technique | recording real pianos

piano principles

RECORDING REAL PIANOS

The piano comes in a variety of forms and is used in many different roles as part of ensembles and as a solo instrument. Many engineers regard the piano as the hardest instrument to record. **Hugh Robjohns** offers some practical hints and tips for getting the right sound.

The essence of recording a musical instrument is to capture the most faithful possible rendition of the performance without distorting the tonal quality of the instrument or veiling it behind undesirable mechanical noises. Every piano presents its own unique set of problems and solutions and in this workshop I shall be suggesting some practical techniques to provide a starting point. The key to recording any musical instrument is to position the microphone in the optimal place and this task is much easier with an understanding of how the instrument works, where the sound comes from, how it radiates from the instrument, and what its frequency and dynamic range is. So, as with all of my workshops to date, I will start with a brief review of the piano to get a feel of what is involved; for some background information on the development and design of the piano, see the 'A Little History' box.

Sound Creation & Radiation

The fundamental of any vibrating piano string tends to be the strongest component in its sound, although the higher harmonics are at least equally strong in the lowest two octaves due to the restricted physical size of the soundboard. At the lowest note (27.5Hz) the fundamental can be as much as 25dB below its strongest harmonics, though this is dependent on the design of the piano. At the upper end, the highest fundamental is around 4100Hz, with harmonics extending beyond 10kHz, although these tend to be relatively weak. The first partial above the top C is typically 20dB below its fundamental, producing an almost sinusoidal sound wave at these upper reaches.

> "Miking a piano is never easy; I have found it to be the most frustrating, yet

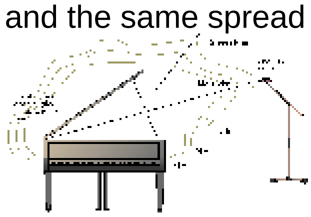
Much of the character of a piano stems from the range of harmonics it produces (many of which are not straightforwardly related to the fundamental) and noise components which are percussive in nature.

rewarding instrument to work with."

The mechanical noises are primarily between 200 and 500Hz for the lower notes, centre around 200Hz for the middle of the instrument's compass, and peak at about 1kHz for the upper regions. This last peak is typically below the fundamental of the notes and so is not masked as effectively as for the lower and middle regions, becoming more obvious to the ear as a consequence. These artefacts, as well as the harmonic components generated by a struck string, are all affected by the hardness and density of the felt on the hammers, as well as the dynamic energy with which the string is struck.

Perhaps surprisingly, the overtones of struck piano strings do not adhere to a strict harmonic frequency relationship because of the percussive nature of their resonance (compared to a continually stimulated stringed instrument), and tend to be slightly higher than the maths would predict. This phenomenon is particularly obvious in the higher registers of smaller pianos where the strings are stiffer than normal due to their required strength and shortness, and results in a less pure and sonorous sound quality.

With the dampers lifted, a piano will resonate for over 10 seconds in the middle registers and over 40 seconds in the bass strings, although the balance of decay times is very dependent on the construction. The top C may last around 3 seconds and the same spread of decay times is apparent within the harmonic series of a single note, with the fundamental or first partial lasting far longer than the upper harmonics. The dynamic range of a piano, measured at the rather distant reach of 10 metres, varies between about 85dBC and 70dBC for the loudest playing (the upper notes being weaker than the bass notes). At the quiet end of the scale, bass notes rest around 50dBC, with mid and upper notes falling to 37dBC.



The radiation of sound from a grand piano is determined fundamentally by its soundboard, but is complicated by reflections from the floor, lid and ceiling. The body of the instrument, as well as the lid, also significantly affects the radiation pattern towards the middle and upper frequencies. Further complications arise from the fact that the vibrations within the soundboard are not only shaped by the frequency of the vibrating string, but also its position on the soundboard. No wonder the instrument is so hard to record! In the lower registers, the sound radiation is largely symmetrical, although at 250Hz the sound level is about 5dB higher behind the piano (to the player's left) compared to the front, because the interference of the lid causes some cancellation of these frequencies which are generated out of phase at opposite ends of the soundboard. Consequently, when standing behind the piano these lower frequencies usually seem to localise below the instrument. The main energy lobe in the horizontal plane is directed forwards over a 60 degree angle to the player's right.

At middle frequencies, the open lid starts to reflect sounds out of the instrument with greater directivity (the long support typically angles the lid at about 38 degrees), with the best projection being forwards (to the right from a player's point of view), and upwards -- typically between horizontal and 55 degrees up. The timbre from directly above the piano is relatively dull due to the HF screening caused by the lid. In the horizontal plane the middle registers are radiated pretty symmetrically, although the rear bottom quarter of the instrument suffers from weakened fundamentals (up to 10dB down compared to the front).

The upper registers of the instrument are much more strongly affected by the lid, with a strong directivity between 15 and 35 degrees from the horizontal towards the front -- the upper edge more or less following the angle of the lid itself. Above and below these limits the upper harmonics can be as much as 10dB below the maximum found 'on-axis'. In the horizontal plane the main lobe is directed straight forward with a second lobe about 30 degrees towards the bottom end of the instrument. These lobes are only about 10 degrees wide for the highest frequencies, so to capture the true brilliance of the instrument a microphone must be placed within a relatively narrow 'sweet spot' (see page 185). The mechanical noise components of the instruments do not radiate in the same way as the musical sounds, and tend to be much stronger, relative to the wanted string sounds, behind the piano than in front. Not a good idea to mic a piano from behind then!

The changes to the sound radiation when the piano lid is closed are fairly obvious. The sound becomes duller as the high frequencies can not radiate as effectively, and the overall level decreases slightly. The radiation pattern loses its tendency to lobe upwards and towards the front, and a stronger lobe appears towards the player (principally through the opening behind the music stand). If the lid is half open, on the short stand, it sets an angle of about 10 degrees but, surprisingly, the radiation pattern is remarkably similar to the condition with the lid fully open. The principal radiation lobes are between 10 and 60 degrees again, although the maximum amplitude is less than with the lid fully open, particularly at the higher frequencies of course. The overall effect is of a slightly duller sound projection, without the full brilliance and clarity of which the instrument is capable.

Taking the lid completely off the piano really messes up the radiation pattern, with a reduction in energy in the horizontal plane and a marked increase in the vertical plane. All obvious stuff really, and it results in the tone of the instrument becoming duller, although this is very dependent on the proximity and reflective characteristics of the ceiling, and the tone often also becomes thinner as there is a pronounced reduction in the low-frequency components. The main high-frequency directional lobe in the horizontal plane is out across the player's right shoulder, about 60 degrees back from the main frontal axis, and upper-mid components (around 1kHz) are mainly directed behind the piano.

A Little History

The practical invention around 1709 of the '*gravicembalo com piano e forte*' is attributed to an Italian, Bartolommeo, who effectively combined the two most popular keyboard instruments of the time, the clavichord and harpsichord. He took the action from the clavichord, replacing its metal blades (which struck the string) with leather-covered wooden hammers, and incorporated the string-damping techniques of the harpsichord. His invention brought viable solutions for the three main problems with this kind of action: an effective mechanism to project the hammer to the string, an 'escapement' allowing the hammer to fall back without rebound regardless of whether the key has been released, and the controlled damping of the resulting sound.

The new instrument was proclaimed at the time as being capable of "producing a sound more or less powerful according to the force with which one depresses the key". However, although these early instruments contain all the elements of a modern piano, they were not an immediate success and much of the pioneering work was forgotten. An organist, Gottlieb Schroter, is often credited as the German inventor of the piano as he reinvented a suitable hammer mechanism in 1717, but it was not until the 1740s that the idea was widely accepted. Another German, Gottlieb Silbermann, came up with the 'Prell Mechanism' to solve the problem of rapid repetition of notes, and Andreas Stein added an escapement to this in the 1770s to produce the celebrated 'German or Viennese Action', which was when composers started taking the instrument seriously. Instruments of this period are generally known as Fortepianos and tend to have a rather dull and overdamped sound in comparison with modern instruments. Many of these pianos retained the overall shape of the harpsichord and resembled a rectangular table (hence the term 'square pianos') with the keyboard along the long side of the instrument, and the strings running perpendicular to the keys, with a single string in the bass and double strings in the treble.

Not all the development of the piano occurred in continental Europe, though; in 1783, John Broadwood took out a patent for an 'English Grand Action' which gained considerable fame for its "rich and powerful sonority". Frenchman Sebastian Erard produced his first piano in 1777 and built a considerable reputation under royal protection, but he left France in 1792 due to the Revolution there, and continued developing the instrument in London. His major claim to fame is the invention of the 'double escapement' in 1818, a mechanism perfected and patented by his nephew, Pierre Erard in 1821. This new action held the hammer close to the string so that notes could be repeated quickly without having to wait for the hammer to fall back to its normal resting position, and most of the major piano makers adopted the action under license -- Steinway in America, Bechstein and Steinweg in Germany, and Broadwood in Britain, for example.

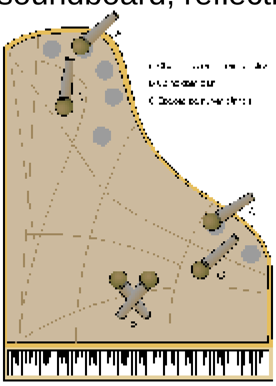
Around this time the piano had a compass of six octaves, *piano* and sustain pedals, and had acquired an iron frame which made it more powerful and allowed triple strings in the treble and single-wound steel strings in the bass. The iron frame of a full-size modern grand piano has to sustain some 20 tons of string tension! In 1828 the idea of an upright piano was conceived, with the strings arranged vertically and crossing diagonally to reduce the overall height, bass from top left to bottom right and treble in the opposite direction. It was in this domestically acceptable form that the piano conquered the drawing rooms of Europe through the end of the 19th and much of the 20th century. The instrument continued to develop in minor ways, Steinway introducing in 1880 a third pedal on their largest instruments to sustain the lowest three octaves independently of the rest of the keyboard, for example.

The modern eight-octave instrument employs felt-covered hammers to strike the strings and a damper mechanism which only damps the string when the key is fully released. A sustain pedal holds the dampers away from the strings regardless of the position of the keys, and the soft pedal either reduces the throw or travel of the hammers so that they strike with less force, or shifts their position so that they strike fewer of the available strings for each note.

Microphone Techniques

Miking a piano is never easy; I have found it to be the most frustrating, yet rewarding instrument to work with. Needless to say, the room plays a very important role, as does the position of the instrument within the room. Experiment with this aspect before you even plug a mic in, because if the instrument is setting off room resonances, the recorded sound will always be poor. I will initially consider grand pianos, then modify the techniques to suit uprights in the box below. There is no one perfect technique for the piano and, like many instruments, different performers can create totally different sounds from the same instrument in the same conditions, often requiring totally different mic techniques to capture the best sound. The suggestions below should only be taken as starting points, not complete solutions!

As with all instruments, the best sound is obtained at a distance where the blend of acoustic elements from the entire piano have combined into their composite form. However, because of the size of a grand piano (anything from five to nine feet long), this distance tends to be far greater than for any other instrument, putting rather more emphasis on the room acoustics and microphone technique. The required sound is a combination of all the constituent parts -- the hammers on the strings, direct radiation, sound emerging from the soundboard, reflections and guidance from the lid, and reflections from the floor and ceiling -- and these sources are spread over a wide physical area, so very close miking is unlikely to be successful! In my experience, this kind of technique typically results in over-emphasis of a particular aspect of the piano sound, producing a coloured and unnatural result, although it is often the only solution.



My ideal technique, used in a large nice-sounding room or hall, would be a coincident or near-coincident pair of mics (typically cardioid or hypercardioid depending on the required image width of the instrument) placed about four metres back from the front of the piano and about two to three metres up, positioned to be just below an imaginary line extending along the axis of the fully open lid. Moving the mics towards the tail of the piano tends to decrease brilliance and increase warmth, whilst coming round more towards the keyboard does the opposite. Often a move of only a few centimetres can make a large difference but there is usually a well defined position somewhere on that arc which sounds just right and a little experimentation will quickly locate it. Use microphones with the smoothest off-axis response and extended bass end if possible -- typically large-diaphragm capacitor mics like the Neumann KM86 or AKG C414. Many of the lower-cost electret mics are equally suitable, but avoid mics with presence peaks.

To save setup time, I would normally rig several pairs of mics in likely positions so that I can quickly compare them and home in on the best array. This helps to win over the pianist, who is usually keyed up to record and doesn't want hours of tedious rehearsing while you find a decent mic position!

It is a matter of personal taste, but for serious solo piano music I would set the microphones such that the piano occupies the central area of the stereo image, say from half left to half right, with the hall acoustic filling the rest of the sound stage. In an orchestral setting, the piano image would be smaller still, allowing it to nestle within, but forward of, the wider orchestra's image. A near-full width image might be more appropriate in pop music, particularly if the piano is not a solo instrument in the final recording. If you have a vocalist with the piano, make sure the vocalist mic is positioned to minimise pickup of the piano as the spill will produce unwanted coloration and reduce your control.

In pop music, the piano is typically recorded from a much closer and drier perspective, giving a perception of greater clarity and detail, and helping to reduce spill from other instruments. Moving the mics in much closer puts far greater demands on them as much of the sound is likely to arrive off-axis. Ideally, use omnidirectional mics, but if you need directional mics to reduce spill from other instruments it is essential that they have the most smooth and progressive off-axis response possible -- sharp dips or peaks in sensitivity at specific frequencies will become very audible as a coloration which can not be removed with desk EQ. It is also important that you don't position the mics too close, because the size of the soundboard and spread of the strings means you will over-emphasise a small part of the instrument's compass. Try to stay at least a quarter of a metre (nine inches) away if at all possible. In a professional studio it should be possible to position the piano so that it fires into a trap, or to position it within a separate booth, both of which will help reduce spill considerably.

There are lots of 'perfect' close mic techniques for the piano, although they are all compromised to some degree. It is worth experimenting with a variety of techniques to find the best for the particular situation. A single mic looking into the piano from about halfway around the curve, half a metre back and about 25cm above the lip can produce pleasant results for a mono contribution -- experiment with its position along the curve for the best balance. A very common stereo technique is a pair of spaced mics, one directly above the treble strings (typically an octave above middle C) and the other above the bass strings, both about a quarter metre above the strings. The top mic needs to be about a quarter of a metre away from the hammers and the bass mic positioned in the foot of the instrument where the smoothest bass response can be obtained. This technique works best with the lid removed or fully open to get the maximum effect from the

Upright Pianos

The constricted physical nature of an upright piano makes life even harder for the engineer than with grand pianos. However, we can immediately discard all the distant-mic techniques (see above) because the piano simply does not radiate sound in an appropriate way. The easiest technique is to open the top lid and mic from above with one or two mics as appropriate. Positioning the mics inside the cavity provides greater isolation but tends to sound coloured, particularly at the top end. Another good technique for isolation is to tape pressure-zone mics to the wall directly behind the soundboard (remove the casework first), or use a bespoke contact mic like the C-Ducers.

A better solution is to remove the kick board at the front of the piano below the keyboard and use a pair of mics to pick up the bass and treble strings to the right and left (respectively). Better still is to remove the back of the piano to reveal the soundboard, and use a pair of mics, one each side as before -- all the positioning rules previously discussed still apply. This gives rather less hammer noise and a better balance of sound to my ears, but make sure the piano is well away from walls -- the soundboard should be facing into the room, not the wall! If there is sufficient space, another technique is to put pressure-zone mics on the floor anything up to a metre away from the piano and slightly wider. It makes little difference whether in front or behind the piano.

soundboard, and it can be impossible to get sufficient height for the microphone at the bass end with the lid only partially open. The two mics can be panned partially left and right as required, but beware phase cancellations in mono. A way around this is to use a coincident pair of cardioids around the middle of the piano, but at a greater mutual angle than normal -- say 110 degrees -- to minimise the tendency to over-emphasise the strings directly below the mic. Again, mics with a very smooth off-axis response are essential: the more accurate and consistent the polar pattern, the better the results.

In general, placing mics closer to the hammers produces a more percussive and dynamic sound, but one lacking in sonority, sustain and warmth. It can be very effective in the right context, but beware transient distortion in the mics, mixing console, and recorders (particularly analogue recorders -- digital machines tend to have very accurate peak-reading meters); consider using microphone pre-attenuators, and leave more headroom than you would normally. Moving the mics towards the tail of the instrument generally reduces the dynamics and creates a richer, smoother sound, free of the clatter of the hammers.

If isolation is a real problem, pressure-zone mics can be taped to the inside of the lid in roughly the same positions as previously described with the lid open, half open, or even shut entirely (dress the cables carefully, though, so that the weight of the lid does not damage them). Apart from the inevitable CLANG as the tape supporting one of the mics gives up half way through the best take, this can be a very effective technique, although some heavy EQ is often needed to remove the boxiness when the lid is shut completely. The other solution to the problem is provided by contact mics like the C-Ducer range. These may be affixed to the underside of the piano, or on to the soundboard from above and give a very clean sound, and although it is rather strange compared to the natural acoustic output of the instrument, it is extremely free of spill!

"In pop music, the piano is typically recorded from a much closer and drier perspective, giving a perception of greater clarity and detail, and helping to reduce spill from other instruments."

Many engineers favour miking a piano in a rhythm-section context near its sound holes in the frame on the curved edge of the instrument, as this gives a good punchy sound and, with the lid closed, great isolation too. For a single-mic technique try a central sound hole, but I prefer two mics, one in the second hole from the top and the other in the first or second hole from the bottom. Position the mics so that they look directly into the hole and make sure that they are below the line of the closed lid. Use heavy low-table stands with felt or sponge on their base, and take care dressing the mic cables so that the weight of the lid does not damage them and they do not vibrate or rattle. Small omni mics work well in this application, and it is often worth using the pre-attenuators. This isolation can be further improved if necessary with heavy drapes over the piano (all the way to the floor preferably), although extensive EQ will be required to make the piano sound more natural and less closed-in -- particularly in the 2 to 6kHz region. Mics with presence peaks can be used to advantage in this context.

For the ultimate in isolation, do as Tori Amos does in her concert tours. Use a piano equipped with MIDI to drive a decent sound module -- the result is total isolation, which is perfectly suitable for live sound when the full band is playing. For the quieter numbers, revert to the mics over the piano. SOS

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