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# INTRODUCING THE HURDY-GURDY

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*Heer is the Queen of Fayere,*
*With harpe and pype and simphonye,*
*Dwelling in this place.*
Geoffrey Chaucer (c1340-1400)

## 1. INTRODUCTION

What did Chaucer mean when he spoke of the simphonye? He didn't mean the grand orchestral work that we call a symphony - these words were written four hundred years before the birth of Haydn, the "Father of the Symphony". What he probably meant was the instrument now known in English as the hurdy-gurdy. This instrument has had many names throughout history, and the name has had many meanings. A more complete description follows but, to avoid confusion, this is what is meant here by a hurdy-gurdy:

The hurdy-gurdy, sketched in Figure 1, is a stringed musical instrument with a body similar in shape and size to that of a lute or guitar. A wooden wheel about 100-150mm in diameter is set in the top plate, or table, on a shaft which is rotated by a handle at the tail end. The strings are stretched across this wheel, which has a smooth rim, rubbed with rosin, and which excites the strings by slip-stick action in the same way as a violin bow. Some of these strings sound continuously as drones and other melody strings (*chanterelles*) are stopped by a keying arrangement, to provide a scale over a range of about one and a half octaves. The *trompette* is an extra drone resting on a loose bridge (the *chien*) which is just stable - the string sounds in the normal way unless disturbed, whereupon the *chien* vibrates with a buzz. The disturbance is applied by jerks of the wrist as the handle is turned and provides rhythmic accompaniment.

Descriptions of the hurdy-gurdy appear in many romances, chronicles, religious manuscripts and learned treatises from the 13th century onwards, notably Michael Praetorius' *Syntagma Musicum* [1]. More recently, a historical review has been carried out by Palmer [2] and a new method has been written by Muskett [3], but apart from these the accessible literature is confined to a few descriptive articles, eg [4]. The acoustics of the instrument appears to have received no attention; this paper represents the first tentative steps of an acoustical investigation.

## 2. A SHORT HISTORY

The hurdy-gurdy first appears in more or less its modern form in Spain about 1150 in stone carvings on the portals of the cathedrals of Soria and Santiago de Compostela. These show a large instrument for two players, one of whom turned the handle while the other used both hands to operate the keys. This version, the organistrum, turned up also in England and France, but was

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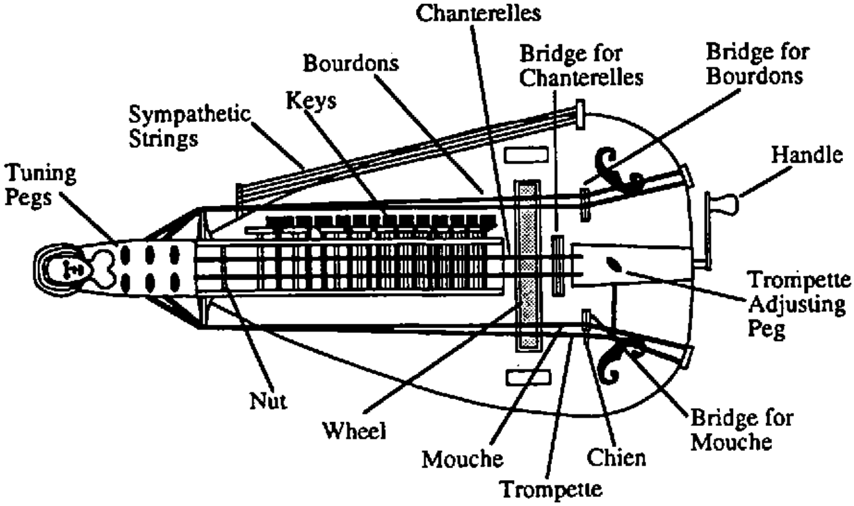


*Fig.1* . *Sketch of modern lute-backed hurdy-gurdy.*

replaced in the 13th century by smaller instruments played by one musician. These were known by names such as symphonie, chyfonie or armonie, although the term symphonie was usually applied to a form where the entire mechanism was enclosed in a rectangular box.

The *trompette* mechanism does not appear until the 15th century. It was first seen in a form generally known as the Bosch style; it is featured in a scene of Hell by Hieronymus Bosch (c1450-1516) depicting the damned being tortured on a harp, hurdy-gurdy, fiddle and several other instruments. The hurdy-gurdy is shown in precise detail: it has six strings, a *trompette* mechanism and eleven or twelve keys for a diatonic compass of one and a half octaves, so by the 15th century the hurdy-gurdy had all the features of modern instruments.

In the middle ages the hurdy-gurdy had been part of the stock-in-trade of the aristocratic troubadours and minstrels as well as being associated with sacred music, but in later centuries it declined in prestige and became an instrument of (usually blind) beggars. Praetorius [1] called it a "lyre for peasants and traipsing women". In the 18th century it enjoyed a revival. By now the instrument was generally called the *vielle à roue* in France, the *Drehleier* in Germany and the hurdy-gurdy or symphony in England, and the modern guitar- and lute-shaped forms had made their appearance. It became a status symbol to have a hurdy-gurdy. It was popular even in the great courts of Versailles and Munich, and some excellent instruments were made in this period with superb inlaid decorative motifs, or elaborate painted designs.

Behind the opulence of the upper classes, however, there was also the continuing misery of the lower orders. It was customary for poorer farmers and their families to take to the road during the winter, coming in large numbers from the Savoy region, and they became known as

"Savoyards". Traditionally they carried a hurdy-gurdy, a marmot in a box, and sometimes a portable peep-show; they spent the winter trying to earn a living by busking and cleaning chimneys. Thus, the hurdy-gurdy had become an instrument of the two social extremes but, in between, it had also established itself as one of the instruments (often alongside bagpipes) used to accompany singing and dancing throughout Europe. Before the end of the 18th century, the golden age of the hurdy-gurdy was over, and it never recovered this former status of pomp and glory, but it has maintained a more steady equilibrium in society in its folk role.

Now, at the end of the 20th century, there are as yet no signs that the hurdy-gurdy is becoming just a museum relic. To the contrary, although no longer played by blind beggars, in many parts of Europe it is regularly heard during festivals, weddings, village ceremonies and in concerts. In England, along with much of our folk tradition, it disappeared during the two World Wars but shared in the revival of the 1960's and 70's and now, although not common, it is played in many folk groups and early music ensembles.

## 3. THE WORKINGS OF THE HURDY-GURDY

A very brief description of the instrument was given in Section 1, and this will be expanded here; refer to Figure 1 for a sketch of the layout. Construction methods and materials are similar to those used in other stringed instruments.

The wheel is located in an opening in the table about 120mm from the tail end, and is usually laminated or built from segments for stability. The shaft is supported by internal struts. A piece of cotton-wool is wrapped round the strings where they touch the wheel to prevents damage to the strings and wheel, and to eliminate scraping sounds. Correct application requires some skill and, along with the amount of rosin, has a considerable effect on the sound of the instrument.

The keybox nowadays is wholly on the body, and usually takes up just over half the length of the table. The keys slide in slots in the sides of the keybox. On the stem of each key are two flag-shaped tangents which stop the *chanterelles* at the appropriate length when the key is pressed. These tangents are adjustable for fine tuning. The keys return to their normal positions by their own weight when released.

Most present day hurdy-gurdies have two melody strings and four drones. All the strings are adjusted by pegs in a pegbox similar to that of a violin except that it is often decorated with an ornate figurehead. Usually there are two low pitched drones known as *bourdons* (bumble bees), a higher pitched *mouche* (the fly) and the *trompette*. The *chanterelles* are carried by a large central bridge and there are two smaller bridges on either side for the drones which pass across the table on either side of the keybox. The *trompette* rests on its loose bridge, the *chien*, which slots into a groove at the base of the bridge carrying the *mouche*. It is adjusted by a peg on the tailpiece from which a short piece of string is arranged so that turning the peg pulls the drone tighter against the wheel. The *chien* usually has a triangular segment cut from its base so that it rests on two legs, and often a piece of ivory or other hard material is inserted in the table under the outer leg. Since the 18th century many hurdy-gurdies have been given four or six sympathetic strings.

Finally, most hurdy-gurdies have two sound-holes, usually circular or C-shaped. Some are fitted with a device to change the pitch of the *trompette* by a whole tone for playing in different keys, and all have buttons for attaching the straps needed to keep the instrument under control.

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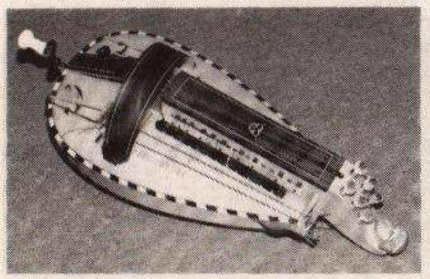

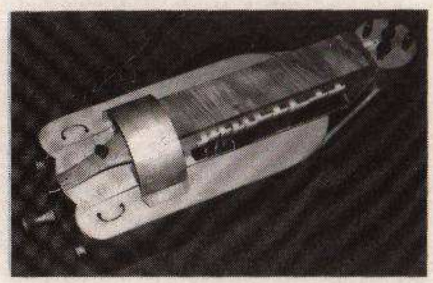

*Fig.2 The two instruments used for the initial measurements. The Eaton is on the left and the Bosch on the right.*

## 4. SOME MEASUREMENTS

In order to begin an acoustical investigation, some "opportunistic" recordings were made of sustained tones from single strings on two instruments. By opportunistic it is meant that no attempt was made to control conditions - the recordings were obtained when a hurdy-gurdy and a tape recorder both happened to be available. There is much wrong with these measurements, and this will be discussed further, but they satisfied the initial objectives which were to determine the characteristics of the signals, to decide on appropriate analysis techniques, and to formulate procedures for acquiring more meaningful data.

The two hurdy-gurdies, both of recent manufacture, are shown in Figure 2. The first was a lute backed instrument made by Chris Eaton of Upton-upon-Severn, and hereafter called the "Eaton". This had the full complement of two *chanterelles*, four drones including *trompette*, and four sympathetic strings, and was recorded on an elderly Akai 1720L reel-to-reel recorder using a Cammic omnidirectional electret microphone. The second was a simpler instrument of Bosch form, referred to as the "Bosch", made by Martin Turner of Redenhall and having only one *Bourdon* and no sympathetic strings. This was recorded with a Sony WM-D6C cassette recorder using a Sony ECM-909 electret microphone.

The recordings were made in large living rooms with the microphone about 600mm from the instrument, normal to the centre of the table. About 30 seconds of continuous tone from each string was recorded. These signals were then digitised at 8 bit resolution, and as both microphones and both tape recorders had nominal cut-offs of 15kHz it was initially assumed that a sampling rate of 32kHz would satisfy the Nyquist criterion; it was later confirmed that there was no significant energy above 10kHz for strings in their normal mode and none above 15kHz for a buzzing *trompette*. At this stage the equipment was not calibrated.

Prior to more detailed analysis, all data files were checked for clipping and normalised to an rms value of unity. The mean level was subtracted to remove any DC component. Figure 3 shows waveforms obtained from (A) the *trompette* (without buzzing) and (B) the *mouche* of the Bosch instrument. Both strings were tuned to $C_4$.

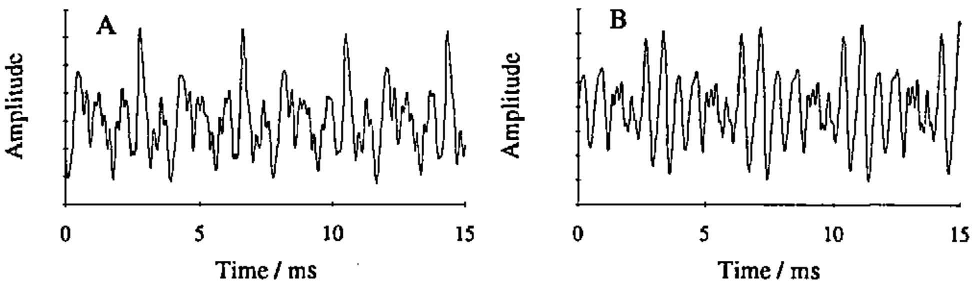


*Fig.3* *Waveforms recorded from (A) the trompette and (B) the mouche strings of the Bosch.*

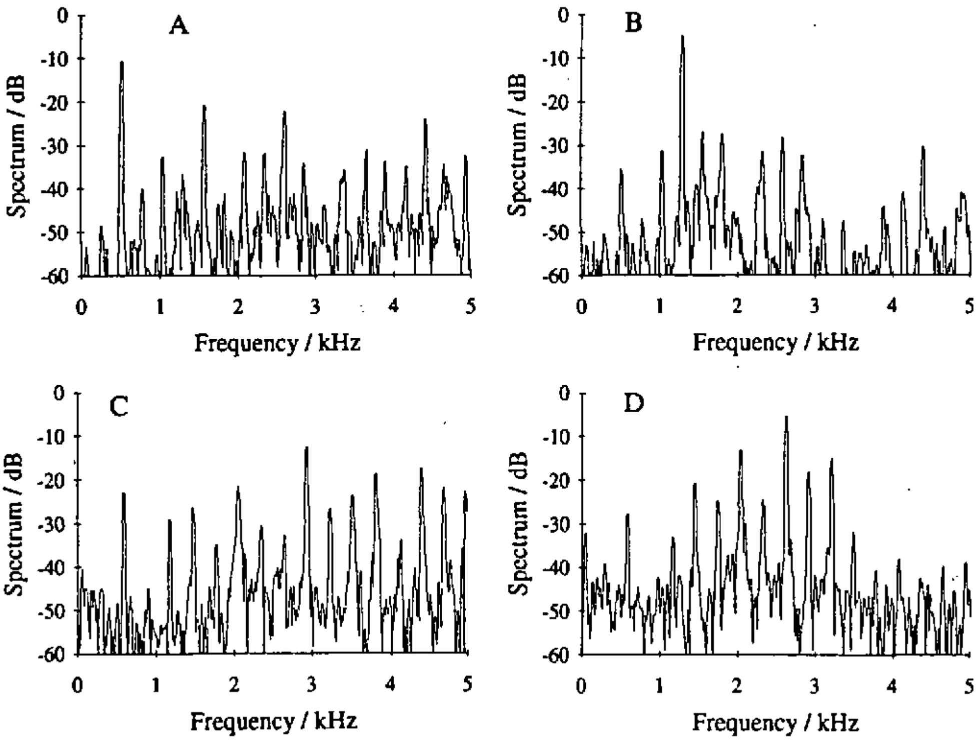


*Fig.4* *Spectra computed from (A) the trompette and (B) the mouche of the Bosch, and (C) the trompette and (D) the mouche of the Eaton.*

## 5. ANALYSIS

The first step in the analysis procedure was to compute spectra. It was known that it might eventually be necessary to estimate spectra by averaging over long records, that the lowest frequency of interest was about 70Hz, and that a precise estimate of harmonic amplitudes was required. Thus, spectra were obtained by averaging FFT's of overlapping windowed segments (see eg [5]). A Flat Top window [6] was chosen for its low amplitude error and sideband level, but at the expense of a wide noise bandwidth, but noise was not expected to be a problem. The segment length was set at 4096, with 50% overlap, giving an effective resolution of 30Hz. Some examples are shown in Figure 4, (A) and (B) from the *trompette* and *mouche* of the Bosch, and (C) and (D) from the *trompette* and *mouche* of the Eaton. It is easy to see that these tones have many overtones, that in each case the fundamental is weak, that the two *trompette* spectra are similar, and that the *mouche* spectra have a greater similarity with a broad peak around 1-3kHz. However, because of the quality of the data it is unwise to read more into these results.

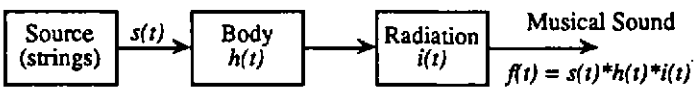


*Fig.5 Basic system for the production of musical sounds.*

Further analysis is possible, which may be more tolerant of uncertainties in the data, if a musical instrument is considered as the simple system shown in Figure 5. The source signal $s(t)$ is modified by resonances in the instrument body which are specified by impulse response $h(t)$, radiated, and further modified by the acoustics of the room which has an impulse response $i(t)$. The observed sound $f(t)$ is the convolution of $s(t)$, $h(t)$ and $i(t)$, and its spectrum $F(\omega)$ is the product of the source spectrum $S(\omega)$ and the two transfer functions $H(\omega)$ and $I(\omega)$. Algebraically,

$$f(t) = s(t)*h(t)*i(t),$$

$$F(\omega) = S(\omega)\cdot H(\omega)\cdot I(\omega)$$

and $$F(\omega) = \Im[f(t)], \quad S(\omega) = \Im[s(t)], \quad H(\omega) = \Im[h(t)], \quad I(\omega) = \Im[i(t)]$$

where $\Im$ represents a Fourier transform. The various components are multiplied in the frequency domain, making them difficult to separate. This problem is eased by expressing the results in decibels as taking logarithms transforms multiplication to addition, thus in terms of power spectra

$$\log|F(\omega)|^2 = \log|S(\omega)|^2 + \log|H(\omega)|^2 + \log|I(\omega)|^2$$

The components, however, still tend to overlap in frequency. A further Fourier transform preserves the additive property, and the components are often separated in the new domain. This is the cepstrum (see eg [7]), the power spectrum of the logarithm of the power spectrum, or

$$C(\tau) = |\Im[\log|F(\omega)|^2]|^2$$

The domain, $\tau$, is termed the quefrency, although it has dimensions of time.

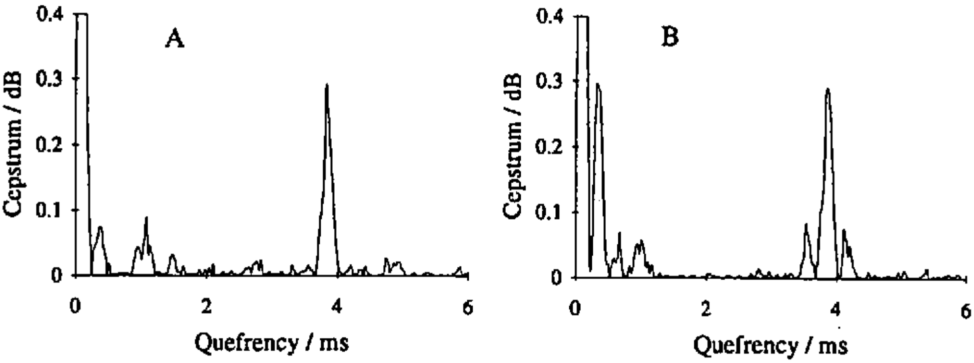


*Fig.6 Cepstra computed from (A) the trompette and (B) the mouche strings of the Bosch.*

When cepstra were first computed from the hurdy-gurdy data it was found that, because of the extensive series of overtones, the component due to the source signal swamped all finer details. This was overcome by restricting the bandwidth to 1kHz and results are shown in Figure 6 for (A) the *trompette* and (B) the *mouche* of the Bosch. It is immediately apparent that the peak due to the source spectrum at 3.8ms is well separated from the instrument formants, which are below about 2ms. The effects of room reverberation are outside the range of these plots.

There are many as yet unexplained features in these results: the symmetrical patterns about the source peak, the small peak in both plots at about 1ms, and the large peak (which has been clipped) close to the origin. Also of interest is the comparison between the single peak at 0.36ms in the *trompette* cepstrum with the two at 0.36 and 0.72ms in the *mouche* plot. It is suggested that these features are due to the different bridges - the main difference between these two strings. It is likely that such features can be identified by repeating measurements with minor alterations to the instrument - bridges and body plates damped, sound holes covered, and so on. It is also noted that, provided all computations are complex, interesting parts of the cepstrum can be isolated and inverse transformed to recover the relevant spectrum or transfer function.

## 6. DISCUSSION AND CONCLUSIONS

The opportunistic nature of these measurements has already been mentioned, and some discussion of their quality is required. The first problem is calibration. It might possibly be assumed that the recorders and sampling equipment are linear and have flat frequency responses over the range of interest, but it must be expected that inexpensive microphones are subject to variations in the order of ± 5dB. This error can of course be corrected once the equipment is calibrated, but it will not be possible to retrieve the absolute sound levels produced by the instruments or even the relative strengths of the different strings.

More fundamental is the acoustical environment. The measurements were made in large rooms with about $75m^3$ volume, $110m^2$ surface area, and 0.25s reverberation times. This implies a mean absorption coefficient of approximately 0.44. The recorded microphone signals are a mixture of direct sound and reflections, and the ratio of reverberant to direct sound $k$ is given by [8]

$$k = 7.1r\,(1 - a)^{1/2}\,(aS)^{-1/2}$$

where $r$ is the distance from source to microphone, $a$ the mean absorption and $S$ the surface area. For these measurements $k$ has a value of about 0.45, so the direct and reverberant signals are roughly equal. The standard deviation of the sound pressure level due to the random nature of the room modes [8] is approximately ± 5.6$k$dB, or ± 2.5dB. Thus, when the microphone response is also considered the potential relative error in these measurements is ± 7.5dB. Echoes could be removed by manipulating the cepstra, leaving only the direct sound, but what is really wanted is more reverberation.

The direct sound pressure level depends upon the directivity of the instrument and is subject to nearfield / farfield variations. A reverberant field measurement on the other hand depends only on the radiated power. Unfortunately, in real rooms the reverberant field is not truly diffuse and is subject to point to point and frequency to frequency variations, but this is easily overcome by averaging measurements from a number of independent positions throughout the room [9]. It is hoped to carry out such measurements in the near future.

Finally, there has been space in this paper for only the briefest history of the hurdy-gurdy and perhaps a hint of the style of music played on it. The hurdy-gurdy has a distinctive sound, although there is considerable variation between instruments, and it must be heard in its natural environment to be comprehended fully. The results obtained so far in this investigation represent the first steps towards explaining the sound and show that cepstral analysis has the potential for simply relating acoustical characteristics to physical and constructional features of the instrument.

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