaptation of the latter. (Francis Day Hunter v Bron, 1963, p. 623)

Ascertaining an objective level of similarity between the disputed works is treated as a question of fact and degree, approached on a case-by-case basis depending on the medium the copyright is secured in. In cases of identical copying (such as sampling) the

degree of similarity becomes irrelevant, instead the focus shifts to whether the copied section represents a substantial part of the claimant's work. In allegations of altered copying, a court must determine whether the works are similar enough to constitute infringement, or different enough to form separate works. When dealing with musical works there are established principles on how to approach the question of similarity, most notably the long held dictum in *Austin v Columbia Gramophone*:[4]

> Infringement of copyright in music is not a question of note for note comparison, but of whether the substance of the original copyright work is taken or not. It falls to be determined by the ear as well as by the eye. (Austin v Columbia Gramophone 1917, at 415 – 409)

The emphasis on the aural perception of similarity as well as a note-for-note comparison reflects the nature of musical copyright; in a musical work similarity should be judged *as musical similarity* not merely as a reduction to the written score, something that can only be a partial representation of music. The method of 'by the ear and the eye' is adhered to in the majority of case law, taking the form of a note-for-note analysis of the scores and the auditory perception of similarity.

Note-for-note comparison

In contrast to other forms of copyright, analysing similarity in musical works presents a far greater challenge. In part this is due to the inherent complexities of music, the importance of stylistic context for the significance of individual elements and the fact that music is a non-verbal domain. Thus, a special technical terminology and descriptive language (e.g. western music theory) is required to argue about structural similarities and the significance of musical elements. Given music's specialised nature, experts (typically musicologists) provide evidence on the degree of similarity, as well as on the significance of the part of music in question. Although the nature of this evidence invariably differs depending on the facts of each case, it usually includes some rudimentary note-for-note analysis. When taking a closer look at the musical material disputed in UK, the majority of cases often focus on the similarity between the melodies. This coincides with Charles Cronin's findings which, based on precedents from US case law, illustrates that melodic elements of musical works are often at the core of the dispute.[5] Cronin argues that the traditional approach courts have adopted, suggests that 'rhythmic originality [that would be legally relevant] is nearly impossible to achieve, harmony is simply the application of well-known rules, and neither can be subject of copyright' (Ref. 5, p. 188).

Given the preponderance of the issue of melodic similarity in judicial reasoning, it is not surprising that a range of methods for indicating similarity have been previously suggested by expert witnesses. Such methods often relied on a form of graphic illustration of melodic structures for courts that may not be able to read a musical score. During the Tin Pan Alley era of the 1910s, the practice of using straight lines or arrows was used to indicate correspondences between the pitches of two melodies. In expert witness reports, lines are drawn between identical pitches in the two melodies in question. Commonly, a relatively large number of lines connecting notes between the two melodies are seen as evidence of similarity. This 'line-drawing' approach is still widely employed today with Cronin illustrating its use for similarity evidence with a number of examples from documented US-American court cases (Ref. 5, pp. 195–200).

However, it is difficult to incorporate rhythmic, harmonic or metrical comparisons between two melodies in this approach along with the pitch that is being equated. As a

result actual melodies are reduced to their pitch information and thus a graphical comparison using this technique often seems to suggest strong similarities. Furthermore, unbiased quantifications of the number of pitches related as against the number of pitches between the two melodies that are unrelated are rarely attempted. Therefore, a graphical image depicting notes connected by lines on two staff notation systems is the only written information that musically non-literate courts have with which to judge the case.[6] This traditional line-drawing approach has been criticised as 'simple', 'primitive', and 'misleading' (Ref. 5, p. 193). Furthermore, as it has never been formally defined, it allows for a large range of discrepancy in its application depending on the expert witnesses' subjective judgment. As Liebesman puts it, this technique invites the 'subjective and limited breakdown and analyses of songs [that] often lead to conflicting interpretations of the experts called to testify'.[7] It is criticisms such as these that have driven a technical answer to similarity detection in musical copyright disputes; not necessarily to replace the current model, but to provide a solid foundation from which arguments on similarity can be based.

Aural perception of similarity

Accompanying the written dissection of the scores is the aural perception of similarity between the claimant and defendant's work. This is largely dependent on the aural perception of the judge, which although is aided by expert evidence, remains a judicial decision. There are two points in relation to the auditory perception of similarity which we have considered in our system. The first is the presumption of a certain degree of knowledge of the listener, and second the appreciation of psychological factors that are absent in other technical proposals.

Although the degree of knowledge a listener should possess has never been formally examined in case law, there seems to be an expectation that the auditory perception of similarity should be of a degree that an average listener could identify it. In *Francis Day Hunter v Bron*[3] Wilberforce J held there was a definite or considerable level of similarity between the disputed musical works to the extent that 'an ordinary reasonably experienced listener might think that perhaps one had come from the other' (Ref. 3, at 610). Indeed, the defendants in *Williamson Music v Pearson*[8] attempted to capitalize on the weight carried by the reasonable listener. The case concerned a parody of the song *There's Nothin' Like a Dame* from Rodgers and Hammerstein's musical *South Pacific*, which had been adapted for a series of adverts for the coach company National Express. The defence presented evidence from an empirical study in which 130 randomly selected members of the public had listened to the defendant's parody and asked whether it reminded them of any other tune. In total, five people identified the claimant's work as being similar to that of the defendants. On analysis, the survey was held to have been too severe, not adequately representing the advert in terms of content or taking into account the repetitive nature of advertising. The fact that five people managed to identify the claimant's work under stringent conditions worked in the claimant's favour (Ref. 8, at 111). The ability to identify distinctive points of similarity between two musical works is partly dependant on an appreciation of existing musical works. In order to emulate the 'reasonably experienced' listener, our system not only analyses the level of similarity between the copyright and infringing works, but (as is discussed in greater depth below) also attempts to mimic the idealised listener by incorporating a large database of songs in its similarity comparison.

Rather than proceed too far down the road of how 'reasonable' a listener should or should not be, we believe that the importance enjoyed by the aural perception of similarity

by the ordinary listener reflects the superiority in the cognitive processes of actual listeners. Indeed, the linguistic reduction of music to a written score or specialised description will always be an imperfect replica of music. Furthermore, this approach safeguards against the risk of subjective judgments by expert witnesses as well as ensuring that musical similarity is judged as a medium for which copyright protection is granted. As we argue in the following sections, the limited number of suggestions for a technical approach to similarity measurement in copyright disputes often avoided addressing the psychological factors in the search for a purely mechanical approach. In contrast, we believe that a system of similarity measurement developed from a technological standpoint, such as the one we propose, takes seriously the importance of psychological factors as well as the fact that no system could ever represent, or supersede, the judgments of human listeners; a technical approach to similarity measurement is, after all, another translation of music to an imperfect medium. As discussed below, these factors have been considered, reflected and integrated in the development of our system. Furthermore, as well as testing our system against the results of copyright disputes, we see perceptual experiments as key to assessing whether our proposed system corresponds to the judgments of actual listeners.

(A part of) The substantial part doctrine

If a claimant is successful in demonstrating a sufficient degree of similarity between the disputed works, the next hurdle is to establish whether the section reproduced represents a 'substantial part' of the claimant's work. Protection for a 'substantial part' made its first legislative appearance in the 1911 Copyright Act s.1(2), and is currently elaborated in s.16(3)(a) of the CDPA 1988. For the purpose of this paper we limit our discussion to three points concerning the substantial part doctrine which we took into account in developing our own system: the point of reference of this inquiry, the criteria for protection, and the non-protection of ideas or commonplace elements.

One way to approach the substantial part doctrine is to consider it in terms of the idea-expression paradigm in copyright, dividing the protected from non-protected elements within a copyright work. Within most copyright works there will be sections that do not attract protection representing common or trivial elements belonging to the public domain. Indeed, the greater level of abstraction the less likely a section will be considered a substantial part (a complete dissection of any copyright work inevitable equals a sum of un-protectable parts or ideas; for example when musical work is reduced to single notes or a novel to single letters).

The first point to consider in a substantial part enquiry is the perspective of the assessment. Once the points of similarity between the works have been identified, these elements must be considered in relation to the claimants work alone. The inquiry is whether the disputed elements form a substantial part of the copyright work not a substantial part of the infringing work. In order to synchronise our technical system with this aspect of copyright law our system adopts an asymmetrical comparison taking the protected work as the point of reference.

When considering whether the disputed part represents a substantial part of the protected work is the onus is placed on the quality rather than the quantity of the part reproduced.[9,10] Furthermore, it was the technological advancement of digital sampling that played a role in shaping the current legal approach to this area of law. Produce Records v BMG (1999)[11] concerned a sample of *Higher and Higher* by The Farm (owned by Produce Records) in the track *Macarena* by Los Del Rio. BMG moved to strike out this action on the grounds, *inter alia*, that it was for the judge alone to determine whether or

not a section constituted a substantial part, a retort to the expert evidence from a musicologist that was presented by Produce Records. Parker J rejected the strike out while accepting judges could be aided by expert musicologists. As well as accepting that expert evidence is indeed permissible at this level of a copyright dispute, some commentators see this case as abolishing the so-called 'three second rule' (a sample of three seconds or under would not constitute infringement) which was thought to exist in considering whether a section constituted a substantial part.[12]

In regards to assessing whether a section constitutes a substantial part, a key authority in is Designer Guild v Russell Williams[13] where the court seemed to approve the test proposed by Laddie who suggested the correct approach is to ask 'Has the infringer incorporated a substantial part of the independent skill, labour etc. contributed by the original author in creating the copyright work?'[14] Indeed, a similar line is followed by Lord Hoffman in the later case of Newspaper Licensing v Marks and Spencer, stating the assessment of quality should be identified; 'by reference to the reason why the work was given copyright protection'.[15] The court needs to evaluate the requisite skill and labour imparted by the author that ensures the work fulfils the legal standard of originality and thus qualifies for protection. In Designer Guild v Russell Williams, Lord Hoffman makes two points at the other end of the scale in regards to un-protectable elements or ideas, which is of particular significance to our technical system. First that 'the more abstract and simple the copied idea, the less likely it is to constitute a substantial part', followed by 'certain ideas expressed by a copyright work may not be protected because [. . .] they are not original, or so commonplace as not to form a substantial part of the work'.[13]

This reasoning is translated in the type of evidence that is often presented to demonstrate a disputed section of music represents only a trivial, and non-protectable, feature. Examples include Creagh v. Hit and Run[16] where the disputed part of the work was deemed '[. . .] not original, forming as they do, notes 1, 2 and 3 of the minor scale and are commonplace'. In the same case, evidence was presented to illustrate the disputed section as appearing in a large number of classical and contemporary musical pieces (Ref. 16, at 49). Likewise, in EMI v Papathanassiou[17] the case focused on a four note sequence referred in the case as the 'turn'. On analysis it was determined: 'The "turn" was a musical commonplace and had been used by Vangelis himself before the composition of "City of Violets"' (Ref. 17, at 313). In the same way, our own system also grades the 'uniqueness' of the disputed section through a comparison to a large database of music. The more often a musical element appears within the database the less importance it is given, while the less common an element features in the database the more significance it is given.

Previous proposals for a technical approach to similarity measurement

The mega-element analysis

Despite the obvious limitation in the traditional approaches to melodic similarity comparisons, there are few attempts in the literature to suggest a more rigorous technological approach. The suggestions put forward by Liebesman[7] constitute an exception, presenting two alternative ideas for objective tests; the first is based around a detailed feature-description of musical pieces that she terms 'Mega-Element Analysis (MEA)' (Ref. 7, p. 345). This involves similarity comparisons between two songs, with the determination of unusual similarities potentially indicative of copyright infringement performed over the distance in feature-space. Detailed feature-descriptions of tunes have a long-standing record in musicology and ethnomusicology[18] and are often used to organise large music collections as well as to facilitate musical search tasks based on similarity. Indeed, the efforts of companies such as

Pandora, Sony, and the All Music Guide have resulted in many finely categorised and described catalogues of music. Liebesman's concept of MEA assumes that two disputed songs can be marked-up according to a finely-grained feature description system resulting in a computed similarity value. In addition, the two songs in question could be compared with other songs from the same genre to give a baseline indication of inter-genre similarity.

While, in principle, this method seems viable to determine similarities in an objective fashion, Liebesman does acknowledge some problems inherent in this approach. First, creating and maintaining a comprehensive database of finely-marked-up music is a time-intensive task for skilled musicians. If an investment on such a magnitude were to be undertaken by a private sector institution, in order to be financially viable it would need to be exploited as a commercial service as well as for use in plagiarism cases.[19] Thus, if the primary purpose of a large feature database is designed with commercial intentions, there is likely to be little incentive for the investing company to allow open and transparent use of their main intellectual asset, which would be a sine qua non requirement for their employment in court cases. Otherwise, this approach to determining similarity would be very much open to criticism. As outlined earlier, musical infringement cases are typically, but not exclusively, focused around the melodic features rather than harmonic, rhythmic and timbral (i.e. sound) aspects which are, for the most part, of less importance. However, musical recommender systems are often centred on harmonic, rhythmic and sound attributes because it is these aspects that usually define musical genres. Therefore, it is questionable whether a database of musical attributes created for use in recommender systems would include melodic feature-descriptors that are fine-grained enough to allow for valid similarity measurements at the level of detail required to aid cases of plagiarism.[20]

Mathematic Modelling Analysis (MMA)

Liebesman's second suggestion for an objective test starts from the idea that a musical piece could be mathematically modelled at the level of sound waves. She calls this test the Mathematical Modelling Analysis (MMA). Her idea is that, once each of the two songs involved in a copyright dispute are modelled, then the distance or similarity between these physical models would be a straightforward matter of applying a mathematical distance metric. While this idea appears appealing due to its complete objectivity, it is does not reflect state-of-the-art computer modelling in contemporary music. Liebesman does concede that despite her own thorough research, she was unable to find a suitable mathematical or computational method that would accurately model pieces of music as a whole (Ref. 7, pp. 355–356). Within the Music Information Retrieval community, many aspects of music have been successfully modelled and a variety of comparison, retrieval and similarity-related tasks developed to the level of commercial application.[21] However, there is still wide discrepancy between the types of musical information that can be represented via mathematical analysis and the musical information that humans represent cognitively. Current computational models are best at representing sound attributes of music crucial for applications such as genre classification, automated recommender systems or the retrieval of specific songs via mobile phones (query-by-example). However, comparing melodies of songs that might wildly differ in aspects of sound, instrumentation, tempo, and structure is still an unsolved task in computational modelling. Solving this problem would potentially require an automatic polyphonic transcription of fully orchestrated pop songs or at least the identification and transcription of the main melody in the mix of instruments. Both tasks are still not solved to the degree of accuracy that would be needed for making comparisons in copyright infringement cases (the current level of polyphonic transcription accuracy lies between 60 and 70%).

It seems that the concept of a fully automatic similarity comparison purely from the audio signals of two songs, as suggested by Liebesman's MMA test, may only be an option for the distant future. Overall, Liebesman's suggestions reveal a lack of insight into the state of technology in computational music processing and the active research area of Music Information Retrieval where tasks similar to the ideas she has proposed have already been put to empirical test.

Geometrical distance measures

Park and collaborators suggest a computational method for the similarity comparison which, they demonstrate, works very effectively on large tune databases.[22] On closer inspection their suggested similarity model is not as novel as the authors claim but conceptually very similar to the 'distance measures' suggested by Müllensiefen and Frieler[23] and the geometric measure proposed by O'Maidin.[24] Besides the fact that their similarity measure contributes very little to the literature on melodic similarity measurement, it also lacks an explanation of why this measure is cognitively adequate and whether it would deliver results when applied to music plagiarism. In addition, they do not provide an evaluation on a substantial set of so-called ground truth data indicating the accuracy of their method.

String-matching approaches

In comparison, the contribution by Robine and colleagues[25] can be regarded as a much more serious attempt to suggest a viable similarity measure for musical infringement. They present a state-of-the-art similarity comparison system based on the string-matching approach, which has been a popular technique in different fields such as computational biology, text comparison as well as music search and retrieval. However, Robine and collaborators[25] make no attempt to synchronise their algorithmic procedures to the requirements of copyright law. Nevertheless, they do provide a small-scale empirical evaluation using four cases of musical copyright infringement taken from a US database. Their results are encouraging in that in two cases the disputed songs showed a high similarity compared with most other tunes in the tune databases. However, the accuracy and practicality in terms of guiding judgements in music plagiarism cases of their approach is yet to be demonstrated on a larger scale and with a wider range of relevant computational tasks. Indeed, it is usually not questioned that the two disputed melodies bear a high similarity; otherwise the case presumably would not have been taken to court. But whether the perceivable similarity is sufficiently high to indicate infringement and whether it is based on original and copyrightable musical material is a different matter that currently cannot be easily addressed using the approach proposed by Robine and collaborators.[25]

A new approach to measure melodic similarity

We recently suggested and discussed a novel system for the computational measurement of melodic similarity and its application to musical copyright infringement. The approach is described in detail in Müllensiefen & Pendzich[26] and therefore here we will limit ourselves to a brief summary on a conceptual level. The approach adopted was motivated by the idea that similarities and identical overlap in highly original and relatively uncommon melodic elements are more likely to be indicative of copyright infringement than overlaps in melodic elements that are common to a greater number of tunes. Or expressed differently, if two songs share trivial melodic elements such as simple movements on a major or minor

scale, broken chords or other very common melodic formulae, then they should be regarded as less important in a legal similarity comparison than shared elements that are highly unusual and original.

Perceptual weighting – substantial part

Technically, this approach combines a perceptual weighting function modelling the originality of melodic elements with a well-known feature-based similarity comparison algorithm from psychological literature. The perceptual weighting function makes use of statistical weighting procedures that have been very successfully employed in text retrieval and natural language processing. They utilise a large database of songs representative of western popular music since about 1950 (consisting of 14,063 highly accurate manual transcriptions of pop songs in MIDI format). The usage of this database is conceptually very similar to vector space approaches in psycho-linguistics such as the Latent Semantic Analysis framework, where cognitive verbal tasks involving semantic processing are very successfully simulated and predicted using statistical information from large text corpora. In our approach, a melody is broken up into small sequences of notes (or melodic elements) of varying lengths. Each melodic element is then weighted according to its relative occurrence in the pop music database, whereby less common elements receive a higher weight and very common elements receive a low weight. Although grading melodic elements according to their 'uniqueness' within a specific, albeit large corpus, is open to criticism insofar as it assumes that the musical experience of an average listener of western popular music can be modelled by aggregate counts, it provides a transparent and quantifiable way of distinguishing between commonplace musical elements, motifs and melodic sequences that are highly characteristic of certain individual songs. We believe this approach does mirror certain principles and evidence presented in determining whether a section constitutes a substantial part of the copyright work.

Similarity measure – asymmetrical comparison

For the melodic similarity measurement we adapted a general and widely used model of similarity perception from the psychological literature proposed by Tversky.[27] Tversky's ratio model of similarity perception considers the amount of overlap between the features that two objects share divided by the total number of features found in both melodies. Indeed, Tversky's model has been shown to work well in a number of domains but had not been adapted for use in musical comparison before. One of its features is that it allows for asymmetric comparisons where the similarity between object A compared with object B is not equal to the similarity of B compared with A. The advantage of such an asymmetric comparison is that it mirrors the focus that is placed on the copyright work when deciding whether the part taken represents a substantial part of their work. We consider the possibility to model asymmetrical similarity relations a meaningful advantage for application in plagiarism cases where the direction of comparison is important (i.e. plaintiff's work to defendant's work as opposed to the opposite comparison). Interestingly, according to the evaluations in Müllensiefen and Pendizich[26] the best-performing algorithm proved to be a variant of the Tversky model that employed a strictly asymmetrical comparison taking the plaintiff's melody as the frame of reference.

Combining perceptual weighting and similarity measurement

Integral to Tversky's model is a perceptual salience function that weighs the features of both objects according to their (idealised) perceptual importance. We argue that the weighting of

melodic elements according to their commonness in a representative music corpus as described above is a reasonably good approximation of this perceptual salience function. Thus, taken together the corpus-based weighting of melodic features and the feature-based similarity comparison following Tversky's model delivers a single numerical similarity value that reflects both the degree of overlap in melodic elements between two melodies and the perceptual importance and originality of the overlapping versus the non-overlapping elements in both melodies.

Note that the fact that we involve a corpus of music in the similarity comparison makes the similarity value depend not only on the two melodies being compared but also on the corpus from which the perceptual weights are derived. We consider this a desirable feature for a similarity comparison approach, since it models an average and idealised listeners' stylistic knowledge and expectations. Furthermore, this aspect of our system mirrors the type of evidence discussed earlier in regards to the substantial part doctrine, namely, the referencing to third party works in determining whether a section of work qualifies for protection. Although such a system could never absolutely reflect decisions relating to whether a section of work constitutes a substantial part of the copyright work, we believe it is a close approximation, which has been shown to provide correct results in empirical tests.

Empirical results

This approach has been quantitatively evaluated and the results of this evaluation have been qualitatively discussed in detail (Ref. 26, pp. 274–286). The evaluation was based on a collection of 20 cases of copyright infringement decided in US courts documented by the *Columbia Law School & UCLA Law Copyright Infringement Project*. All were selected on the basis that the primary argument focused on the melodic similarity between the disputed tunes. This evaluation set contained 13 cases that were eventually decided as constituting infringement and seven cases where the court decided in favour of the defendant. This similarity measure achieved a classification accuracy of 90% (i.e. concurred with the court's decision in 18 out of 20 cases). Musicological scrutiny and extensive discussion of the correctly, and the two incorrectly, classified predicted cases revealed the approach seems to reflect well the most relevant aspects of plagiarism trial. On the other hand, it failed to classify the court's decision correctly in cases seemingly containing a high degree of idiosyncrasy.

Furthermore, the transparency of our proposed system is to such an extent that it can be easily deconstructed by anyone with a sufficient understanding of relatively simple computational algorithms. Thus, on a practical level, if utilised either within a copyright infringement case or at a pre-trial stage, the system is amenable enough to be scrutinised and dissected rather than operating as a clandestine technical assessment.

Conclusion

When considering the current state of the art in musical comparison technology against the current approach of the courts in determining similarity in musical copyright infringement cases, it is clearly desirable to apply such a technology in a judicial setting. In contrast to previous technical proposals, which are subject-specific, our system has been built from a strictly interdisciplinary foundation; subject-specific suggestions, as we discussed earlier, demonstrated either a lack of technical knowledge or an appreciation of legal practice and principles. Although no technical approach could ever replicate the law, or take into consideration the multiple factors involved in copyright disputes, it can assist the court

in the same way that expert evidence currently does, but with a greater degree of objectivity, transparency and accuracy.

Features of our system, such as the specific database of commercial pop music, the chosen weighting function for perceptual salience or the similarity computation itself as a ratio of shared versus non-shared features aim, however imperfectly, to reflect copyright law. As our system is designed to model the reasoning and decisions of expert witnesses and the judiciary, in an application scenario it is intended to guide and inform human judgements by providing a platform or a starting point for arguing the nature and extent of similarities between two tunes as well as affording an insight into whether the disputed section would qualify for protection.

Although the system has produced encouraging results, in its present state it is still limited in application. Currently, it is only able to handle two melodies if they are strictly monophonic. Other musical aspects such as timbre/sound, harmony/chords, lyrics, or polyphony (i.e. several melodic voices playing simultaneously), issues that have been raised in some disputes, cannot be represented at the moment. Cross-validating the system on our collection of Commonwealth cases as well as continental law is paramount for assessing its robustness, while potentially providing insight into the approach of different jurisdictions from a unique technical perspective.

In addition to this evaluation strategy, it is important to provide evidence that the technical system not only agrees with court decisions but also with the perception of ordinary listeners. To this end we are currently initiating a series of perceptual experiments collecting implicit and explicit similarity judgements from participants who are not informed about the connection between the experiments and their forensic application. If algorithmic similarity measurements are in agreement with the perception of human listeners as well as with court decisions, this would further support the hypothesis that our system models the actual cognitive processes that are relevant for the evaluation and judgement of musical similarity.

Beyond its practical use, the greater impact of the system we propose lies in providing a new perspective with which to interrogate legal concepts on an empirical basis. Our system demonstrates the impact and interrelationship between emerging technologies and the law, and, in particular, technologies that are tailored for application in the legal field.

Notes

1. Hargreaves, I. 2011. Digital opportunity, a review of intellectual property and growth. Retrieved from: http://www.ipo.gov.uk/ipreview-finalreport.pdf
2. Copyright Design and Patents Act, Ch 48 (1988).
3. Francis Day Hunter Ltd v Bron, Ch. 587 [1963].
4. Austin v Columbia Gramophone Ltd MacG CC (1917) – 1923 at 415 and 409.
5. Cronin, C. 1998. Concepts of melodic similarity in music-copyright infringement suits in melodic similarity - concepts, procedures, and applications. In *Computing and musicology 11*, eds W.B. Hewlett and E. Selfridge-Field, pp. 187–209. Cambridge, MA: MIT Press.
6. Variants of this approach include the colour-coding of pitches, the inclusion of timing information by lengthening the note symbols to rectangle, or the replacement of musical notation by numbers and symbols.
7. Liebesman, Y. 2007. Using innovative technologies to analyse for similarity between musical works in copyright infringement disputes. *American Intellectual Property Law Association* 35: 331–362.
8. Williamson Music v Pearson [1987] F.S.R 97.
9. *Ladbroke (Football) Ltd. V William Hill (Football) Ltd.* [1964] 1 All ER 465, at 276.
10. Within a musical setting this was nicely demonstrated in the case of Besten v CBS UK Ltd (1994) E.M.L.R 467 where it was held the percussion line of the claimant's work, although quantitatively large (the entire length of the music), did not fulfil the qualitative test.

11. Produce Records Limited v. BMG Entertainment International UK and Ireland Limited (1999) All England Official Transcripts (1997-2008).
12. Challis, B. 2003. United Kingdom: the song remains the same: musical sampling in the digital age. Retrieved from: http://www.mondaq.com/article.asp?articleid=23823&latestnews.html.
13. Designer Guild v Williams [2000] All ER (D) 1950.
14. Laddie, J., Prescott, P., and Vitoria, M. 1995. *Modern Law of Copyright and Designs*, 2nd edn., UK: Butterworth, 92–93.
15. Newspaper Licensing Agency Ltd v Marks and Spencer plc [2003] 1 AC 551 at 559.
16. Creagh v Hit and Run Publishing Ltd [2002] All ER (D) 349 (May).
17. EMI Music Publishing Ltd v Papathanasiou [1987] E.M.L.R 306.
18. Well-known examples include Bartok's collection of Serbo-Croatian folksongs – Bartók, B., and Lord, A.B. 1951. *Serbo-Croatian folk songs*. New York: Columbia University Press – and the Cantometrics project initiated by Alan Lomax – Lomax, A. 1977. *Cantometrics: an approach to the anthropology of music*. Berkley: University of California.
19. For instance, companies such as Pandora and Sony created their music catalogues with recommender applications in mind with a view to enhancing music sales and commercial services.
20. This concern is shared by Pandora's founder, Tim Westgren, who estimates that for use in copyright infringement, a characterisation of songs on approximately 10,000 musical attributes would be necessary as opposed to the 400 attributes that Pandora uses at the moment (Liebesman, 'Using Innovative Technologies', 349).
21. One example is the so-called query-by-example where a piece of music can be retrieved from a large database when only a short excerpt at an impoverished sound quality is given as a query. Shazam is one of the companies that has commercialised this search method for mobile phone applications.
22. Park, J., Kim, S., and Shin, M. 2005. Music plagiarism detection using melody databases. In *Knowledge-based intelligent information and engineering systems*, Lecture Notes in Computer Science, eds R. Khosla, R. Howlett, and L.C. Jain, 684–693. Berlin: Springer. doi:10.1007/11553939_98.
23. Müllensiefen, D., and Frieler, K. 2004. Cognitive adequacy in the measurement of melodic similarity: algorithmic vs. human judgements. In *Music query: methods, models, and user studies: computing in musicology 13*, eds W.B. Hewlett and E. Selfridge-Field, 147–177. Cambridge, MA: MIT Press.
24. O'Maidin, D.S., and Donncha, A. 1998. Geometrical algorithm for melodic difference in melodic similarity. In *Melodic similarity: concepts, procedures, and applications: computing in musicology 11*, eds W.B. Hewlett and E. Selfridge-Field, 65–72. Cambridge, MA: MIT Press.
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26. Müllensiefen, D., and Pendzich, M. 2009. Court decisions on music plagiarism and the predictive value of similarity algorithms. In *Musicae Scientiae*, Discussion Forum 4B, 257–295. doi:10.1177/102986490901300111.
27. Tversky, A. 1977. Features of similarity. *Psychological Review* 84: 327–352.