Fractal correlation dimensions and discrete-pseudo-phase-plots of percussion instruments in relation to cultural world view

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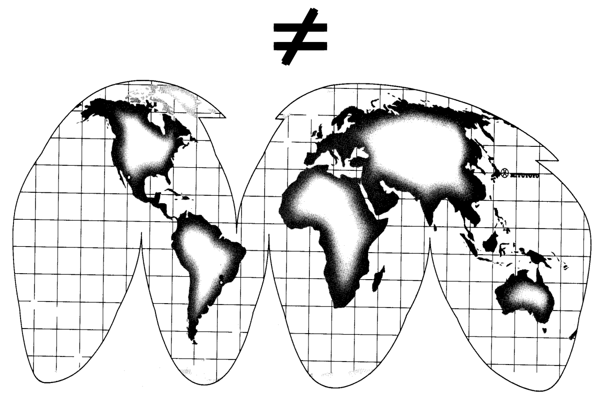
Abstract

Fractal correlation dimensions C and discrete-pseudo-phase-plots are presented for four percussion instruments to show basic kinds of persussion instrument behaviour. The xylophone and the churchbell - a small and a large instrument - are two western examples, which are shaped in a way to have - among inharmonicity - at least some harmonic partials. The tibetian zimbel and the javanese gong gede - again a small and a large one - are non-western instruments with just inharmonic overtone structures. The initian of the small instruments have C = 3.5 (xylophone) and C ≈ 6 (zimbel) within the first 25ms respectively 50ms. Then the inharmonicity dies out and it is C = 1 in both cases.The second integration time of the ear, which is about 50ms, makes it impossible for listeners not to perceive these initians as a whole, because of the shortness of the initian. So a real initian like in non-percussion instruments is present here. The large instruments on the other side keep their values throughout the first 400ms. The gong gede is the only instrument examined (which includes also non-percussion instruments in former studies), which can be struck in a way, that no chaoticity appears. The try of western music to have a harmonic structure in partials, which is not present e.g. in indonesian music is interpreted in terms of the different world views of these cultures.

Keywords: Percussion instruments, fractal correlation dimensions, discrete-pseudo-phase-plots.

INTRODUCTION

Initial transients of musical instruments are in many cases cruicial for identification of the instrument class [Reuter 1995,[1] Grey 1977,[2] Grey & Moorer 1977,[3] Wessel 1979,[4] Krumhansl 1989,[5] Iverson & Krumhansl 1993,[6] Mc Adams et al.1995].[7] In Multidimensional Scaling Technique (MDS) the similarity judgements of subjects are related to the physical parameters of the sound. It comes out, that three dimensions are enough to explain about 80 % of all judgements. The most



common dimension is the spectral centroid Z, which is

$$z = \frac{\sum \text{frecuency} \bullet \text{amplitude(fecuency)}}{\sum \text{amplitude(frecuency)}} \qquad (1)$$

So after transformation of the time series by FFT - or by Wavelet-Transform - the weighted frequencies, renormaliezed by the amplitudes is what is also referred to as brightness. The more higher frequencies with greater amplitudes exist, the brighter is the sound. It is widely agreed, that this is the best identification procedure for instrument sounds during the so called steady-state [Kostek 2001].[8] This steady-state is reached after about 50ms in general. But this range can vay a lot [Luce & Clark 1965].[9] So a piano sound has a transient phase, which lasts for about 2ms in a middle pitch region, while an flute organ pipe can take about 300ms to finally reach the steady state.

But this steady state is also not totally steady. It is also referred to as a quasi-steady-state. This is because instruments like the violin or the saxophone keep producing the tone after the initian by steady bowing

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or blowing. So during continuing the sound, there are wide possibilities of controlling it like canges in loudness, or brightness (the centroid) or through vibrato. In MDS experiments this feature comes out to be the second dimension. The instruments where the player is able to continue the sound, have during the continuation in a middle pitch region very good identification possilibities, e.g. the violin can be identified due to the bowing noise which is produced by steady glueing and releasing of the bow on the string. The release break causes a short impulse, which is the cause of the noise [Güth 1995].[10] The lip- and reed-driven instruments are said to have a formant region, a frequency band, in which the harmonic overtones have always higher amplitudes independent from the played pitch. The reason is a constant closing time of the reed or lip during the vibration over all playable notes of the instrument This causes a frequency band to act as formant, which can be seen by Wavelet-Transforms. But also these instruments are sometines hard to identify. The saxophone is very hard to distinguish from a clarinet in high regions. The fundamentals in the overtone structure get higher than the formats of the instrument. Also the initian is so short, that it can no longer serve as identification.

The third dimension in the MDS is the initial transient. It was referred to as inharmonicity. Investigations concerning the ‘chaoticity’ of sounds, namely the fractal correlation dimension and an information structure [Bader 2001 a, b][11, 12] showed that violins have the most complex initian with dimensions up do D=8. The reed-instruments like the clarinet and the saxophone are in a middle region - together with the classical guitar - and have dimensions around D=3. In was shown, that the value of the dimension is related to the overall rules, governing the sound. A harmonic overtone spectrum is D=1. Each inharmonic component above a certain amplitude threshold increases the correlation dimension by one. Also strong amplitude changes are taken as an own rule and again increase the dimension by one.

But the pitch and the musical expression of the player change the dimension from sound to sound. There is not a single dimension value for each instrument. This is caused by the fact that music is lively and rich and instruments are built, which have a hughe amount of degrees of freedom. The violin shows an independence of the dimension in regard of pitch, but a variety of possibilities with loudness and attack (hard or soft attack). The guitar on the other side is not so much dependent on loudness, but on pitch, because the lower strings are much more stiff and are not able to vibrate in very complex fashion. Although the clarinet is able to increase the sound continuesly after the initian and so avoids a hard attack, the low initian itself has never just a dimension of D=1, like the steady-state thereafter. But the pianissimo beginning makes the tone sound very smooth even with such an initian.

Now the initian of percussion instruments is caused by the most simplest driving mechanism: an impulse. This impulse has the strcture of a gauss distribution with a drift to smaller time values. [Borg 1983].[13] If the impulse would be a dirac delta impulse, it would have an continous spectrum (or white noise musically speaking). The impulse is not a perfect dirac delta, but serves here in the same way by driving all possible eigenvalues of the vibrating system nearly with the same energy. These eigenvalues or eigenfrequencies of the intrument normally need no more than at least one sinusodial period to be stable and so there is no initian as with the other instruments, which are mostly coupled vibration systems. But nevertheless do percussion instruments have an initial transient. This is because most of the driven modes are damped very fast. They appear just within the first 50ms or so and die out imeadietly. So they do not reach the time border of 50ms (second integration time of the ear) beyond which a clear pitch is percieved. They sometimes not even reach the first integration ear time of 5ms, which is at least needed to built up the critical bands in the coclea. So subjectivly for the listener, there is an initian, which is a ‘conscious unit’, that means, it can not be divided into smaller subpieces in means of perception or even analysed by the listener.

But there are also findings, that the initian sometimes is more complex. First, instruments struck by soft mallets can be damped by that mallet, which is not moved away from the surface of the instrument after struck quickly enough. This can be the case with large gongs, like the javanese gamelan gong gede, which is a about 80cm in diameter [Schneider 1998].[14] The backdriving of the gongs surface after the struck back against the mallet is relatively slow, but as the gong is played in a more meditativly way, the mallet is also moved not too fast. The mallet dampes the initian a bit, which is then expressed in the time series by an short amplitude breakdown after the initian. Then the sound continues with normal amplitude.

When interpreting the initian by fractal correlation dimension and discrete pseudo-phase-plots, each frequency component has an own dimensional value. This is, because most percussion instruments do not have an harmonic, but an inharmonic overtone structure. The vibration is one of bending modes, not of transverse vibration. Bending, which mathematically speaking is caused by the fouth derivation of the space variable compared to transverse vibration (of a string, air column etc.), which is the second derivation of the space variable is like the relationship of dependence of the curvature of curvature to just the curvature (because curvature is the second derivation in space).

$$\frac{\partial^2 y}{\partial t^2} = c^2 \frac{\partial^2 y}{\partial x^2} \qquad \text{(2a)}$$

$$\frac{\partial^2 y}{\partial t^2} = -\frac{E \bullet K^2}{\rho} \bullet \frac{\partial^4 y}{\partial x^4} \qquad \text{(2b)}$$

In 2b, the partial differential equation of the bending, x and y are the space coordinates, t is time, E is Youngs modulus, ρ is density and K is the radius of gyration. In 2a, the equation of the string vibration, c is the speed of the soundwave. As 2a has as solution a harmonic overtone structure, 2b when applyed e.g. to a rod has an inharmonic overtone structure independent from boundary conditions. These boundary conditions chance the eigenvalues, but they never come to be harmonic.

In western tonal music there is nearly always an harmonic overtone structure wanted. From a standpoint of the instrument builder this is much harder to achiev. The strings has to be streched with much tension, a drum skin has to be very thin but must stand strong pressures, when streched. The only easy example is an air column. And this also is the only way to get loud sounds without the use of a resonance body, which again acts with bending modes. So a harmonic overtone structure is much harder to achieve, because one has to overcome the gyration of mater.

The only western percussion instrument, which has a nearly harmonic overtone structure is the xylophone. This palisander stick has a cutoff so that the second eigenvalue of the stick is the double octave of the fundamental. [Borg 1983,[13] reviewed in Fletcher & Rossing 1999].[15] Also round percussion instruments, like some drums or cymbals have not only inharmonic relations, but also some harmonic ones, because of the the combination modes of ring- and radialmodes.

The used xylophone beam made of Palisol, which is a substitute for the rare wood Palisander.

METHODS

Fractal Correlation Dimension

Correlation dimensions are well known in fractal geometry and used to calculate a fractal dimension from a time series. The other fractal dimension calculations like the information dimension or the box-counting dimension are normally only used with two-dimensional fields, in which several points (i.e. measurement values) are plotted. There is no timelike relation between the plotted points, what matters is just the spatial distribution. These dimensions could be applied to more than two-dimensional fields, but the calculations are very complicated then (especially with the information dimension).

The dimensional-problem does not occur with the correlation dimension. High dimensions can be created easily. We have to keep in mind, that a 2-dimensional field as mentioned above may be i.e. a surface structure of a material and it would make no sense to transform it into a higher dimensional field. Time series on the other hand are originally just one-dimensional. So any higher dimensionality with time series is always artificial. But it is a way to describe the time series content in a more abstract way. To see this, we have to look first at the formalism of higher dimensional embedding.

The time series is embedded in a d-dimensional space which is done by forming vectors of length d. Their components are the values of the discrete time series of the sound, staring from time point t and taking the values t + n * δ, (n = 0, 1, 2, 3 .. d-1). δ is called delay variable and in this paper δ = 4 is always used with correlation dimensions. δ = 4 is the minimum value which causes correct results. Greater values can be used, but no smaller ones [Keefe & Laden 1991].[16] So taking δ = 4 and i.e. d = 5, the fist vector would consist of the amplitudes taken at time points (1, 5, 9, 13, 17). The second vector would be the amplitudes of the time points (2, 5, 10, 14, 18) etc. So in the end for a time series of N points, we have N - δ * d vectors (the last δ vectors cannot be formed, because the time series ends).

The reason for this embedding is, that complex time series are made simple (but with the disadvantage of high dimensionality). Would we take a sinusodial time series, in a two dimensional space, a circle would arise. If we add another sinusodial component, in the same two-dimensional space there would be seen a kind of Lissajous figure. But if the take a three dimensional embedding, this figure dissolves into two circles. For more complex time series higher embeddings are used. In theory, for a final fractal correlation dimension d, (2 * d) + 1 embedding dimensions have to bee used. In practise this is true for time series, which are very long and do not change through time. For transients, which are analysed in this paper with short and changing time series, much higher embedding dimensions are necessary. In short a harmonic overtone structure will result in a fractal correlation dimension of C = 1, no matter how many harmonic components there are. If just one inharmonic component is added, C rises by one. As an example, in Table I there are correlation values for a balinese xylophone with a loud inharmonic overtone structure.

Plate	$C_{initian}$	$C_{after\ 1s}$
1	6.8	2.5
2	4.4	2.5
3	5.5	2.0
4	3.6	1.5
5	6.5	1.2
6	5.0	1.3
7	6.5	2.5
8	3.5	3.0
9	6.5	3.0
10	6.2	3.5

Tabla I. Correlation dimensions of a balinese Gender dasa plates 1 (lowest) - 10 for the transient and at t = 1s after the initian. The value of the dimension is the amout of inharmonic overtones within the spectrum over a certain threshold. As the tone of this bronze xylophone is hearable even a minute after the struck, most of the eigenvalues of the plates are gone short after initian. These fast damped frequencies can be said to be the initial transient of the gender. The time intervall of calculation is both times 50ms.

The used balinese bronze xylophone Gender dasa, which means Gender with ten plates. The frame is usually with wood-carving. This one was bought by the auther directly from a manifacturer in the town of Sawang, Bali and is a single instrument not used in an orchestra before, a typical practicing instrument used by musicians at home.

Now out of the N-d * δ vectors a matrix is built, which represent the distances of each of the vectors from all others. Then the vectors-distances have to be counted, which are larger than a threshold r,

$$c(r) = \frac{1}{\frac{(N-n\bullet\delta)}{2}} = \sum_{k=1}^{N-n\bullet\delta} \sum_{1=k}^{N-n\bullet\delta} \Theta(r - |v(t_k) - v(t_1)|) \quad (3)$$

and normalized by, as can be seen in (3). The Heavyside function is 1 for the distance of a vector beeing geater than r and otherwise it is 0. The slope of the plot Log C(r) vs. Log r is the correlation dimension. The Log / Log - plot is the usual calculation method for fractal geometry, which seem to be a phaenomenon often found in nature [West 2001].[17]

Discrete pseudo-phase-plot

The second method used here is a visual representation, the discrete pseudo-phase-plot. It is based on the calculations of the d - dimensional embedding discussed with the correlation dimension. But here we have only d = 2, because the output should be a two-dimensional graphical representation. Now all the vectors created through the embedding are plotted into a two dimensional grid with a certain box size. All points falling into one box are counted, so this is also a kind of box-counting method known from fractal geometry. So each box has a certain value and therefore certain plot methods can be used to show the results (3D plot, density plot, contour-plot etc). Here a contour plot is used for a 3D plot would have to have a viewing angle and therefore the plot may not be represented in a good overall view.

The right box size is crucial for good results. For a very wide box would have too many points in it, so there would be no good differentiation. On the other hand, boxes that are too narrow may count just a few points (or even just one). This representation would be the same as plotting just the points in a two-dimensional array, which can be helpfull sometimes with time series, which are quite regular. The transient time series used here are more complex and it was found, that the discrete pseudo-phase-plots are a very good graphical representation for them.

Wavelet transform

Also Wavelet-Transforms are used here. This method is an excellent tool for small time series as transients, as one can zoom into the sound as needed. Also the relation of frequency vs. time accurancy, the problem of the uncertainty principle, can be choosen freely. Here a complex Morlet Wavelet is used [Haase et al. 2002][18] in the discrete form, because the input is the discrete sampled sound time series:

$$DWf(\omega,b) = \frac{1}{N} = \sum_t f(t+b) \bullet e^{-1/\omega_o \, t^2/2} e^{i\omega t} \quad (4)$$

Here, the Discrete Wavelet-Transform DWf depends on the frequency ω and the place in the time series (the physical time) for which the transform is done. f is the discrete time function and N is the actual number of time points, which are summerized. ω_0 is comparable with the time window in classical FFT. A larger value of ω_0 will separate nearby frequencies, a smaller value will show the detailed amplitude structure and frequency shifts.

RESULTS

To show the difference between western and non-western percussion instruments in their physical structure and in their sounds, four instruments have been analysed. With the two western instruments there is a small one - the western xylophone - and a large one - a churchbell. This idea was also used with the non - western instruments, a small one - the tibetian zimbel - and a large one - the javanese Gong "Gong Gede".

It is shown, that both western instruments are prepared in a way to have a harmonic overtone structure, while the two non-western instruments are not tuned like this. The reason for the - in western eyes - untuned manner of the zimbel and the Gong Gede can not be found in any carless construction. For the Gong Gede is found to be not exactly round, causing a vibrating sound, which represents the quality of the Gong. And the zimbel is made with beautiful handcraft and formed very precise in shape.

Tibetian zimbel

First we examined a tibetian zimbel, which is usually used in religios context. It is a small handbell and is 9cm in diameter and 7cm in hight without the stick. [For an overview of the vibration of handbells see Rossing 2001].[19]

The used handbell, normally used in religious ceremonies, e.g. in tibet.

Figure 1 shows the time evolution of the discrete-speudo-phase-plott for the first 400ms from initian. It shows up, that the initian itself has a correlation dimension which is about C ≈ 6 but very unstable, so the sound ist really chaotic. This can clearly be seen with the Wavelet - Transform (Figure 2).

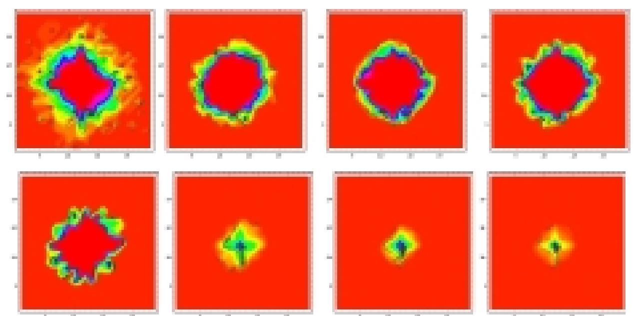

Fig. 1. Discrete pseudo-phase-plots of a zimbel. Time step: 50ms, last plot up to 400ms. Here C is just approximable for the first 50ms. There are too many frequencies. At least it is about C » 6 but there is too mach 'chaoticity' in the initian. But the second 50ms have a clear dimension of C=1.8, which decreases with time up to C=1.0 for a sinusodial. The sound of a zimbel also lasts for about a minute to die out, but here the higher harmonics are just present within the first 50ms over a certain threshold.

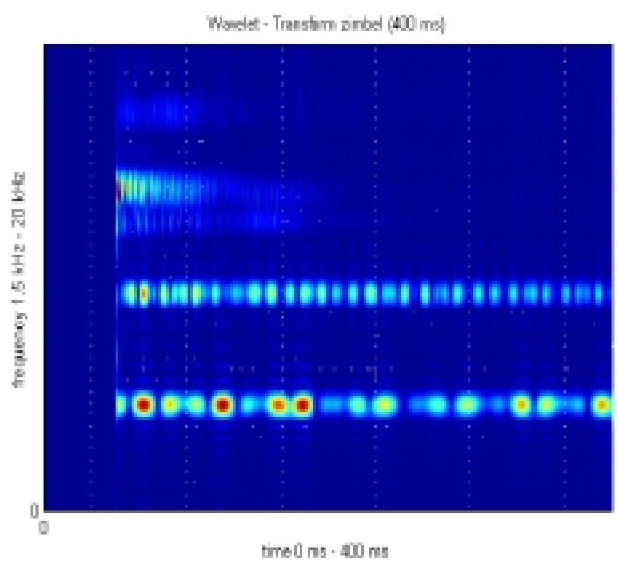

Fig. 2. Wavelet -Transform of the zimbel sound in the first 400ms.

The initian has broad bands of frequencies instead of discrete values. This would be very unusual for non-percussion instruments. But after this initian, the values decrease to between $1 < D < 2$, so there is just one strong harmonic partial left. The other partial in figure 2, that can be seen is much lower in amplitude. In higher regions over 10 kHz there are partial dying out very quickly. Also a constant amplitude oscillation can be observed in all partials. This is always the case in any kind of instruments. It may be caused by an interchange of energy between the modes.

Western xylophone

Next a xylophone beam was examined theoretically and experimentally. For the theoretical values a method of Borg [Borg 1983][13] was used. It takes the Rung-Kutta method to evaluate the eigenvalues. As the differential equation is fourth order, two Rung-Kutta algorithms are combined. The xylophone has a cutoff (Fig. 3) for tuning the second and third partials to the double octave and the fifth over the third octave (or the middle of the major and minor third over the third octave, which listeners found as the most interesting sound color). The first cutoff tunes the second partial, the second cutoff tunes the third partial. Now this cutoffs cause the radius of gyration to change throughout the beam. This changing can be modelled by the Runge-Kutta method, because this method partitions the beam. Each partition is given his own radius of gyration. For calculation of the correct eigenvalue, a certain value is estimated. This first extimation is not correct, but we increase or decrease this value as long as we found the right one. Now, the Runge-Kutta is calculated twice for one eigenvalue which different boundary conditions. The two curvatures of the beam w can be expressed as a linear combination of the two single versions with two constants C:

$$w(x) = c_1 w_1(x) + c_2 w_2(x)$$

Now the two curvatures are for the boundarys in x = 0 as $w_1(0) = 1$ and $w_2(0) = 0$. Only when the chosen eigenfrequency is correct, this is also fullfilled with the momenta - second derivation - and the force - third derivation - (which is not the restoring force). The results when reaching the end of the beam can be written in two equations, which only when both are satisfied, if the eigenvalue of.

$$\mathrm{M}(1) = 0 = C_1\left(\frac{d^2 w_1}{d^2 x^2}\right)_{x=1} + C_1\left(\frac{d^2 w_1}{d^2 x^2}\right)_{x=1}$$

$$F(1) = 0 = C_1\left(\frac{d^3 w_1}{d^3 x^3}\right)_{x=1} + C_1\left(\frac{d^3 w_1}{d^3 x^3}\right)_{x=1}$$

is correct. Then the determinant of the two equations becomes zero. The algorithm was implemented with the assumption of the first curvature being a sinusodial curve from phase $\varphi = 0$ to $\varphi = \pi/2$. When powered by values $p < 1$, the curvature becomes more flat. As there is no rule for the curvature, different values of p were used. A pure sine curve seems to fit best.

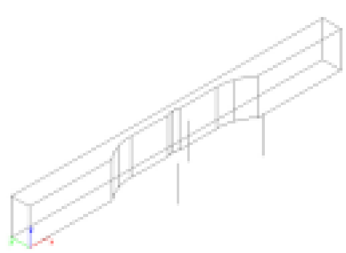

Fig. 3. Shape of the xylophone-beam of length 31 cm with two cutoffs, the large first cutoff and the small second cutoff in the middle. The length from top to the beginn of the cutoff is 8,2 cm, the curvature of the cutoff 3,0 cm, the way to the second cuttoff in the middle is 3,7 cm, the second cuttoff is 1,2 cm. The curvature is $\sin(x)^p$.

But in all cases, there was one mode missing compared to the measured results (Table II). The frequencies f1, f2, f5 and f6 of the theoretical calculations fit satisfying to the measured f1, f2, f6 and f7, but f3 and f4 (theoretical) face f3, f4 and f5

Measured f1 260,1 Hz f2 1055,0 Hz 24,1 cent + 1 Okt f3 2658,1 Hz 423,9 cent + 3 Okt f4 4954,6 Hz 302,0 cent + 4 Okt f5 6496,8 Hz 771,1 cent + 4 Okt f6 8198,1 Hz -26,2 cent + 5 Okt f7 10 324,3 Hz 373,0 cent + 5 Okt	**Theoretical (p = 1)** f1 263,1 Hz f2 1050,4 Hz -3,5 cent + 2Okt f3 2912,3 Hz 561,5 cent + 3 Okt f4 5814,2 Hz 3558,4 cent + 4 Okt f5 8279,1 Hz -29,7 cent + 5Okt f6 10 688,2 Hz -413,1 cent + 5 Okt
Theoretical (p = .7) f1 261,9 Hz f2 1030,9 Hz -27,9 cent + 2 Ok t f3 2808,2 Hz 5072,0 cent + 3 Okt f4 5644,4 Hz 3515,7 cent + 4 Okt f5 8245,5 Hz -28,2 cent + 5 Okt f6 10 691,6 Hz 421,6 cent + 5 Okt	**Theoretical (p = .4)** f1 259,6 Hz f2 997,6 Hz -69,3 cent + 2 Okt f3 2648,0 Hz 420,0 cent + 3 Okt f4 5368,9 Hz 444,3 cent + 4 Okt f5 8143,1 Hz -34,5 cent + 5 Okt f6 10 712,2 Hz -4140,2 cent + 5 Okt

Tabla II. Measured and calculated eigenvalues of a Orff-Xylophone beam of length 31 cm. It can be seen, that for all curvatures p = 1, p = .7 and p = .4, there is one mode missing compared to the measured values. This may be caused by a mixed mode of longitudinal and transversal bending. All of the values exept for the fundamental frequency exist just within the first 40 ms after the struck.

(experimental) with no clear connection. There seems to be a combination mode along and perpendicular to the beam length, which causes a new eigenvalue. In theory, the beam was assumed just as beam, not as plate which has combined modes.

The phase-space in figure 4 shows the time evolution of the xylophone. The fractal correlation dimension is C=2.5 in the first 25ms. Then it decreases to 1 < C < 2. The low value for the initian is explained due to three partials beeing in harmonic relations as mentioned above. A harmonic overtone structure has the Dimension C=1, so here at least 1 more overtone is present in the sound. The second reason here is that the beam was struck as soft as possible. But even then a dimension of C=1 for the initian can not be reached.

Churchbell

After the results for small instruments, here the xylophone and the handbell zimbel, two large vibrating systems, a churchbell and a gamelan gong gede are examined.

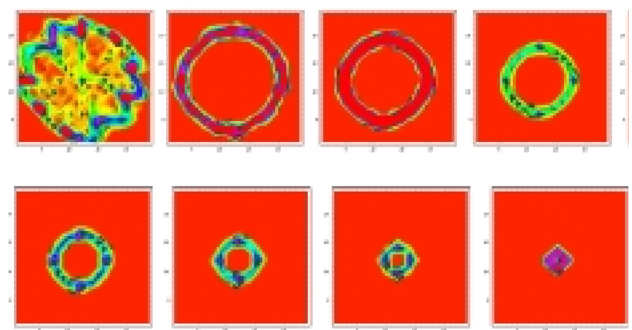

Fig. 4. Discrete pseudo-phase-plots of a palisander Orff-xylophon. Time step50ms. Like in the case of the zimbel, the first 25ms have C=2.5, which is not so much, because the strike was as smooth as possible. But even then there are at least 4 overtones above the threshold, because the xylophon has three harmonic partials, which would rise to a dimension of D=1. But the higher partials die out quickly for only the time interval 25ms < t < 50ms has a dimension of C=1.5. This can clearly be seen by the nearly perfect circle in the second picture of this figure. Also the overall amplitude of the sound decrease quickly. Because of a high sampling frequency of 96kHz, it was possible to calculate a dimension within only 25ms istead of the usual limit of 50ms.

The churchbell sounds for a long time. Figure 5 shows the phase-plot evolution. There seems to be no fundamental change through time, which is also expressed in the correlation dimension value of C≈3.5 throughout the 400ms. A churchbell also has a kind of tuned overtone structure with octaves and normally

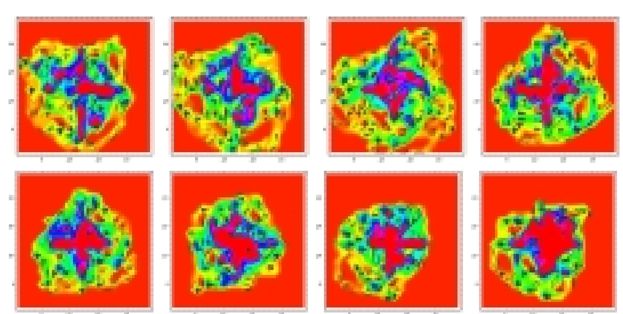

Fig. 5. Discrete pseudo-phase-plots of a church-bell. Time step: 50ms, last plot up to 400ms. The fractal dimension of C = 3.5 does not change during the sound. Church bells continue their sound long after initian. Because of the finite number of points in a sampled sound interval, it hardly possible to calculate fractal correlation dimensions for time

a minor third [minor-third bell see Rossing 2001].[19] So this value of 3.5 means at least two strong additional overtones added to the harmonic structure. As a characterization of a churchbell it is said, that the initial struck is bright and first the prime tone is heared as a fundamental. But after a while the so called hum tone, which is an octave beneath the fundamental is accepted as the fundamental, because the higher modes died out. But this lasts more then 400ms. So here it can be seen, that compared to the smaller instruments, the compexity of a church bell stays on, as expected. The initial burst of inharmonic high components in a Wavelet-Transform is was found, that this special sound actually do not have an initial struck, the partials are just starting, which itself is heard as a struck. But the sound itself is percieved still as a normal church bell sound.

Javenese gong «Gong gede»

The last example is that of a javanese gong gede with a diameter of d ≈ 80cm. It is the only instrument we observed which has a correlation dimension value for the initian C < 2, which means there are no large inharmonic overtones or any other chaotic behaviour. figure 6 shows the time evolution in phase-space. The pictures show a clear circle which is getting larger and smaller. This is due to the so called 'ombak'. The diameters of the gong are not exact equal. So for each diameter there are different mode frequencies, which vary only a bit. The result is an amplitude oscillation, a beat, which is a quality criterion for that gong. But of course this does not change the dimension. It could only do so, if a very large time window would be used for calculation. The listener hears a very low sound with the ombak and without a certain initian just due to the fact, that the sound starts.

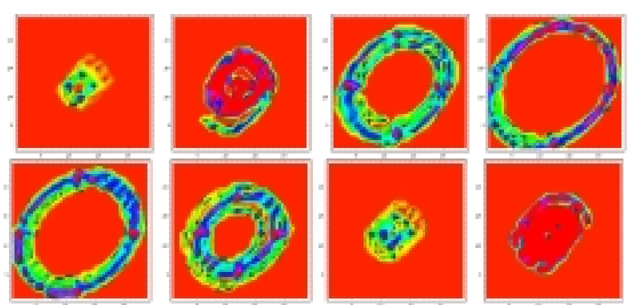

Fig. 6. Discrete pseudo-phase-plotts of a Gamelan Gong Gede. Time step: 50ms, last plot 400ms. The Gong has a strong fundamental frequency and so is one of the few examples, of a correlation dimension of C = 1.3 throughout the initian (a sine tone would have a circle in the phase plot, which is also the case here). The beakdown of amplitude towards picture 7 of this series and again an increase in picture 8 shows the so called 'ombak' of this Gong.

But in musicology not only the pure sounds have to be analysed. There is also a need of an interpretation in terms of what music means to people. Although a detailed discussion is beyond the scope of this paper, just a few ideas should be presented here. The hermeneutical interpretation of music is derived out of analogies between the structure found in the musical syntax or sound and the structures underlying non-musical terms. [For an analogy between the world view of cultures and the music they use see e.g. Bar-Yosef 2001].[20]

In terms of musical syntax a very widely known concept is that of tention and relaxation, of kinetic and static energy in the musical flow [Kurth 1931].[21] A possible analogy in terms of an inharmonic overtone structure is the missing fusion of sounds. [A review of fusion as used by the phenomenology and gestalt-psychology especially by Stumpf see Schneider 1997].[22] Fusion means, that in the case of a hamonic structure, the listener is not able to perceive the singel sinusodial components out of the sound. Fusion is a hole of individual components. But these components do not loose their individuality through fusion. Rather without these individualities, fusion would not exist. Inharmonic overtones are not fused. Every component is heard as a single one.

The inharmonic structure can be refered to the hindu religios concept of many diversive parts existing next to each other, but without a need of a common rule, for a hindu does percieve god as the nature of all things in all things [which may be compared with Heideggers „Ding an sich", which means existence per se].[23] Just the pure existence is the common rule, not a special individual property. The Western thinking in contrast is hieracically. There is a search of common rules building up the structure, which are found in a common fraction of the sinusodial frequency values. The connection between the harmonic / inharmonic overtone structure and the world view is argued to be through the consious space being the same in both cases. If we hear an inharmonic sound, the conscious space, in which we are in that moment, is one of diversive things existing next to each other without a common denominator.

The same thing happens, if we imagine - or have to deal with - different diversive cultures, which are all at once in our consious field. The subjects are different - here overtones, there cultures - but in abstraction, it is the same experience we make. This can also be refered to by the fact, that all sensual information adapted by different senses all end to be activation potentals in the nervous brain system. This may be the cause of many spacious words - derived from vision - in terms of music (high / low pitches etc.). The cultural diversity is more abstract than that, but it may be the same phaenomenon on a higher level.

Of course we have to be carefull in this field, because analogies work in some places but can fail in other example. Hindu religion also have a hierarchy of gods and know hierarcical structures. But they also have the world view mentioned above and this can be refered to with the problem of inharmonic spectra. So like in statistical empirical work, just tendencies can be found. In the case of Bali, where I did some field work, the analogy is quite obvious and the hindu concept of accepting foreign ways of thinking is a major part of the incredible continuation of tradition in Bali. For each year there enter the same amount of tourists the island, than it has inhabitants.

CONCLUSION

There is a try with western percussion instrument to create an harmonic overtone structure by verying the shape of the instruments. This try is not found in indonesian culture among others. The reason could be found in the different world views of these cultures. The hindu thinking of the only common feature of all things being the existence of these things is different from the western view of a hierarcical structure of nature, which is found in the cognitive fusion of harmonic partials in just one not seperatable sound sensation.

Also a special behaviour is found with the percussion instruments discussed here compared to non-percussion instruments. Normally non-percussion instruments (as discussed in the introduction of this paper) are not able to start without a kind of chaotic behaviour or a strong complexity. But with one of the here analysed percussion instruments - the Gong Gede - there actually is no such chaos within the initial transient. This is unusual and may be caused by the hugh weight of such a big instrument as a gong, for also the churchbell does not change its correlation dimension value through time.

As expected, larger percussion instruments keep their complexity for a much longer time. So their initian - if one should say so - is very long. On the other hand, small percussion instruments have such a short initian, that it is beyond the second integration time of the ear and can just be perceived as a whole. They have a real initian like non-percussion instruments - the violin or the saxophone as discussed in the introduction. Short after the inition, the fractal correlation dimension decreases to $1 < C < 2$, so just one strong sinusodial partial is left behind (or only the harmonic overtone structure, when talking in terms of non-percussion instruments).

These findings like everything in experimental data in music are just tendencies. There may - and there will - be found exeptions.

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