Updating the Classifications of Mobile Music Projects

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ABSTRACT
This paper reviews the mobile music projects that have been presented at NIME in the past ten years in order to assess whether the changes in technology have affected the activities of mobile music research. An overview of mobile music projects is presented using the categories that describe the main activities: projects that explore the influence of and make use of location; applications that share audio or promote collaborative composition; interaction using wearable devices; the use of mobile phones as performance devices; projects that explore HCI design issues. The relative activity between different of categories of mobile music is assessed in order to identify trends. The classification according to technological, social or geographic showed an overwhelming bias to the technological, followed by social investigations. An alternative classification of survey, product, or artefact reveals an increase in the number of products described with a corresponding decline in the number of surveys and artistic projects. The increase in technical papers appears to be due to an enthusiasm to make use of increased capability of mobile phones, although there are signs that the initial interest has already peaked, and researchers are again interested to explore technologies and artistic expression beyond what can be provided by existing mobile phones.

Keywords
Mobile Music, interactive music, proximity sensing, wearable devices, mobile phone performance, interaction design

1. INTRODUCTION
It is now ten years since the first mobile music related paper appeared in the proceedings of the New Interfaces for Musical Expression (NIME) conference [12]. Since then mobile technology has increased dramatically; in particular the capability of mobile phones have increased enormously. This paper surveys the activities represented in the 98 papers published at NIME, and the related workshops, in order to identify trends, detect whether there has been a change in emphasis of mobile music projects and examine whether the definition of mobile music based on current activities needs to be revised.

This paper first examines how mobile music projects have been categorized in the past, then describes the range of mobile music activities described at NIME and related workshops, then compares the relative activity of each type of project and the interests of the authors to finally draw some conclusions about the current direction of mobile music activities.

NIME'13, May 27-30, 2013, KAIST, Daejeon, Korea.

2. CATEGORISING MOBILE MUSIC ACTIVITIES
The definitions of mobile music found on the high ranked web pages returned by Internet search engines are mainly limited to the passive consumption of pre-recorded music using mobile devices, e.g.:

> "*The term Mobile Music generically defines digital content that can be directly sourced using a mobile device such as a smartphone (iPhone, etc.), Internet tablet, or other portable device capable of connecting to the Internet or a Wi-Fi network.*" [10]

To a community of artists, researchers and product developers, however, mobile music goes far beyond this limited use of technology to include music making activities that are performed with portable devices. Areas of investigation include how the devices can be made to connect to each other, to networks or to the Internet; how users can interact with the devices, and interact with each other through the devices; and how the devices can detect and respond to context and location.

In 2005 Behrendt [3] developed a taxonomy and classified mobile music in terms of three sets of activities: technological, social and geographic. The technological projects focused on how network technology can enable mobile devices to connect with each other in new ways; the social projects investigated new possibilities of interaction that can allow audiences to participate in the music creation process; the geographical projects examined the influence that geographic location or proximity can have on the creation of music.

In 2006 Gaye et al. devised a definition to cover the wide range music making activities using mobile technology:

> "*Mobile Music is a new field concerned with musical interaction in mobile settings, using portable technology*" [8]

The expanded definition covered any musical activity that used a mobile device that involved activities including;

- interaction with other devices/technology directly or through a network
- interaction with the location
- context awareness
- location sensing
- awareness of the presence of other participants
- responds to changes in the social or geographical context

The 2006 definition explored the breadth of mobile music related activity among artists researchers and developers, while the products that were available to home users on Personal Digital Assistants (PDAs) and mobile phones were explored in more detail by Elsdon in 2007 [6]. The commercial applications described ranged from samplers, sequencers and drum machines to editing and mixing programs. The usage of these applications was found to be on the way to work and at lunch

breaks as recreation. The main emphasis of product development among manufacturers was the creation of controllers or handheld versions of software that was already available on desktops, while there was limited interest in using the devices in a collaborative setting among the producers or users. The potential of more refined sensors in mobile phones was recognized, but at that stage few applications had proved influential.

In the last five years there have been an increased number of mobile phone apps presented at NIME that exploit the new features of mobile phones. The ability of the device to recognise more sophisticated user gestures through the use of touch screens or physical movements are turning mobile phones into new types of instrument. Researchers are interested in the use of mobile phones in collaboration with other users but so far the majority of commercial mobile phone apps remain stand-alone for the use of individual users or for use as controllers of local hardware.

3. MOBILE MUSIC ACTIVITIES

This section will describe the range of mobile music projects presented in the proceedings of NIME. This represents a wide range of activities, and many projects fit within several of the classifications presented below.

The classifications below were derived from the 2006 definition [8] and from an analysis of the most frequent type of activities described in the NIME papers between 2003 and 2012. The relative activity is described with one or two examples to illustrate the type of activity that is involved.

3.1 Exploring the influence of location

Many mobile music projects make use location within their investigation. 16% of all projects included some form of context awareness, responsiveness to the proximity of other objects or devices or individual, while 22% of the projects ascribed some significance to the geographical position and changes of position.

One example that explored the influence of location is Sonic City [9] that generated an electronic music soundtrack in real time as a result of users interaction with the urban environment. Input came from a wide range of environment sensors including microphones, detectors of proximity, metal, pollution, or light, and sensors relating to the user, such heartbeat or speed of movement.

Geographic location is explored in a number of projects, for example Tactical Sound Garden [17] in which users participate in personalizing their experience of the city environment by planting sounds in specific locations that can be experienced by other users of the network.

3.2 File sharing and collaborative composition

26% of projects explored the social interaction implications of sharing audio between users connected to networks or connected to each other on an ad hoc basis. Activities range from file sharing and playlist sharing to collaborative composition.

The Mobile Music Making project [18] explored collaborative composing and mixing using a customized handheld device to enable users to make conscious and unconscious contributions to the shared soundscape.

File sharing projects such as Undersound [2] explored the possibilities of file sharing within London underground carriages. One feature of the proposed system was to reinforce a sense of location by associating specific audio files with individual tube stations.

Most file and playlist sharing projects face the same issues relating to copyright law and propose different methods of how to share files in a way that does not breach copyright and does not oblige participants to buy files they have not expressly agreed to purchase.

3.3 Interaction using Wearable devices

10% of the projects have designed clothes that contain sensors that provide input for applications. Sonic City [9] built sensors into clothing so normal movement will not to hampered, while other projects purposely made the clothing that contained the sensors abnormal. The T-Garden project [15] used sensor-integrated clothing that were designed to encourage unusual movement. Worn within a purpose built unusual environment the clothing contributed to a disembodied experience. An appropriate soundscape was generated based on the individual's movement and interactions between the wearer, the environment and other participants.

More recently the Sound Gloves project [11] proposes to use of a pair of gloves fitted with a touch sensors and accelerometers that are worn by performers interacting with an audience.

3.4 Using the mobile phone as a performance device

27% of all projects were specifically investigating the use of the mobile phone as a performance device. The development of the mobile phone within the past ten years has enabled more possibilities than were available in 2003. The development of unique combinations of gestures using phones has the potential of creating new types of instrument. A large amount of effort has gone into turning the phone a controller that can respond to intuitive gestures by the user.

Modern mobile phones offer a wide range of possibilities for input and output. The following examples illustrate the research activity that has been conducted to explore ways output through the speaker and the visual display can be presented within an artistic performance, and how input through the microphone, key pad, touch screen, and changing the orientation of the device can be used to control the device.

Using the mobile phone speaker can provide audio output that can be heard by an audience in the immediate vicinity. There are several ensembles using mobile phones to perform to audiences such as the Stanford Mobile Phone Orchestra [13]. The Pocket Gamelan project [16] is performed with several spinning mobile phones to create a harmonic effects through the phone speakers. The phone keys are used to input commands to a server that each device is connected to.

Mobile phone microphones have been used for a variety of uses. The Cellphonia projects [5] use the microphone as a means for inputting audio that will be used to create a collaborative soundscape. The microphone is also used by Smule as means of detecting breath input in their Ocarina virtual wind instrument [19].

The touch screen is used as a means to input commands into many different applications, and is also used to display responses back to the user. Smule uses the touch screen to allow users to input finger positions in both the Ocarina and Magic Fiddle applications [19, 20].

Use of a mobile phone camera as input has been explored in the CaMus project [14]. The camera is moved over a grid which controls a musical performance when specific images are detected by the system. Specific gestures can be recognized such as rotating the hand around a control.

The development of gestures are further explored in the ZooZBeat [21] project, which uses a combination of touch screen and accelerometer to recognize a number of gestures,

including tilting, tapping and shaking. The gestures are used to control a re-mixing application on the phone, and to communicate with other devices.

3.5 Examining mobile HCI design issues

48% of all projects make specific reference to design issues influencing interaction. Most projects are concerned with solving their specific interaction problems, while other projects are concerned with establishing new methods of interaction between the user and mobile devices that can be universally used.

In the ZooZBeat [21] project the emphasis of the research has been to provide an intuitive interface to allows non-musicians to create music. Another project that focuses on musical interaction design is the Mobile Music (MoMu) toolkit [4]. The toolkit provides the procedure for manipulating the mobile sensors used by the Stanford Mobile Phone Orchestra for music making.

Other HCI oriented projects examine different aspects of using mobile equipment. The Music Mood Wheel project [1] seeks to use audio cues to reduce the stress of struggling with technology when searching for specific songs. The system will automatically find the song that best fits with the user's mood and context.

In the SpeedDail project [7] the aim is provide a generic interface that gives the user control to re-configure the mapping of input to output sound during a performance, and making this remapping process a feature of the performance.

4. COMPARISON OF MOBILE MUSIC PROJECTS

This section will compare the relative amount of activity that is conducted within different of categories of mobile music based on the number of papers published of each type. In addition the interests of authors will be examined in order to compare the relative activity between artists, researchers and commercial product developers. Finally the number of citations NIME papers have obtained will be examined to assess the influence that these projects have had on the wider community of researchers.

4.1 Comparison by project type

The 98 mobile music related articles and reports published at NIME were categorized using Behrendt's classification [3] of technological, social and geographic projects. As shown in Figure 1 the majority of papers investigates the technical aspects of the project (67 papers out of 98), while 46 were interested in the social implications of using the technology. Only 22 were concerned with the interaction depending on the geographic location. This shows that while there is significant activity in each of the categories that Behrendt described there is not equal effort in each category.

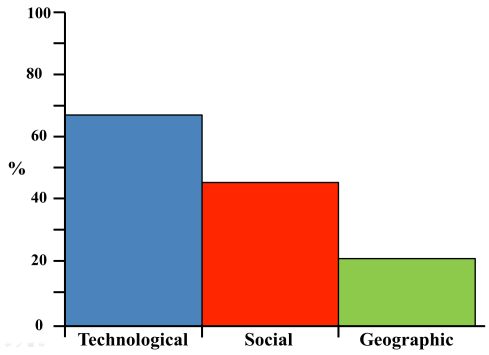

Figure 1. Comparison of Technological, Social and Geographical projects.

In addition to this imbalance of activities, there is much overlap between the technical, social and geographical projects, as approximated in figure 2. The amount of projects that are primarily concerned with discussing the technical issues remains the highest (43 projects). The projects that were concerned with investigating social implications of mobile devices (excluding the projects concerned with geographic issues) were evenly split between purely social oriented (15) and social and technical projects (15). Only three studies investigated geographic location issues without reference to the technological or social issues. More of the projects that were concerned with geographical location issues were also were also involved with investigating social issues (10) than were exclusively investigating the technological issues (3). This shows that while each category is being investigated, half of the projects that involve an investigation into the social issue of mobile music will also be investigating the technical issues, and the majority of projects investigating the effect of geographic location will be doing so as part of a wider investigation into the technical or social issues. Almost half of the projects investigating the technology supporting mobile music did so without referring to social or geographic issues.

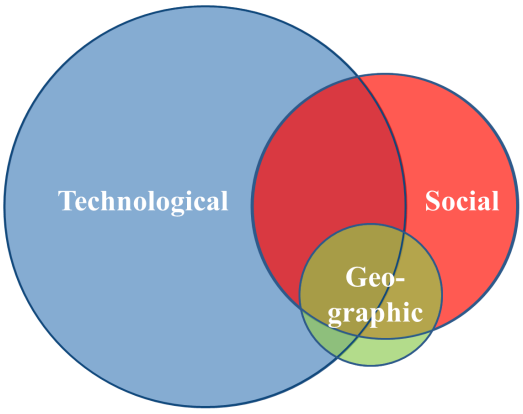

Figure 2. Distribution of Technological, Social and Geographical projects.

Next, the distribution between the three categories of was plotted over ten years.

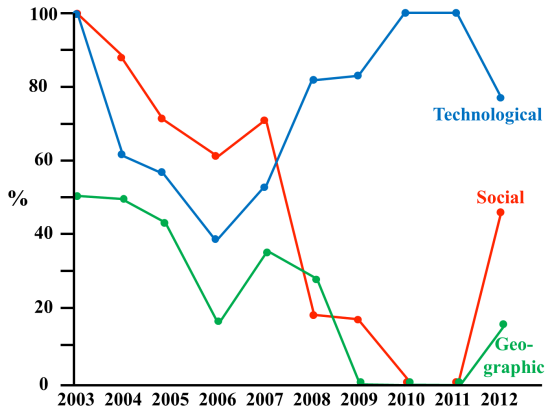

Figure 3. Percentage of Technological, Social and Geographical projects 2003-2012.

Figure 3 shows the overlap between the different classifications of project between 2003 and 2012. In 2003 all papers contained technical accounts of projects that were investigating social issues, while only half of these investigated the influence that geographic location had on the project.

All types of project fell as a percentage of the total in 2006. In that year the number of projects presented in the workshops expanded and therefore there was a wider range of topics covered, but with less room to discuss all the areas being investigated, so there is more apparent distinction between the projects.

After 2007 the trend shows a fall in the percentage of investigations into the social aspects and fewer investigations into the influence of geographic location. Between 2009 and 2010 the projects described were almost exclusively technical descriptions of products. This coincided with the explosion of the number of mobile phone applications that were developed. Also during this period the workshops had ceased and there were fewer mobile phone related papers published.

In 2012 there was a recovery in the number of projects investigating the social and geographical issues, which suggests that the capabilities of the latest generation of mobile phones are becoming established, and therefore less innovation is associated with creating mobile apps, stimulating a renewed interest in the exploration of alternative technologies.

As an alternative to the above classification of technological, social and geographic projects, the articles were classified in terms of whether they were surveys, products or artistic artefacts.

- The surveys include reviews of issues relating to mobile music and investigations into the social implications of mobile technology. This category also includes products that were developed primarily as a vehicle to investigate social interaction.
- The products category includes descriptions of physical product or conceptual frameworks that enable people to interact or create their own artefacts (both for research or commercial purposes).
- The artefact category includes papers describing the creation of products or performances where the prime motivation is the artistic output.

All papers between 2003 and 2012 were re-classified according to the category which they were most closely matched, without allowing individual papers to be counted in more than one category.

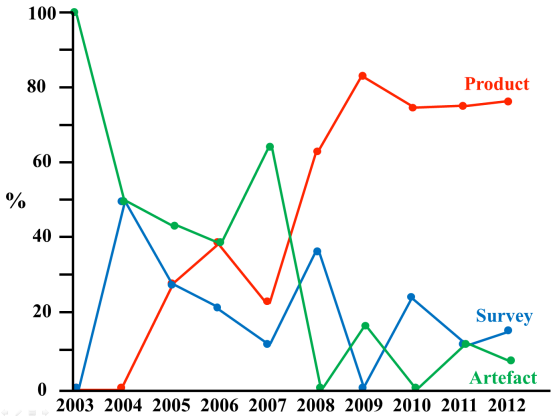

Figure 4. Percentage of Surveys, Products and Artistic Artefacts 2003-2012.

Figure 4 shows the percentage distribution of projects in the categories of surveys, products and artefacts from 2003 to 2012. This shows that while the first reported activity was almost exclusively artistic driven in 2003 there has been a significant reduction of the artistic artefacts described in papers. Similarly there has been a reduction in the number of surveys, while there has been a corresponding increase in percentage of products described in the literature.

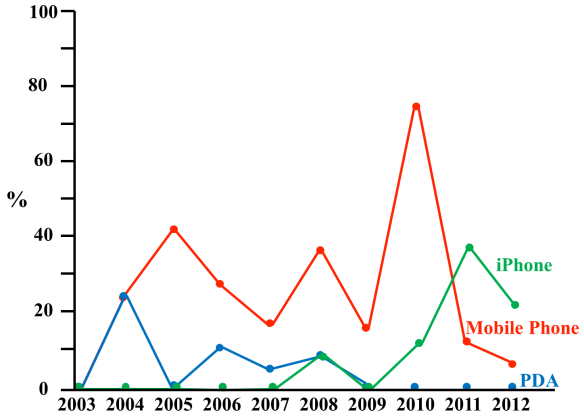

Figure 5. Percentage of projects developing for PDA and mobile phones 2003-2012.

The issue about papers describing development for mobile phones required further examination, and so the relative activity between projects developing different types of mobile device as a percentage of all papers were plotted in Figure 5. Initially development was performed equally on PDAs and mobile phones. A distinction is made here between iPhones and other mobile phones (including smartphones). As the capabilities and ownership of mobile phones began to outstrip PDA devices development switched to mobile phones, and the decline PDAs were matched by the introduction of iPhones.

The spike in popularity of non-iPhone mobile phones corresponds with the time when fewer projects were presented when the workshops ceased and the majority of papers chosen described the development of products. The more recent fall in mobile phone activity is partly due to separation of papers describing iPhone development, which overtook other types of phone in 2011.

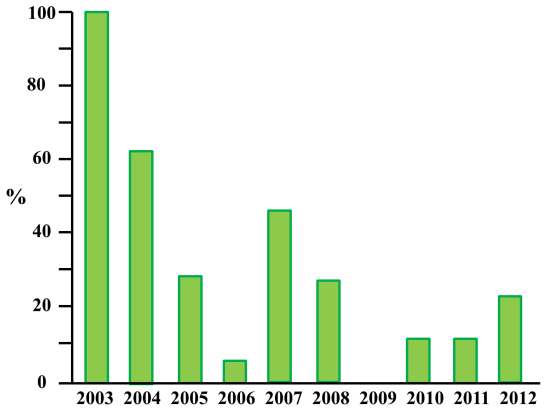

Figure 6. Percentage of projects developing specialized hardware 2003-2012.

One final classification of the literature was undertaken to identify the projects that developed their own unique hardware. The percentage of projects developing hardware between 2003 and 2012 is shown in Figure 6. In the early projects hardware devices were not available to meet the needs of the project without developing specialized hardware as part of the project. Then, as the capability of mobile phones increased the production of specialized hardware was not as necessary. As there was an increase in more projects using unmodified mobile phones there has been a corresponding fall in the number of projects developing their own hardware. In 2009 there were no projects that described the development of hardware as the

main activity. Since 2010 there has been a revival in the number of projects developing their own hardware which indicates there is more interest in exploring areas outside of producing applications for mobile phones. The hardware described in these projects are mainly sensors that provide data that has to be processed elsewhere, but as the processing power of mobile phones and other mobile devices increases it is likely that more processing will take place within the device in the future.

4.2 Comparison by author type

In addition to categorising projects by type, the authors of the papers were categorised in order to draw conclusions about their interests and motivations.

Between 2003 and 2012 the 98 papers published at NIME listed 223 authors and co-authors. This figure comprised 160 separate individuals, many of whom contributed to more than one paper. Author's interests were categorised by the type of publication and by examining the biographical information given within papers, on their personal web pages. Three main types were of author were identified:

- Artists (including composers and performers)
- Academics (professors, lecturers, PhD or MSc students or individuals attached to Educational establishments, Universities or Arts Institutes)
- Others (e.g. commercial manufacturers including employees at industry research centres, private companies, or individuals for whom the affiliation is not evident)

Authors often fit into more than one category, but they have been categorised here according to the type of publication and their declared interest, e.g. authors who describe themselves as artists or academics are counted as artists if they contributed to performances at NIME or authored papers that described performances, while artists who contributed to technical papers are counted as academics.

Table 1. Classification of all authors

Category	Count	Percentage
Artists	83	37.22%
Academics	121	54.26%
Other	19	8.52%

Table 1 shows the distribution of all 223 authors (counting individuals for each paper they appear as author). This reveals the majority of authors are academics (54.25%), but over a third are artists (37.22%).

Table 2. Classification of individual authors

Category	Count	Percentage
Artists	52	32.5%
Academics	90	56.25%
Other	18	11.25%

Table 2 shows the distribution of all individuals who were involved as authors (160 individuals) counting individuals once whether they contributed to more than one paper. This shows a higher percentage of academics (56.25%) revealing a high degree of collaboration between academics. The higher percentage of individuals in the other category (11.25%) also reveals a higher degree of collaboration between academics and commercial manufacturers of mobile devices.

Table 3. Classification of primary authors

Category	Count	Percentage
Artists	40	40.82%
Academics	49	50.00%
Other	9	9.18%

Table 3 limits the comparison to primary authors only excluding any co-authors (98 individuals) counting the first author listed in papers with one or more authors. Individuals are counted more than once if they were the primary author of more than one paper. This reveals a higher degree of artists being the driving force of projects (40.82%).

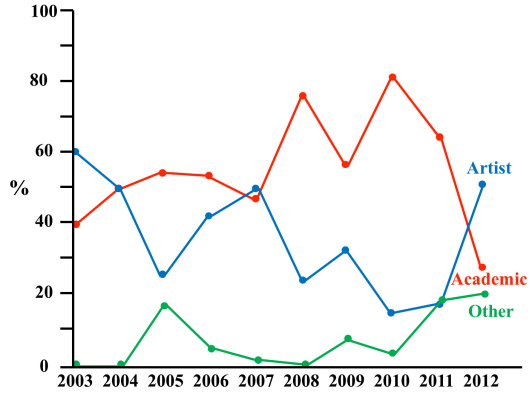

Figure 7. Classification of individual authors 2003-2012.

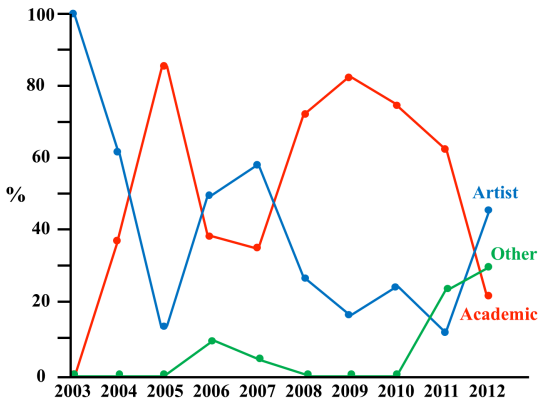

Figure 8. Classification of primary authors 2003-2012.

Figure 7 shows the percentage of all authors by classification each year between 2003 and 2012, while Figure 8 restricts the data to the primary authors only.

The authors of the early projects were primarily classified as artists but they were soon overtaken by academics. The effect is more extreme when viewing the trend of primary authors only (figure 8). The number of projects increased as a series of mobile music technology workshops were held between 2004 and 2009, and in the middle of this period the relative number of artistic projects increased again. The end of these workshops coincided with the increased interest in the development of new mobile phone hardware, and between 2009 and 2011 academics dominated the number of projects that were published, with an increased involvement of authors employed by manufacturers since 2010. Some of the authors who published as academics have since gone on to be employed by manufacturing companies. Recently there has been a revival in artistic activities represented at NIME and the number of artists who are first authors is increasing again.

4.3 Comparison of citations

The number of citations NIME papers have attracted as listed by Google scholar was examined to gain an appreciation of the attention that other researchers are paying to these mobile music projects.

By February 2013 NIME articles had attracted over 700 citations. Articles from older conferences have had most time to accumulate citations, and the highest ranked paper with over 100 citations was the description of Sonic City from 2003 [9]. This was a novel application that described the use of a wide range of sensors that makes it attractive to other researchers. The second highest ranked paper was the report on Mobile Music Making from 2004 [18] that described an early and influential system that supported collaborative music creation. The third ranked article was the article that contained the 2006 definition of mobile music [8]. Two other articles from 2010 are worth noting that have already attracted over twenty citations in just over two years: the report of the Stanford Mobile Phone Orchestra [13] and description of the Mobile Music Toolkit that the orchestra has used [4].

The difference in number of citations between August 2012 and February 2013 was calculated and it was discovered that NIME had picked up an additional 62 citations during this period, which reflects a healthy state of activity.

5. CONCLUSION

This paper reviewed the mobile music projects that have been presented at NIME over the past ten years in order to assess how changes in technology have affected the activities of mobile music researchers. The main difference has been the increase in capabilities of mobile phones. Early activities were dominated by artists (although in a relatively small pool of projects). The percentage of projects led by academic increased, and there was an increased focus on developing products, particularly mobile phone based applications. More recently, however there are already signs that the possibilities of the current generation of mobile phones are understood and innovations are being sought beyond their boundaries. There is also a re-emergence in the artistic related projects. The 2006 definition of mobile music still has a wide representation of projects within the different categories described, but the categories should not be regarded as mutually exclusive. The 2005 classification was useful to show the breadth of activities but does not give an indication of the relative activity within each category. The classification used in this to describe the range of activity attempted to divide the projects up in the main areas of interest.

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