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School-Use Seismographs Employing 3D-Printed Parts -Subsequent Developments and Practical Issues-

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OBJECTIVES （研究の目的）

Purpose:

i) To build a standard procedure for seismograph making and preparing for classrooms.

ii) To evaluate observation circumstances for not specialized situations of schools and homes instead of a prepared site or conditions.

iii) Based on the above evaluation, to establish a standard method not only for teachers but also for students themselves.

iv) To collect local and foreign seismograms for geoscience classroom use.

SEISMOGRSPHS（地震計）

The system details were already presented at JpGU2022. Please refer to the reference or the web.

http://seagull.stars.ne.jp/2022_JpGU/ePoster/index.html

Here, a simplified overview is presented.

Bodies and Pendulums:

A 3-D Printer Ender-3 pro used using PLA+ filament

An iron coil spring is used for the vertical pendulum suspension. Phosphorous copper thin leaf-springs are used for pendulum pivots.

Electro-magnetic Sensors:

Lathe-winding coils and Neodymium magnets

Electronic circuit:

Integrated amplifier, level-shifter, and low-pass filter (Now we were out-sourcing for PCB as described later)

Micro-controler (A/D converter):

Arduino Uno R3

Software:

Arduino IDE + own-made Processing code

PC-based logging system:

Linux Mint (OS) is installed for signal displaying and recording. Some Windows PCs are also used.

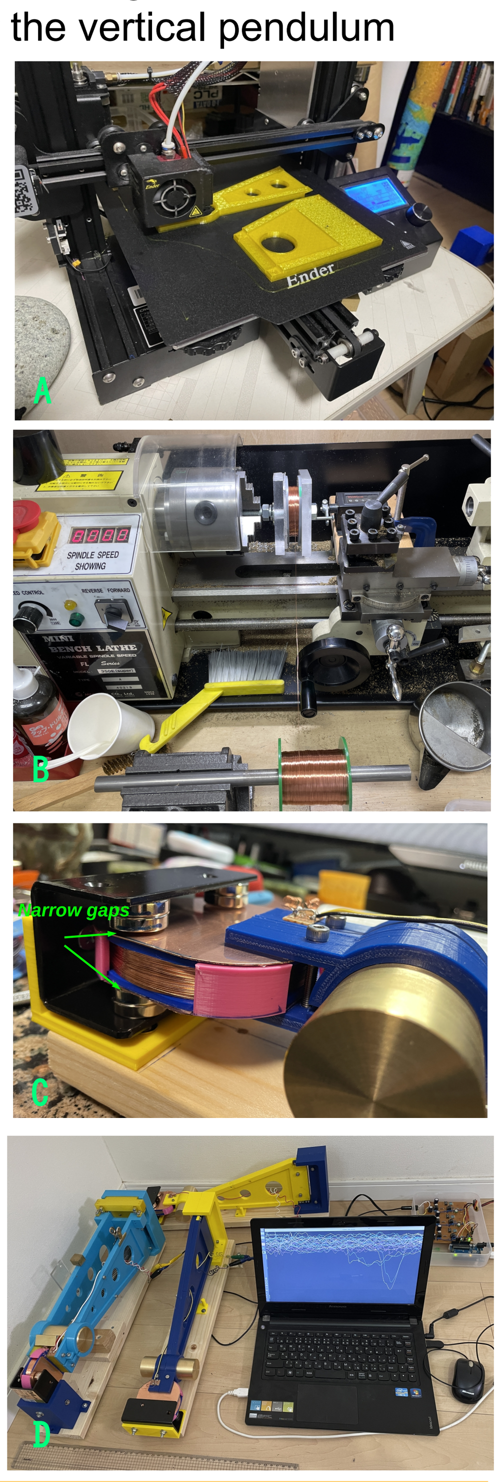


Fig.1
A. 3D printing by Ender 3 Pro
B. Coil winding on a lathe
C. Magnetic circuit
D. Whole system

IMPROVED POINTS（改良点）

1. Making processes are improved

The following is our assembly example of a horizontal seismograph and a magnetic circuit.

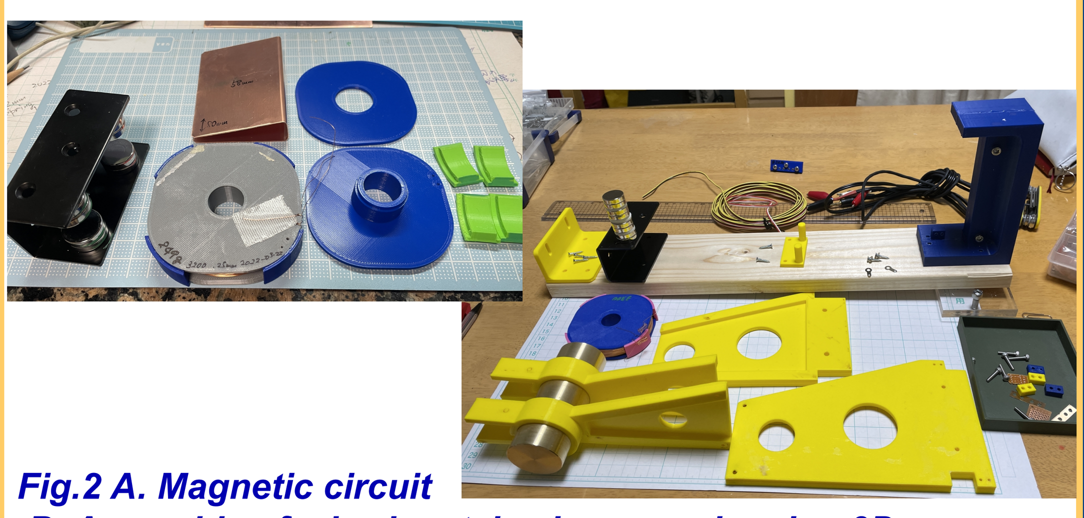


Fig.2 A. Magnetic circuit
B. Assembly of a horizontal seismograph using 3D printed parts and some other materials.

2. Out-sourcing of some materials

I) Main coil spring of the vertical pendulum

Please refer to our previous presentation.

ii) Printed circuit board made by a Chinese factory

As mentioned in the later chapter

OBSERVATION SITES（観測サイト）

Observation sites:

A mid-school science room, a university office, and author's houses: These sites are not prepared with a special situation for seismic observation.

School or Office:

Fig.3 Observation sites at Shinoda Mid-School (left, in a science room, 2F Building) and Taisei-Gakuin University (right, in a staff office room 2F, Building)

Private Houses:

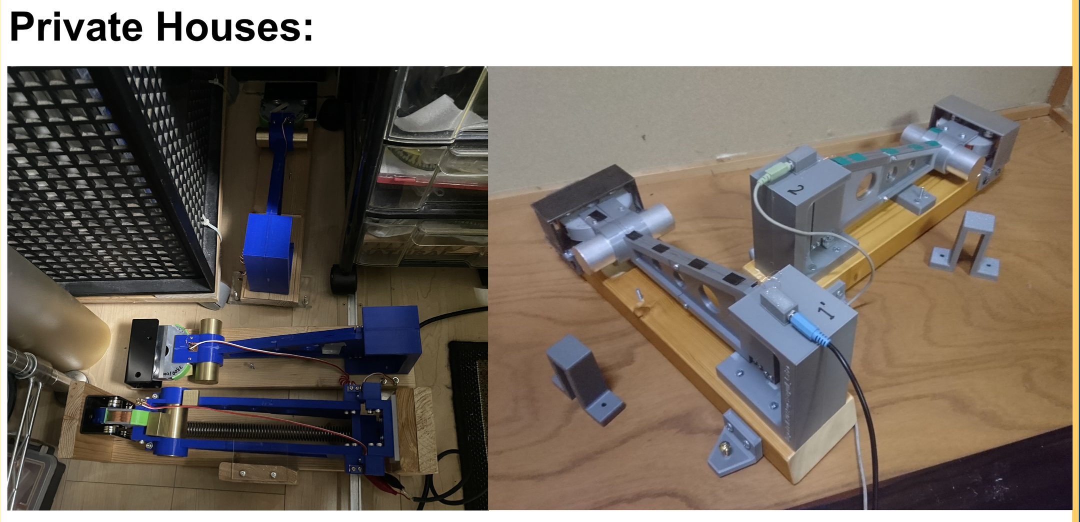


Fig.4 Observation sites at the first author's home (left, in a closet 2F, wooden house) and the fourth author's home (right, in a room 1F, wooden house, no vertical comp.)

SEISMOGRAMS （地震波形）

After several months of observation, we were vexed with vibration noises and some equipment malfunctions;

i) Some show short-time noises caused by humans or traffic around the recording sites, particularly in the daytime.

ii) This seems to be caused by soft ground bases and not rigid building structures

iii) Such noises are particularly severe on cold, windy wintertime days when the strong sea waves hit the seashore and cause long period tremors (2 to 6 [sec]) invading land areas.

iv) Therefore, we sometimes can not distinguish the natural earthquake signals from these long period noises.

v) We encountered some malfunctions; PC troubles, mechanical errors (the coil contacts the magnet, etc.)

vi) Nevertheless, many seismograms (local and teleseismic) are recorded, particularly on mild weather days and in calm night-time conditions.

Now, here are some examples:

<Daily and weather-generated noises>

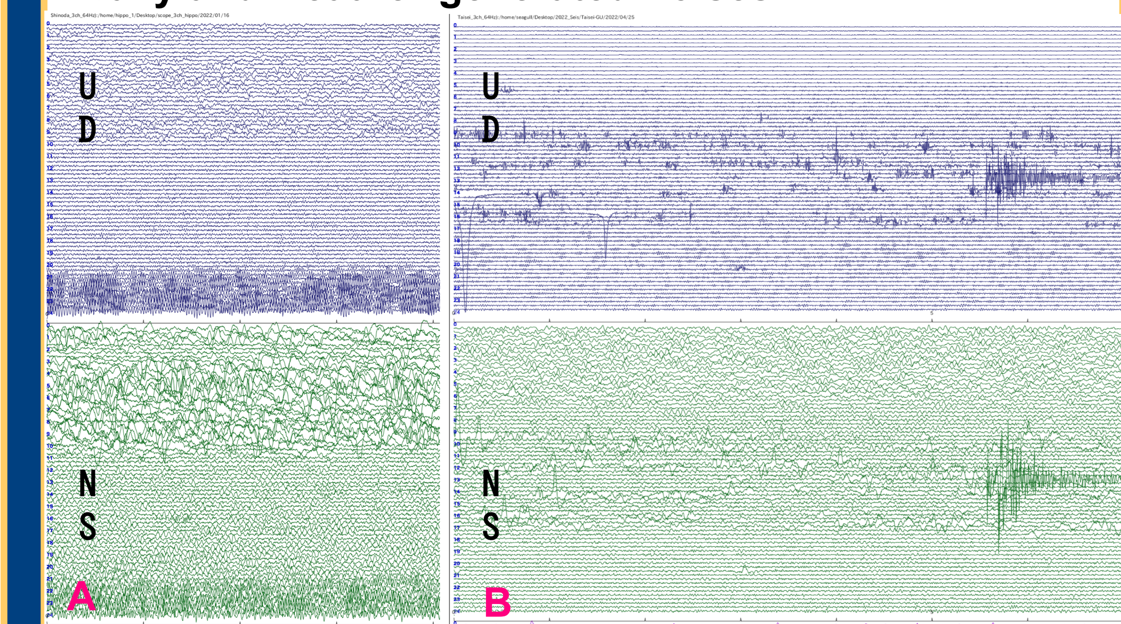
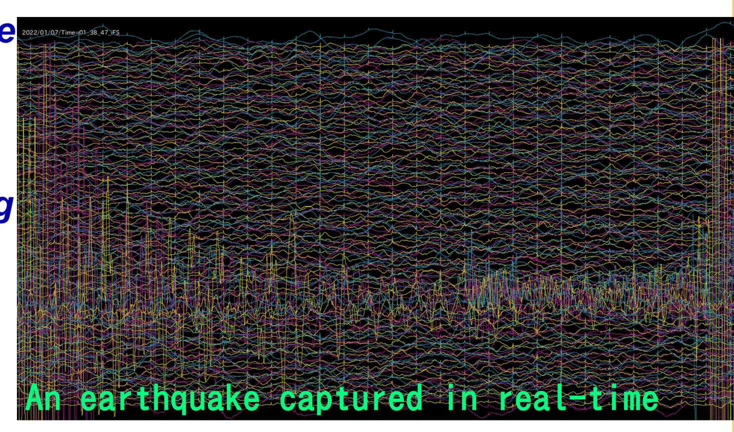


Fig.5 A. Two kinds of tremors caused by a cold storm, Cut 4 [min] each hours record at Shinoda Middle school
B. Daily noises in an office with an earthquake partly cut 7 [min] record at Taisei-Gaikuin University

<Natural earthquakes>

Fig.6 An earthquake is caught on the real-time display, and the digit data are used for making a seismogram as fig.7A; Also a daily record is made like Fig.8 (bottom) as routine work.



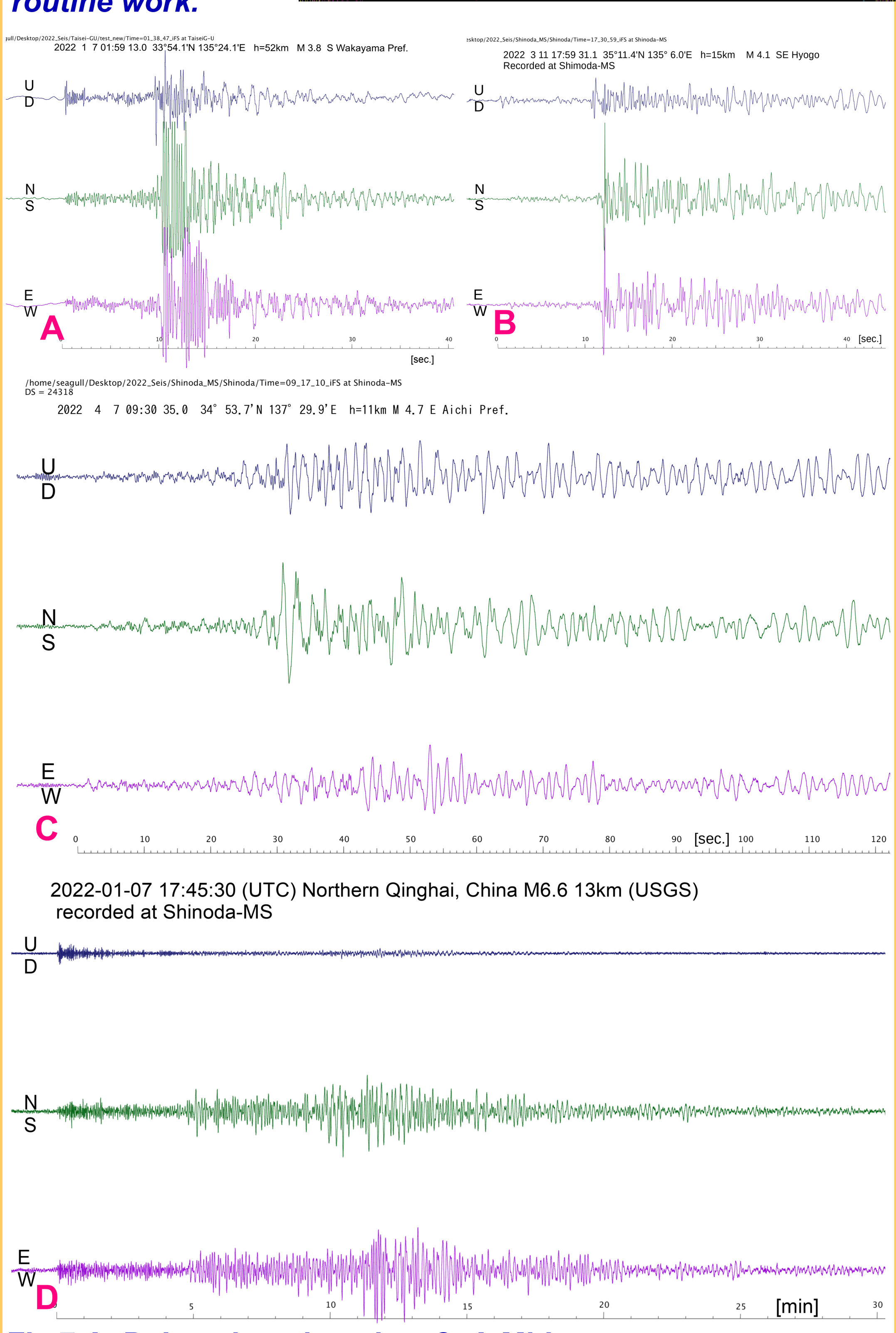


Fig.7 A. B. Local earthquakes C. A Mid-range event
D. A Foreign earthquake

2022-05-02 Daily Record at Taisei-Gakuin University

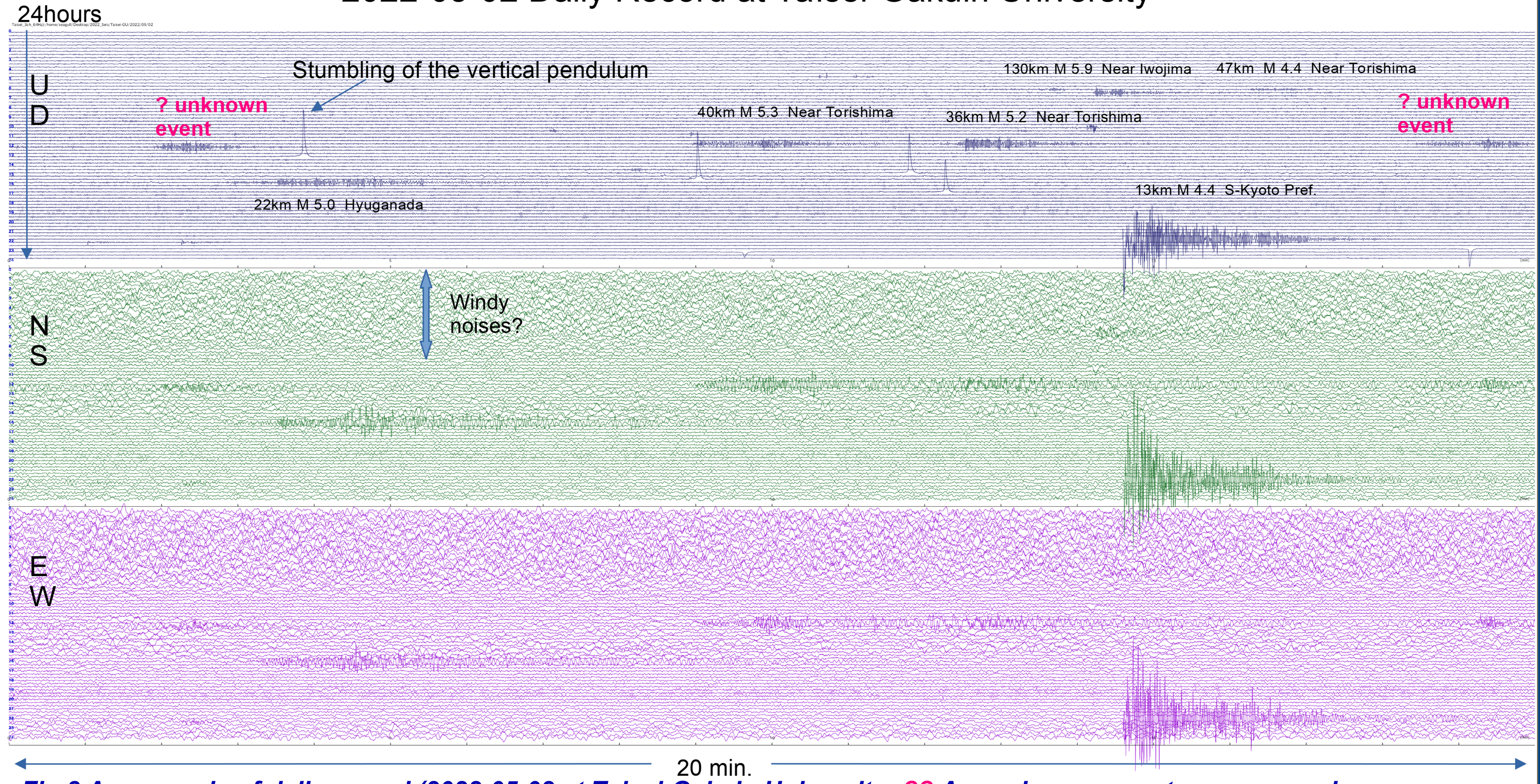


Fig.8 An example of daily record (2022-05-02 at Taisei-Gakuin University; ?? Are unknown events or some noises.

MISCELLANEOUS （雑）

<Out-sourcing of PCB>

Making a printed circuit board of the amplifier is troublesome work for beginners. Therefore, we ordered a PCB works factory to make PCBs with our own made gerber-files for PCB works. It costs only 3 USD for one piece. It is an incredible cheap cost! The factory will complete the soldering parts with an additional cost if you want. However, here we did it by ourselves.

Fig.9
Left. A Printed circuit board hand-made by us. The detail is in my website.
Right. A PCB out-sourced, however, soldering parts by us.

DISCUSSION （議論）

Some problems have arisen:

i) Sampling rate is limited on an old PC (32Hz or 64Hz).

ii) The order of the channel inputs is sometimes changed under unknown conditions.

iii) The filament PLA(+) used in the 3D printer, which made bodies and pendulums, is not always so rigid for a long time. Therefore, some deterioration by aging is recognized, especially in pendulum pivots or bodies.

iv) This causes contact between coils and magnets (see Fig.1c Narrow gaps), the worst trouble for seismographs, and their friction spoils the seismic records.

v) Data handling for making seismograms is now using our hand-made software, which is not so sophisticated. So the process is time-consuming and sometimes makes mistakes.

To solve the problems:

i) The design and construction should be improved.

ii) The alternatives for PLA and wood will be tested.

iii) The data format will be changed to the existing ones; win format or sac. These can be easy-to-use professional seismic tools; win. Ama-seis etc.

To the future:

Our final hope is to make “school seismic networks” not only domestic but also around the world. Now we are requested to develop school seismograph stations for some Thailand science high schools. Therefore, this initiative will co-operate with a global vision.

CONCLUSIONS （結論）

i) The making process for school seismographs is successfully improved by manufacturing parts using a 3D printer and outsourcing.

ii) The test observation is carried out under various circumstances, schools, offices, and homes.

iii) Therefore, we get much know-how about seismic observation not in specialized places but in familiar places.

iv) Also, we obtained many seismograms despite the deadly noises due to the not rigid construction.

v) Our experience will contribute to the development of school seismic networks worldwide.

REFERENCES （参考文献）

Previous presentation at JpGU2022 by the first author is ;
Yoshio Okamoto: School seismographs made with 3D printed parts
http://seagull.stars.ne.jp/2022_JpGU/Seismograph_related.html
Also, the recipe for making this model is,
http://seagull.stars.ne.jp/2022_JpGU/Seismograph_related.html
3D printers and Arduino related references are omitted.
Factory information for PCB outsourcing:
JLCPCB https://jlcpcb.com/VGB
PCB/Gerber Editor: Minimal Board Editor (Japanese only):
https://www.suigyodo.com/online/mbe/manual/set/set.htm
An alternative for foreigners: KiCAD:
https://www.kicad.org
Earthquake information used here is from JMA and USGS.

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