KeTCindy/KeTCindyJS—A Bridge between Teachers and Students

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Abstract. *KETCindy is a plug-in for Cinderella2, a Dynamic Geometry Software (DGS). originally developed as a kind of preprocessor of LATEX graphical code systems. It is particularly useful for teachers to produce printed materials with figures to be distributed in the classes of Mathematics or Physics. Moreover, KETCindy has enhanced functions to call* `Maxima`*, the result of which we can use in the subsequent steps of KETCindy. Recently, we have implemented KETCindyJS to produce more interactive materials. It is a collaborative work of KETCindy and CindyJS by a group of Technical University of Munich. Using KETCindyJS, teachers can various materials on the web. As a result, KETCindy and KETCindyJS will provide interactive ennrionment in the class.*

1 Introduction

KETCindy is a plug-in for Cinderella2 originally developed as a kind of preprocessor of LATEX graphical code systems such as tpic, pict2e and TikZ. It is based on KETpic the first author had been developing with the use of Maple, Mathematica, Scilab and R. Cinderella2 works as a graphical user interface of KETCindy and one can create figures for TeX documents interactively and easily. In particular, it is useful for teachers to produce printed materials with figures to be distributed in the classes of Mathematics or Physics. As an example, we draw the integral curve $\frac{d^2y}{dx^2}+4y = \sin ax$ with the initial condtions $y(0) = 3,\ y'(0) = 0$. RungeKutta method (RK4) has been implemented in KETCindy, and one can draw the graph with function 'Deqplot". Codes of CindyScript, which is the programming language of Cinderella2, are as follows.

```
Ketinit();
Slider("A",[0,YMIN-1],[XMAX,YMIN-1]);
fundeq="y''=-4*y+sin(a*x)";
Deqplot("2",fundeq,"x=[0,XMAX]",0,[3,0],["Num=200"]);
Windispg();
```

Here, the function whose name begins with a capital letter is of KETCindy, and variables such as XMIN and XMAX, which determine the drawing range of the figure in LaTeX, are global ones. One can put a slider in the Cindy Screen with function 'Slider". The followings are the screen shots.

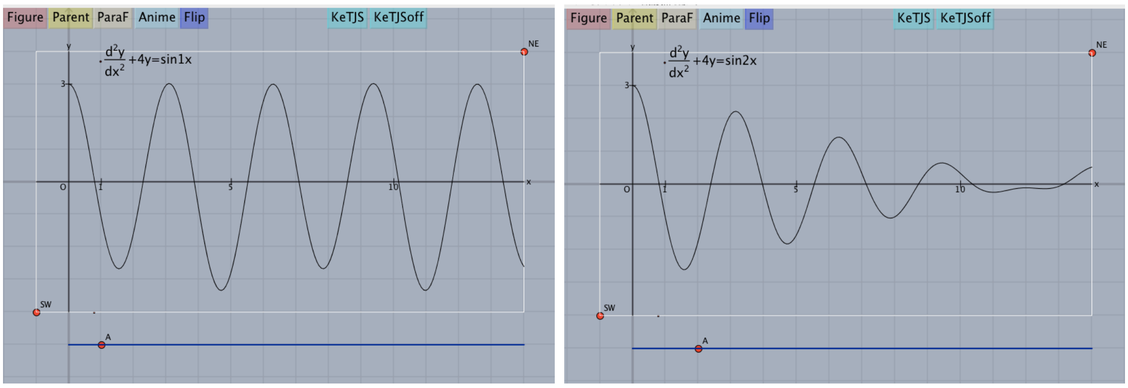


Figure 1: Cindy Screen for $a = 1,\ 2$

Press only the button 'Figure' in Cindy Screen, then a LaTeX compiler will run and the figure data file will be generated. These files are available in any LaTeX document.

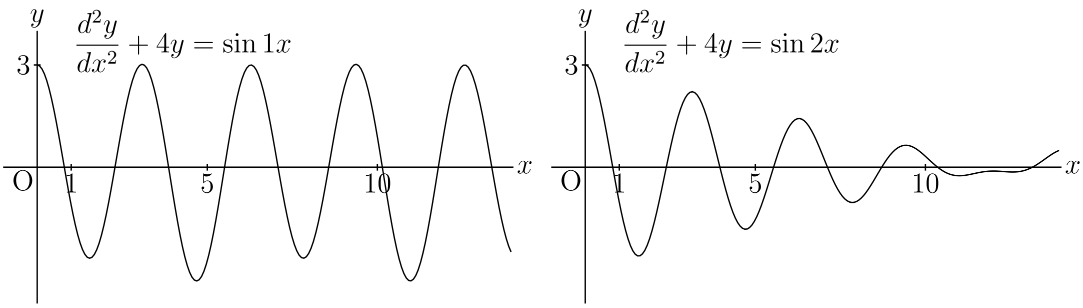


Figure 2: Pdf Files for $a = 1,\ 2$

Moreover, KETCindy has enhanced functions to call `Maxima`, `Mxfun` for a single command, `CalcbyM` for multiple commands and `Mxtex` to get LaTeX form. For example, one can obtain the exact solutions as follows.

```
cmdL=[
 "solg1:ode2('diff(y,x,2)+4*y=sin(a*x),y,x)",[],
 "sol1:ic2(solg1,x=0,y=3,'diff(y,x)=0)",[],
 "solg2:ode2('diff(y,x,2)+4*y=sin(2*x),y,x)",[],
 "sol2:ic2(solg2,x=0,y=3,'diff(y,x)=0)",[],
 "sol1::sol2",[]
];
CalcbyM("sol",cmdL);
```

The results calculated by Maxima and the graphs are shown in the following screen, which shows the numeric solutions of figure 2 give good approximations.

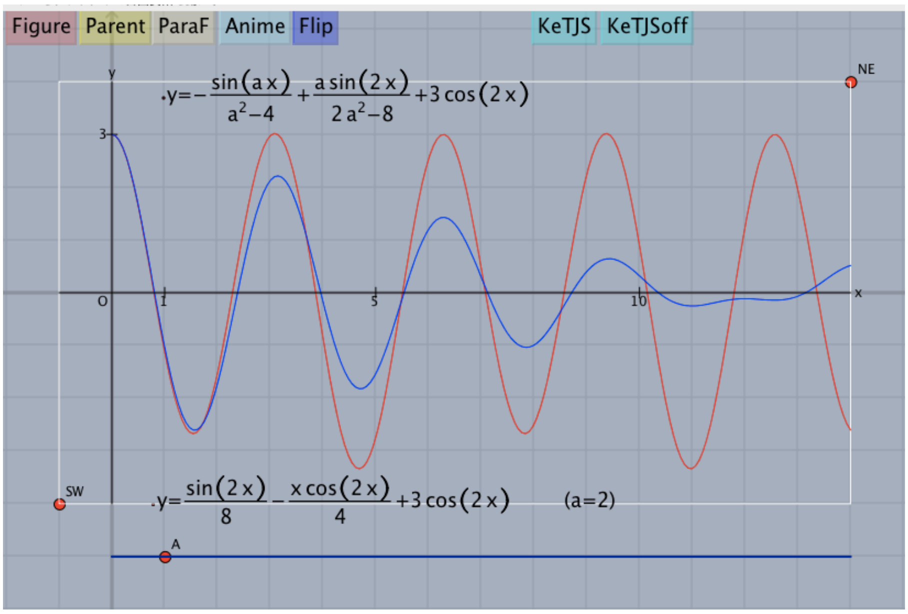


Figure 3: Exact Solutions

In 2018, we tidied up folder configuration of KETCindy and made the instalatio process more easy. Then CTAN(Comprehensive TEX Archive Network) has uploaded KETCindy to the site. As well known, and as stated in Wikipedia,

> CTAN is the authoritative place where TeX related material and software can be found for download,

and one can download the package of KETCindy directly from

`https://ctan.org/pkg/ketcindy`.

In section 2, we will introduce how to install and usse KETCindy after downloading.

In addtiton to printed materials with figures, KETCindy can produce PDF-based presentation slildes with two types of animations, an oridinary animation by the use of `animate.sty` and a 'flip animation' like a flip book. These functions have changed our styles or plannning of our class more interactively. For example, a teacher may prepare a handout to make students understand the graph of logarithmic functions as follows.

1. Plot points displayed on the screen.
2. Draw the graph.

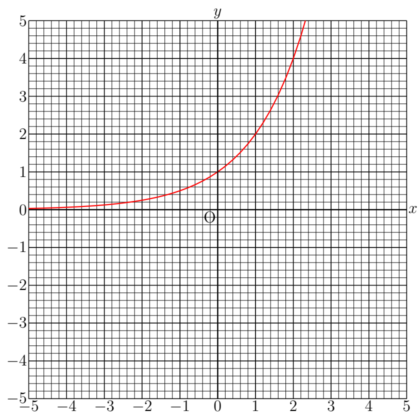


Figure 4: Handout to be distributed

And she/he will prepare presentation slides as follows.

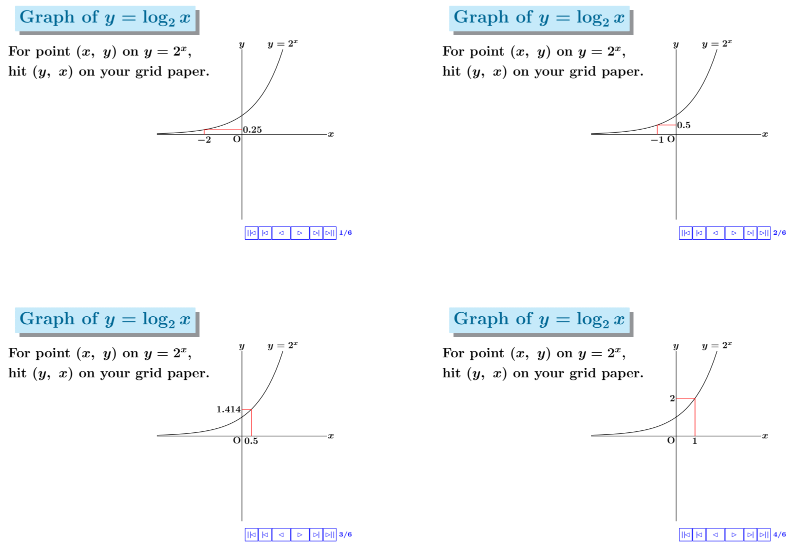


Figure 5: Presentation Slides

Figure 5 is the type of a flip animation animated only when pressing Up/Down key continuously or one by one, which might be more useful sometimes in the class. KETCindy helps teachers produce these materials, and as a result, will provide interactive environment in the class.

Recently, we have implemented KETCindyJS to produce more interactive materials. We will introduce it in section 3.

2 Installing of KETCindy

Download ‘ketcindy(-master),zip’ from the site of `ctan` mentioned in section 1. You can choose either ‘Download” for the stable version or ‘Repository” for the latest one. Read `readme.txt` which is included in folder ‘forMac’, ‘forWindows’ or ‘forLinux’. KETCindy needs a TEX system, Cinderella2([?]), R([?]) and Maxima([?]). Sumatra([?]) will be needed only for Windows. As the TEX system, Tex Live([?]) is recommended because the recent version contains KETCindy. Download and install these softwares. Then open ‘ketcindyfolder’ in the folder ‘ketcindy(-master)’.

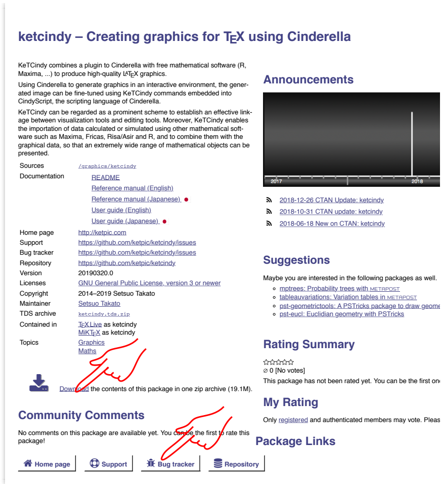


Figure 6: CTAN page

From here, we instruct in the case of Windows. The case of other system are also similar.

1. Right click setketcindytexlive.bat and select ‘Run as adiministrator’.
    - In the case of Windows10, unblock the security block.
    - As the TEX(typeset), usually choose latex, xelatex or pdflatex.
    - Input the version numbers of R, Maxima, for example,3.4.2 and 5.37.3.
2. Double-click setwork.bat, then work directory ‘ketcindy’ will be generated in Users home.
3. Double-click file ‘template1basic.cdy’ in the work folder ‘ketcindy’, then a frame in white will appear in the screen after a while.
4. Press button ‘Figure’ at the top left in the screen, then the final PDF output will be displayed.

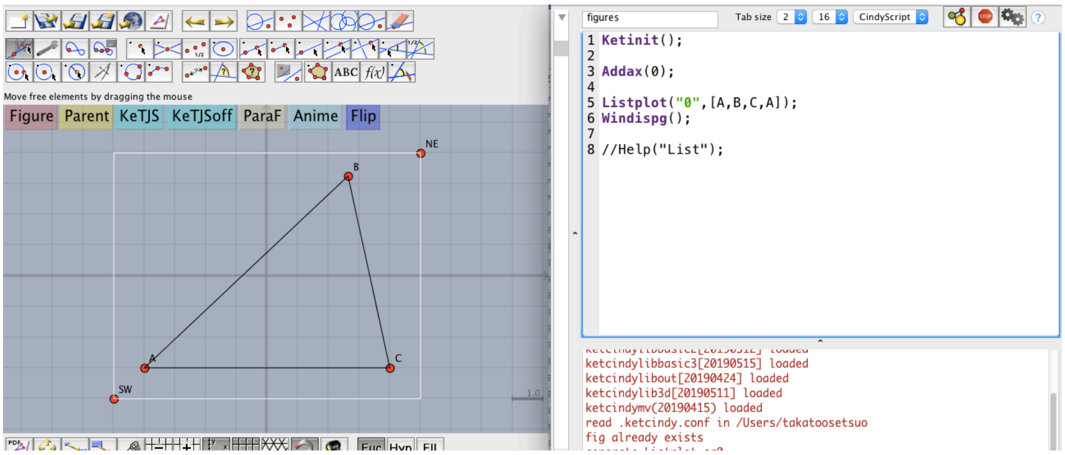


Figure 7: Screen and Script Editor 1

To add/edit graphical components, choose from the top menu

`Scripting > Edit Scripts` ,

then the right of figure 7 will appear. Add several lines as follows and press the run button, then figures will be changed.

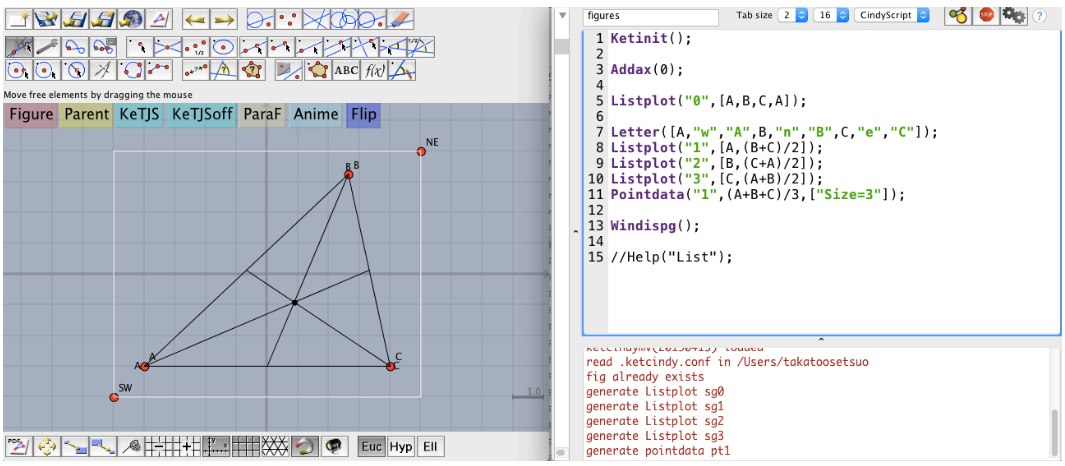
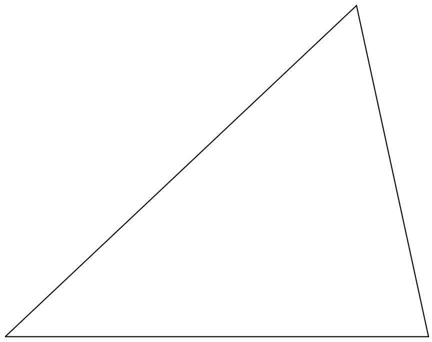


Figure 8: Screen and Script Editor 2

Pressing button 'Figure' again, new figures will be obtained.



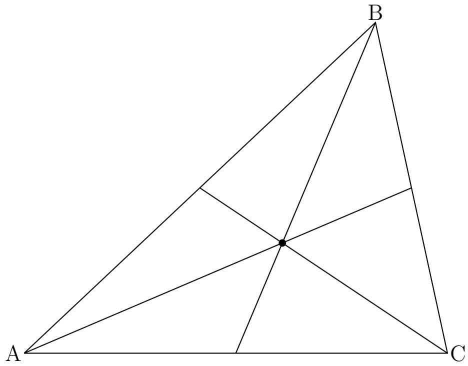


Figure 9: Modifying Figure

For more details, refer to `ketcindyguide.pdf` and `ketcindyreference.pdf` copied to work folder 'ketcindy' in user's home.

3 Development of KETCindyJS

A group of Technical University of Munich, 'cindyJS.org' has been developing CindyJS[?] which is introduced in the site as

> CindyJS is a framework to create interactive (mathematical) content for the web. It aims to be compatible with Cinderella, providing an interpreter for the scripting language CindyScript as well as a set of geometric operations which can be used to describe constructions.

Cinderella2 can export components in Cindy Screen and codes written in Cindy Scripts to a HTML file of CindyJS choosing menu `File > Export to CindyJS`. Double clicking the file, library of 'Cindy.js' is imported and many of functions of Cinderella2 are realized on the web.

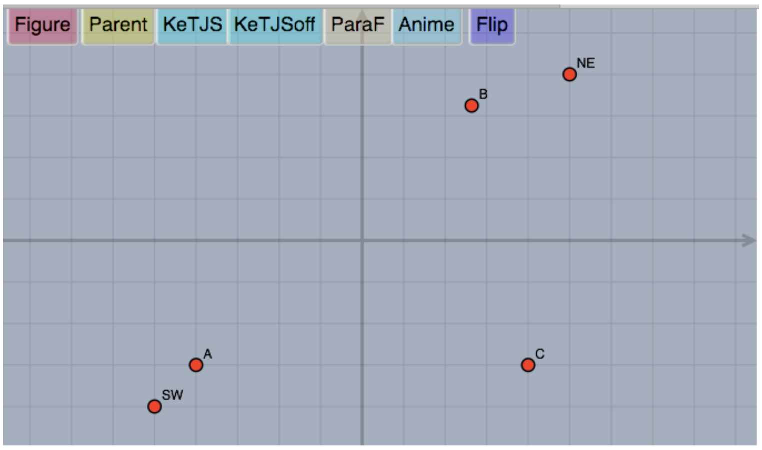


Figure 10: HTML only with CindyJS

All elements in the screen are movable, but lines are not diplayed because function `Listplot` used in figure 7 or 8 is not of Cinderella2 but of KETCindy. KETCindyJS is an enhanced function to add functions of KETCindy used in Cindy Scripts to the HTML file.

To be more specific,

1. We have developed a program to make a file contained of a list of data of functions, for example

   `Listplot,basic1,3995,4076,Divoptions,Strsplit,...`

   Here, 3995 and 4076 mean this function is written from line 3995 to line 4076. The subsequent is functions used in 'Listplot'. Runnnig the program everytime when libraries of KETCindy are updated, we can keep it up-to-date.

2. Pressing button 'KeTJS' for on-line mode or 'KeTJSoff' for off-line mode, KETCindy extracts all functions written in Cindy Scripts of the original HTML and adds them to HTML together with functions used in them.

3. Also, KETCindy modifies definitions or settings written in the HTML according to options described at 'Setketcindyjs'. For example,

   `Setketcindyjs(["Nolabel=all","Color=white"]);`

   removes all labels of points and changes the background color to white.

With these functions, we can produce HTML which contains functions of KETCindy. Moreover, geometric elements in the screen are movavle on the web.

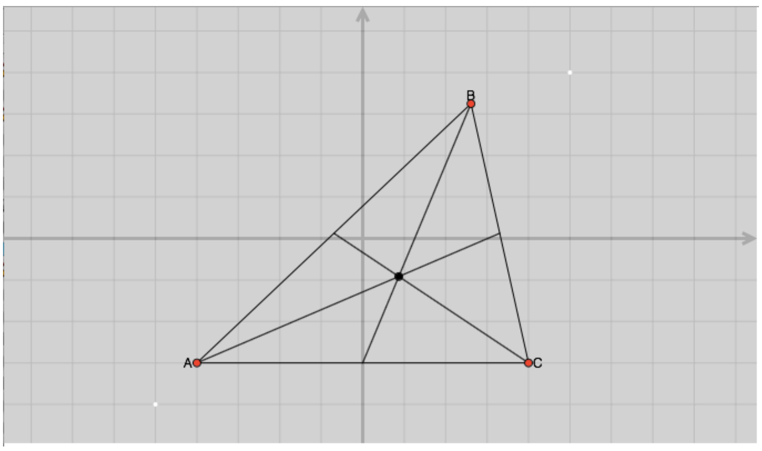


Figure 11: HTML with KETCindyJS

Originally, we had made a compact library of KETCindyJS manually from those of KETCindy. But a number of lines reached more than 6000. Moreover, it was hard to be changed according to the updating of libraries of KETCindy. By improving as above, the lines have decreased in number, for example, 1300 lines for figure 11.

In the next section, we show several examples produced with KETCindyJS. These files have been uploaded to the page

`https:s-takato.github.io/ketcindysample/forpapers`

4 Samples of K$_E$TCindyJS

4.1 Material of Trigonometric Ratio

The following figures are copies from a HTML material to make students find values of trigonometric ratios. Upper-left one is the initial screen. When students input the values, ‘Correct’/‘Not corrct’ will be displayed under input boxes (see upper-right). Here, simple TEX-like form such as `frac(sqrt(3),2)` or more simply `fr(sq(3),2)` is available instead of usual form of Cindy Scripts such as `sqrt(3)/2`(see lower-left and lower-right). Two internal functions `Tocindyform` and `Totexform` have been implemented to K$_E$TCindy for students to input a formula without a mistake in text mode. For example, let

```
str="frac(cos(x)+sqrt(3)*sin(x),sin(x)+sqrt(3)*cos(x))"
```

then `Tocindyform(str)` and `Totexform(str)` return

```
(cos(x)+sqrt(3)*sin(x))/(sin(x)+sqrt(3)*cos(x))
```

and `\frac{\cos{x}+\sqrt{3} \sin{x}}{\sin{x}+\sqrt{3} \cos{x}}`

respectively.

Students can give other value of angle α, then the triangle will be changed. Counting points marked per 0.5 length on the edge, they will find $\mathrm{AB} = 5, \mathrm{AC} \approx 2.1$ and $\mathrm{BC} \approx 4.5$, so they can calculate values of trigonometric ratio(see lower-right).

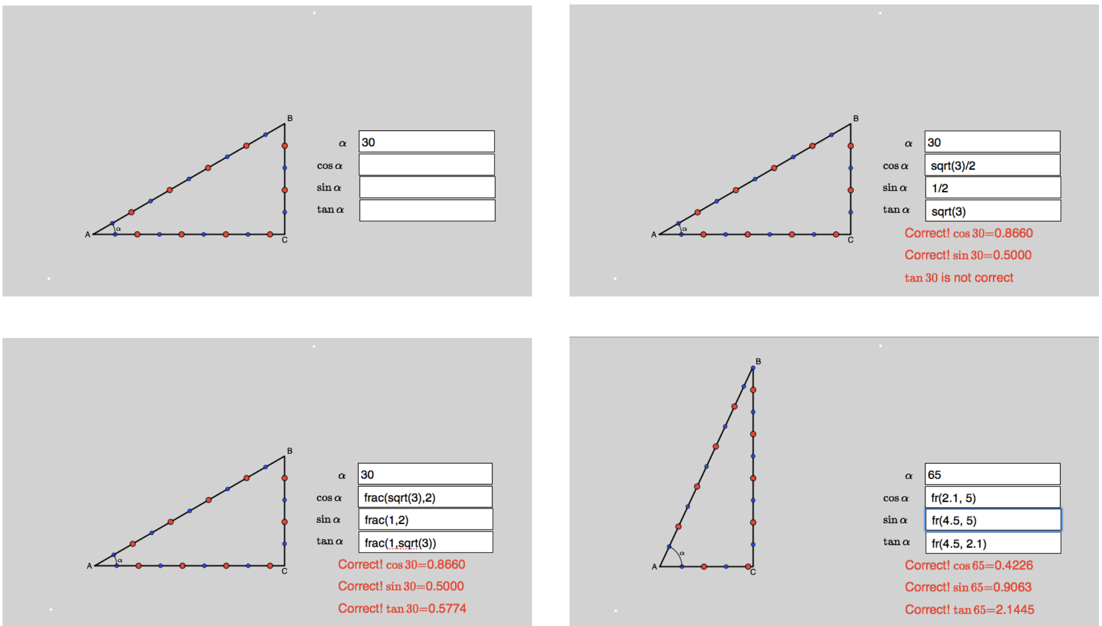


Figure 12: Copies from the HTML

4.2 Drawing Sine Curve

In calculus course, it is important for students to understand `radian` has two meaings, angle and length. For example, $\frac{\pi}{3}$ represents both angle $60°$ radian and length $1.0471\ldots$. The graph of $y = \sin x$ should be drawn based on this two-sided meanings. The following is a material for the purpose.

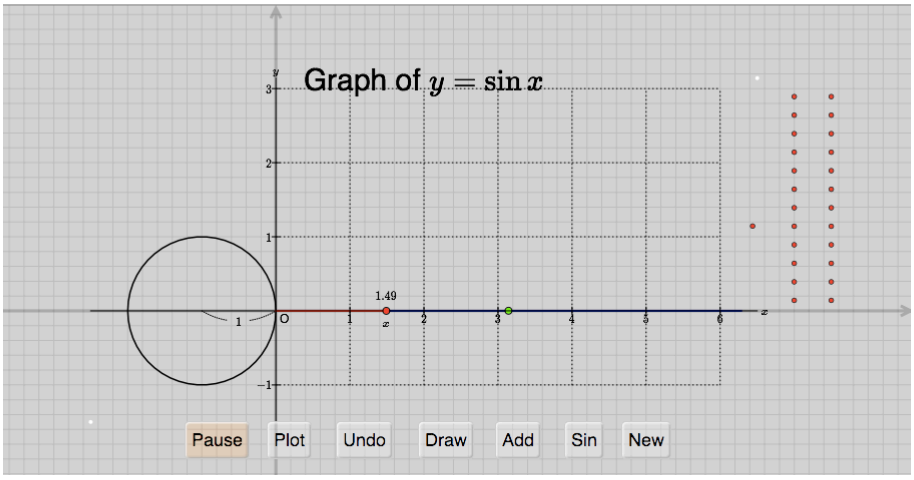


Figure 13: Initial screen of the HTML

Pressing button ‘Plot’ starts an animation, in which the segment from the origin to point $(x, 0)$ rotates and winds around the circle.

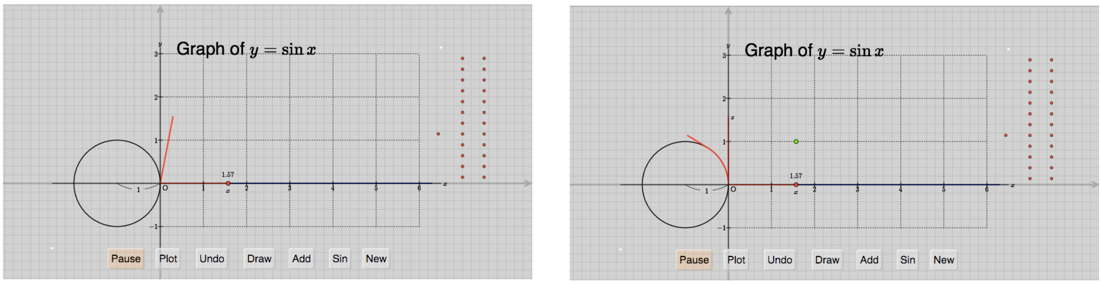


Figure 14: Winding around the circle

Then point $(x,\ \sin x)$ is plotted and added to a list of points. Pressing ‘Draw’, all points of the list will be connected by the Bézier curve and the control points will be plotted. Moreover, difference between the curve and the exact graph of $y = \sin x$ will be displayed.

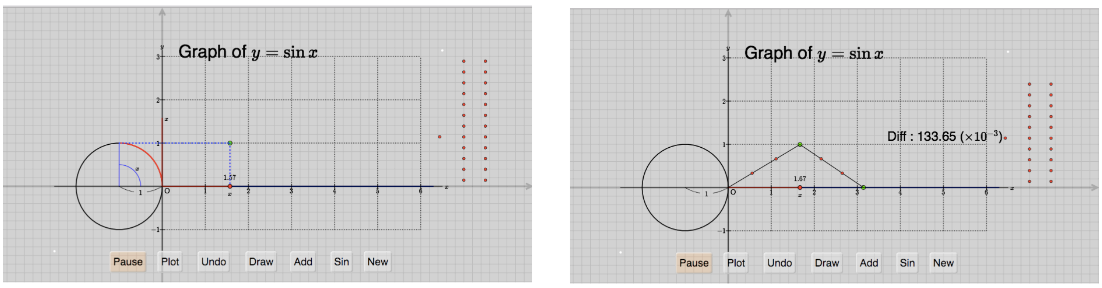


Figure 15: Plotting point on the graph

Students can move these control points so as to decrease the difference. If they press button ‘sin” , the graph of $y = \sin x$ will be displayed.

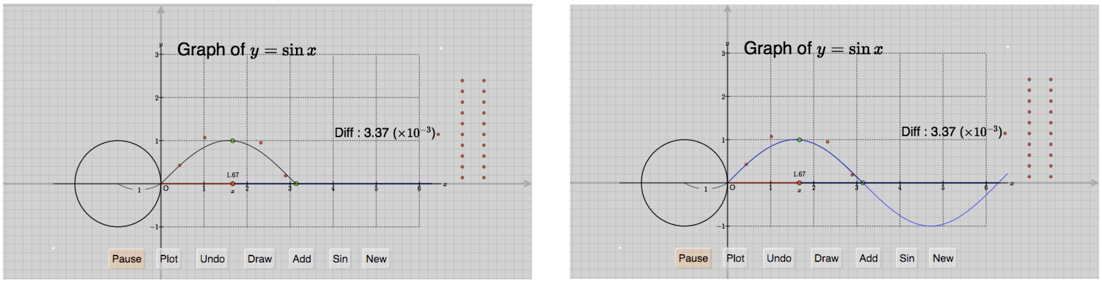


Figure 16: Decreasing the difference

This material will help students understand the meaning of radian and the shape of the sine curve.

4.3 Animation of an Atwood's Machine

The third author analyzed movement of the folowing Atwood's machine([?]).

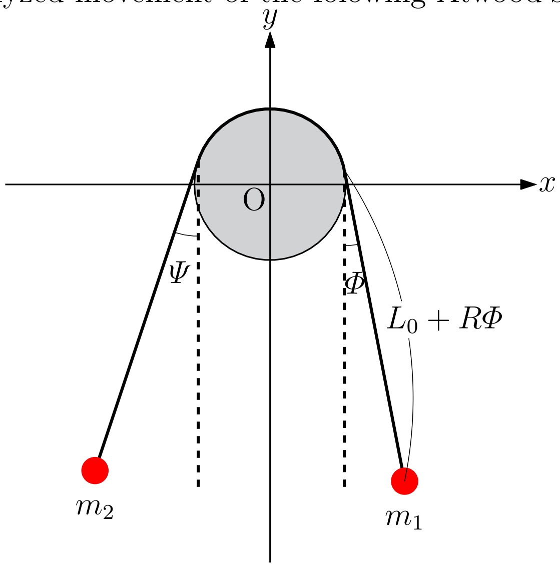


Figure 17: Swinging Atwood's machine

And he obtained the differential equation system as follows.

$$\begin{aligned}
\ddot{\Psi} &= \frac{R\left(g\ (m_2 - \cos\Phi\, m_1) - \dot{\Phi}^2\ ((\Phi - \Psi)\ R + L_0)\ m_1\right)}{R^2\ (m_2 + m_1) + I_0} \\
\ddot{\Phi} &= \frac{-\sin\Phi\, g + 2\,\dot{\Phi}\dot{\Psi}\, R - \dot{\Phi}^2\, R}{(\Phi - \Psi)\ R + L_0}
\end{aligned}$$

Here $R, I_0, m_1, m2_2, L_0, g$ are physical quantities of this system and we give their values as

$$R = 1, I_0 = 0.05, m_1 = 1, m_2 = 1.05, L_0 = 4, g = 9.8$$

KETCindy can solve the above equation system numerically with command `Deqdata` under the initial condition

$$\Phi = 0, \Psi = 0, \ddot{\Phi} = 0.6, \ddot{\Psi} = 0$$

```
lhs="[P,Q,F,G]";
rhs="[Q,R/(I0+(m1+m2)*R^2)*(g*(m2-m1*cos(F))-m1*(L0+R*(F-P))*G^2),
     G,1/(L0+R*(F-P))*(2*R*Q*G-g*sin(F)-R*G^2)]";
eqs=Assign(rhs,["F","Phi","G","DPhi","P","Psi","Q","DPsi"]);
eq=lhs+"'="+rhs;
repnm=["R","I0","m1","m2","g","L0"];
repva=[1,0.05,1,1.05,9.8,4];
rep=apply(1..(length(repnm)),[repnm_#,repva_#]);
rep=flatten(rep);
eqn=Assign(eq,rep);
vL=Deqdata(eqn,"t=[0,30]",0,[0,0,0,0.6],300);
```

Here vL is a list of $[t, \Phi, \dot{\Phi}, \Psi, \dot{\Psi}]$. Using KETCindyJS, we create the following animation of HTML.

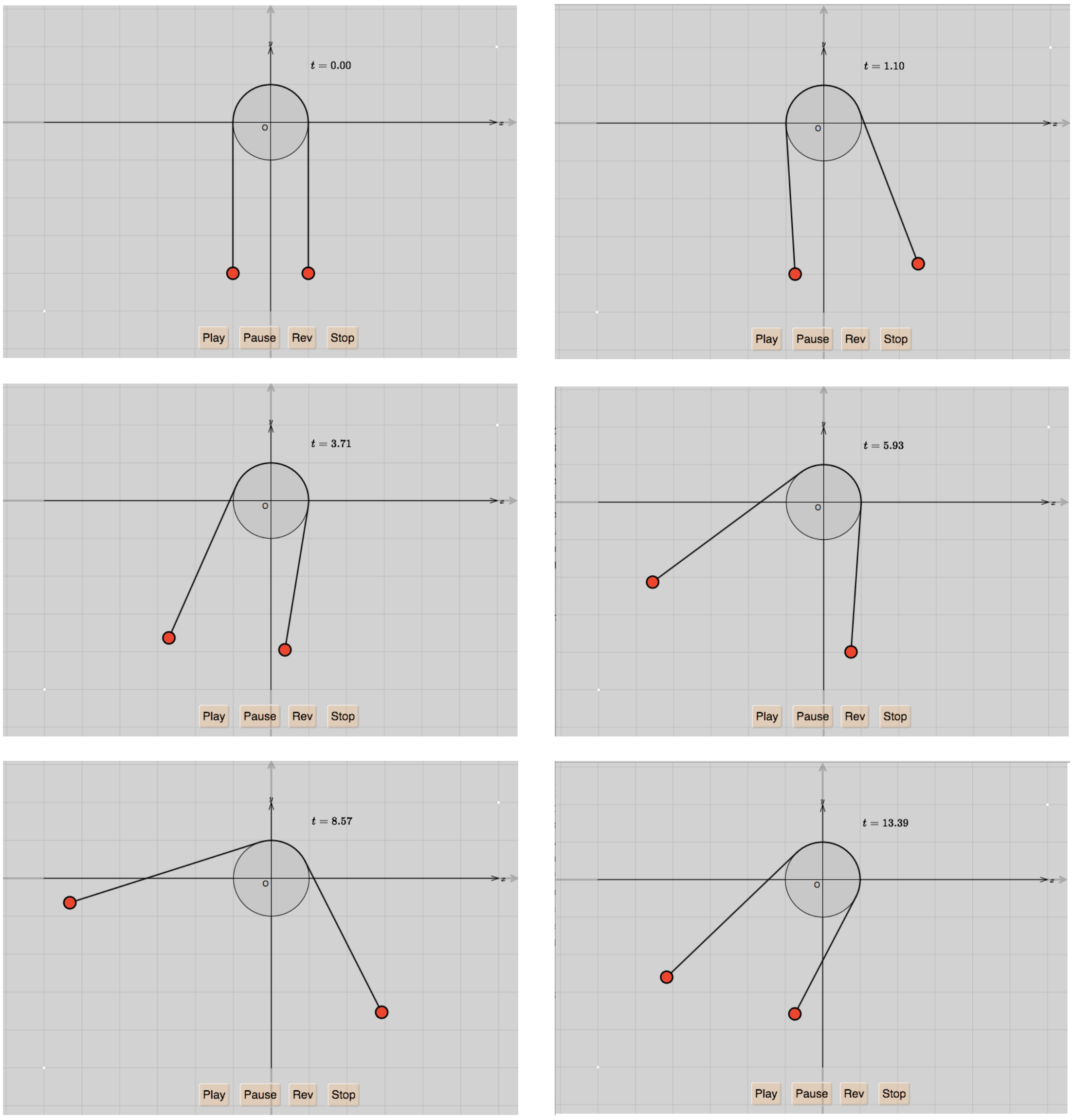


Figure 18: Animation of an Atwood's machine

4.4 Graph of Fourier Finite Series

The second author developed a package of `Maxima` to return Fourier coefficients for a given periodic function([?]). For example, if the funciton is defined as

```
if (-2<=x and x<-1) then 1 elseif (-1<=x and x<1) then 1-x^2
    elseif (1<=x and x<2) then 2-x,
```

then the package returns c_0, c_n, s_n as follows:

$$\begin{aligned} c_0 &= \frac{17}{24} \\ c_n &= \frac{-\left(2\,\pi^2\,n^2-16\right)\,\sin\left(\frac{\pi\,n}{2}\right)-6\,\pi\,n\,\cos\left(\frac{\pi\,n}{2}\right)-2\,\pi\,n\,\left(-1\right)^n}{\pi^3\,n^3} \\ s_n &= \frac{2\,\sin\left(\frac{\pi\,n}{2}\right)+\pi\,n\,\left(-1\right)^n}{\pi^2\,n^2} \end{aligned}$$

Though the package is a powerful and convienient tool to manupulate Fourier series, the defintion of a period function may be slightly convoluted. So we have implemented the function `Periodun` to KETCindy, which converts simpler form such as

```
defL=["1",[-2,-1],1,"1-x^2",[-1,1],50,"2-x",[1,2],1];
```

to that of Maxima and draws the graph of the function. Using function `Fourierseries` such like

```
Fourierseries("1",coeffs,4,10,"x=[-2,2]",["Num=200"]);,
```

we can also draw the graph of the Fourier finite series.

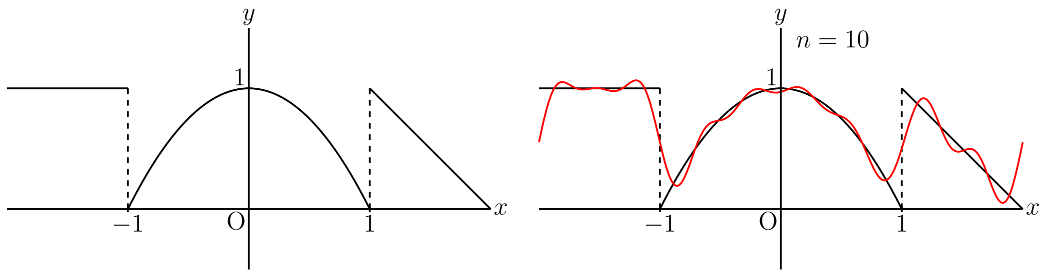
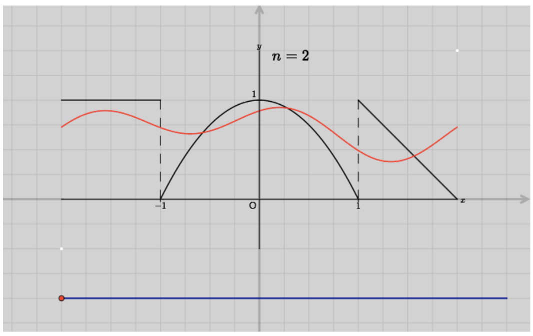
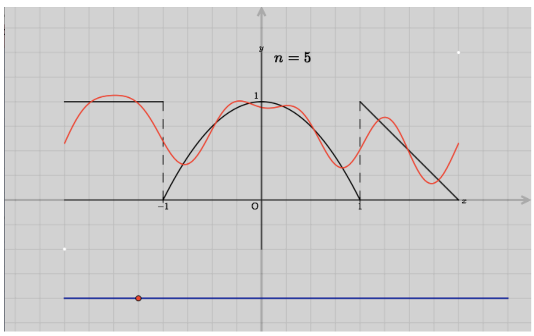


Figure 19: Graph of periodic function and Fourier finite series

KETCindyJS does not support a function to call a CAS for now, but function `ketcindyjsdata` adds the result from Maxima to the HTML so we can create an interactive material on the web. Animation can be created in the same way as the Atwood's machine.





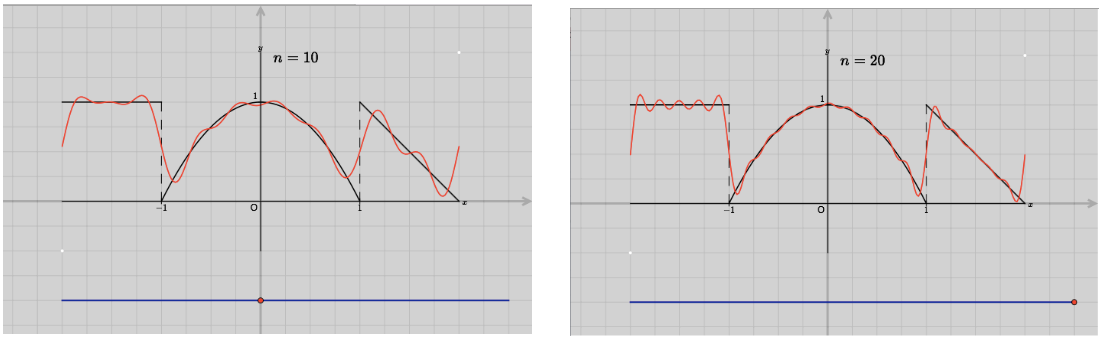


Figure 20: Interactive HTML with KETCindyJS

5 Conclusions

Acknowledgments

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References

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