Violin sounds are chaotic

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Among sounds of many instruments, sounds of strings have one of the most complicated patterns. For example, the sounds of a violin show complicated twisted orbits. Since these orbits looked like a strange attractor, we wondered whether or not the sounds of violin are of deterministic chaos, which is a question we will answer in this talk.

Until now, many physicists have tried to model the sounds of strings. Although a number of researches have constructed mathematical models of strings, there are few researches that have analyzed real data observed from string instruments such as violins. Here, we make clear the nonlinear properties of violin sounds using methods of nonlinear time series analysis.

Although there are many definitions of deterministic chaos, their common requirement is sensitive dependence on initial conditions. As for an index of sensitive dependence on initial conditions, the maximal Lyapunov exponent is often used. We estimated the maximal Lyapunov exponent using the method of Kantz and found that it is positive. The positive maximal Lyapunov exponent is a sign of deterministic chaos.

However, there are some concerns that random time series may also exhibit a positive maximal Lyapunov exponent. To eliminate these concerns, we used 4 different surrogate tests with the Wayland statistic as a test statistic. The results show that violin sounds are nonlinear and have determinism beyond pseudo-periodicity. Our results show that violin sounds are likely to be of deterministic chaos.