G05-P02 An improved spring-block model for educational use and its analysis – Nanso Satomi "Hakkenzan" Model –

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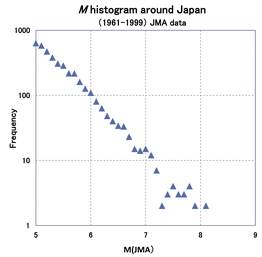
Preface

The Gutenberg-Richter's law of earthquake sizes and frequency is famous among seismologists, however, not popular for ordinary people, so the text books at high-school level seldom treat its details. Regarding importance of this law, I have been developing some teaching tools related with this law since a couple of decades ago. "Go-game model for classroom"(Okamoto, 1999) is an example. On the other hand, Kato (2011) improved the first Spring-Block model (Burridge-Knopoff, 1967) as a teaching tool. Inspired by this work, I tried to make similar models. Our first prototype (Okamoto, 2015) which is assembled with thick iron brocks and rubber bands, show an interesting power law behavior. However this model needs metal processing skills, so it could not spread in classrooms. This time the model is improved to assemble using simpler parts which are purchased at one dollar shops. Also, an analysis employing a motor-drive unit and a motion-tracking software will be described here compared with naked eye observations.



Apparatus & Experiments

<Materials>
Block: "Kenzan" for flower art (38mm square, 70g, 1 dollar shop)
Lead mount + iron nails: "coupled with nails each other"
Spring: Color rubber band (#16, 60mm, Elastic coeff.= 35gw/cm)
Wooden frame (92x21cm)
Vinyl chloride sheet (1mm thick) : important for **stick-slip** motion

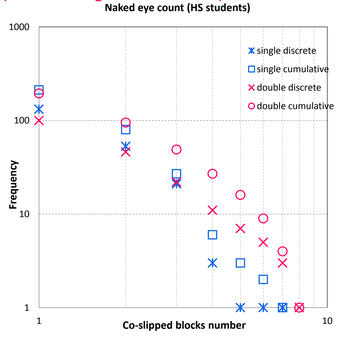
<Experiment>
i) Move slowly the wooden frame by hand.
ii) Watch carefully , as block moved then the frame is stopped.
iii) Record the motion of blocks as a time sequence.
iii) Only count the block number within moved adjacently.
v) The number of co-slipped blocks are thought to be an "earthquake size".
vi) Make a graph earthquake sizes vs. frequency on a log-log paper.

Old model("Hakkenden")

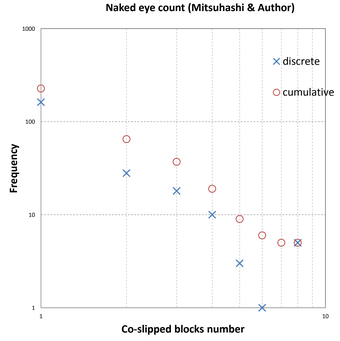

Old model(upper lft.)
Using New model (upper right)
Comparison of whole system(left)
Blocks and Rubber bands(Right)

Counting examples by naked eyes

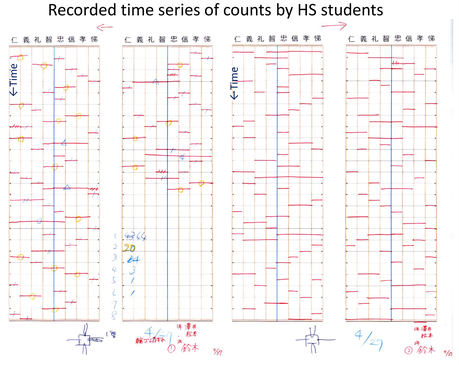
By high-school students
(No knowledge about G-R law)



By undergraduate student and Author
(Already study G-R law)

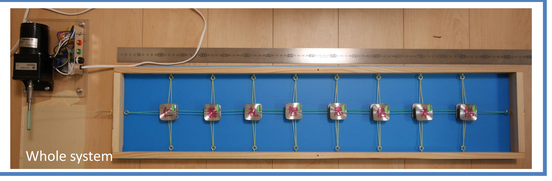


Recorded time series of counts by HS students



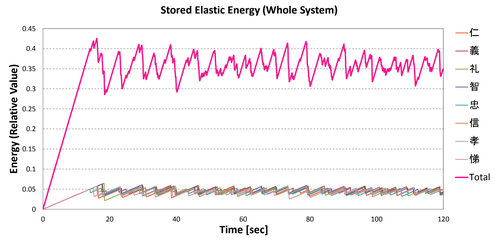
Motor Drive

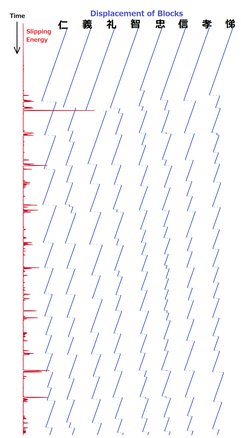
Motor driving unit:
Oriental motor 2SK4GK-A
+1:180 Gear unit 2GK-180K
Φ 6mm shaft
Driving speed: 3.6mm/sec

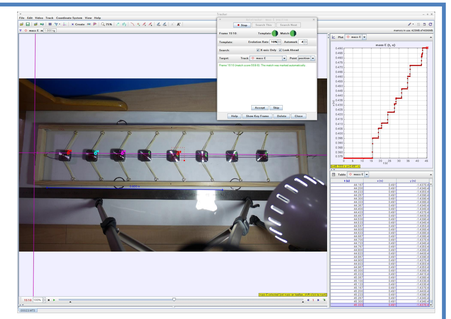


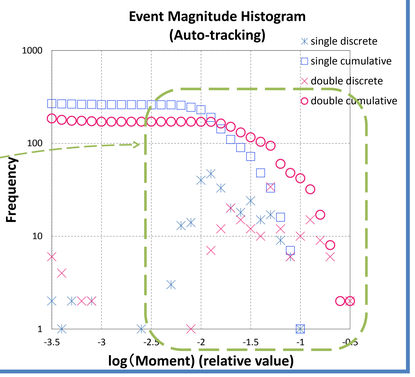
Analysis using Tracker etc.

1. Video recording of a motor driving train
2. Using auto motion-tracker: **Tracker** (freeware)
   Attached markers on blocks (right)
   Motions of blocks are recorded as x,y positions.
   An example of data (center-right figure)
3. Time sequence of stored elastic energy (below)
   Stored elastic energies are calculated
   with Burridge-Knopoff, 1967.

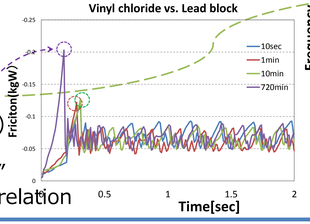








4. Log (earthquake moment) vs. Frequency
   log $(\sum_1^N \{slip\ displacement\})$:
   = an earthquake size (Carlson & Langer,1989)
   Less linearity rather than "naked-eye" counts
5. **Memory effect** of friction(eg. Sakaguchi, 2004)
   rest time vs. peak friction"(right fig.)
   measured by a digital force gage "SIMPO FGP-5"
   rest times and peak frictions have a positive correlation



Discussion & conclusions

1. The naked eye counts show more linear power law behavior than the "Tracker" energy analysis.
2. To use the numbers of co-slip blocks as a substitute of earthquake energy may be useful as a qualitative teaching tool.
3. The useful stick-slip condition by naked eye observation is strongly controlled by the strength of rubber bands, the mass of blocks and the friction between a floor material and blocks.
4. The space and time sequence of slipping blocks are interesting compared with the natural earthquake occurrence.
5. The stored energy sequence of blocks shows neither time-predictable nor slip-predictable as same as Kato (2011).

Conclusion

1. Naked eyes counting and block motion analysis suggest a typical power law behavior of slip events.
2. An easy assemble structure and a simple measurement are suitable for use in a classroom.
3. This model successfully shows the origin of G-R law and the seismic characteristic in space and time qualitatively as a qualitative teaching tools.
4. "Tracker" (Freeware) is an excellent tool for quantitative motion analysis, particularly teaching physics.
5. The analysis using PC simulation is now under developing.

References & Acknowledgement

<References>
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The details of this study will be available on my website: http://yossi-okamoto.net/