Technology enhanced learning in Statistics

Jérémie Houssineau

28 May 2021

Outline

1. TEL in general
2. TEL in Statistics
3. Interactive plots
4. Notebooks
5. Comparative judgement *by Ian Hamilton*

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Why TEL

Source

HEFCE (Higher Education Funding Council for England) (2009). "Enhancing Learning and Teaching Through the Use of Technology."

Potential benefits of TEL:

1. Efficiency
   → existing processes carried out in a more cost-effective, time-effective, sustainable or scalable manner

2. Enhancement
   → improving existing processes and the outcomes

3. Transformation
   → radical, positive change in existing processes or introducing new processes

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Enhanced?

Source

Kirkwood A. & Price L. (2014). "Technology-enhanced learning and teaching in higher education: what is 'enhanced' and how do we know? A critical literature review." Learning, Media and Technology, 39(1), 6-36

Types of enhancement:

1. Operational improvement
   → greater flexibility for students; resources more accessible
2. Quantitative change in learning
   → increased engagement; improved test scores
3. Qualitative change in learning
   → promoting reflection on learning; deeper engagement; richer understanding

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Static v.s. animated

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Tversky, B., Morrison, J.B. & Betrancourt, M. (2002). "Animation: can it facilitate?" International journal of human-computer studies, 57(4), 247-262

1. Static graphics?
   → only if carefully designed

2. Animated graphics?
   → research on efficacy not encouraging
   → often too complex or too fast to be accurately perceived
   → judicious use of interactivity may overcome both these disadvantages

A few examples: Tesseract | Simulated annealing | Dirichlet process

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Longevity of TEL tools?

1. Trends
   → Article from 2013: *Is it a tool suitable for learning? A critical review of the literature on Facebook as a technology-enhanced learning environment*

2. Support
   → Flash no longer supported

3. Maintenance
   → Backward compatibility not always ensured

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Home / Explore features of probability distributions

Select a distribution:

Poisson

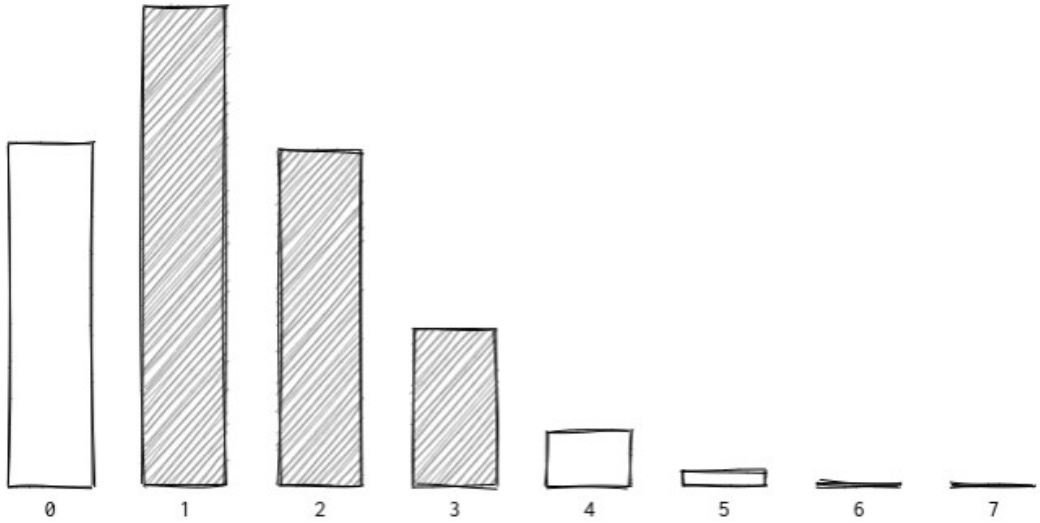
Parameter(s):

λ = 1.4 *mean rate*

Explore features

Highlight outcomes between 1 and 3

$P(1 \leq X \leq 3) = 0.6997$



Developed by Anna Fergusson, Department of Statistics, University of Auckland

Link

Home / Explore goodness-of-fit for probability distributions

Clear

The situation

Variable description: x

Rounding - nearest: 1

Sample data:

1,2,3,4,5,6,1,2,3,4,1,2,3,1,2,1,3,4,3,4,3,4,2,2,2,2,2,5,5

Update | Compare to model

The model

Select distribution: Poisson

λ = 2.828

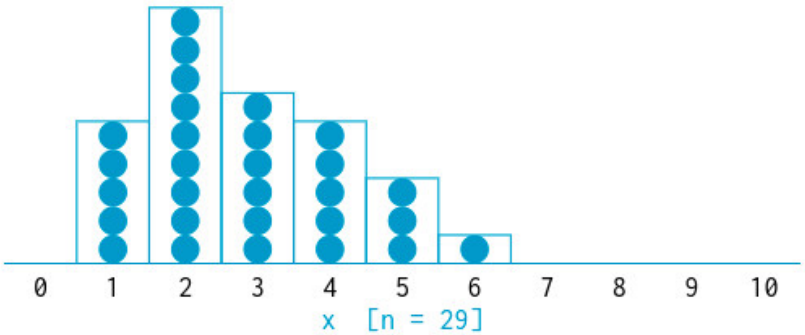
Simulated data

Generate 29 values

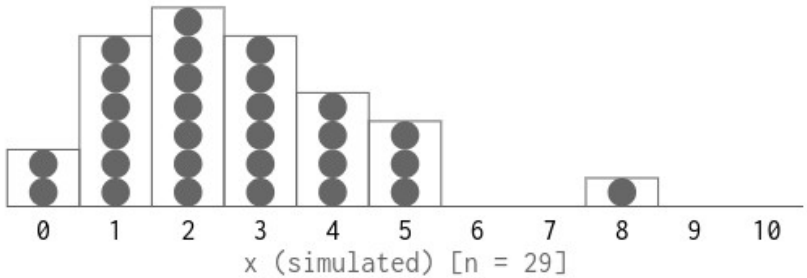
Simulate data | Start animation | Build over-fitted shape

Show over-fitted shape

mean = 2.828



mean = 2.655



Show mean | Show standard deviation | Show middle 95%

Developed by Anna Fergusson, Department of Statistics, University of Auckland

Link

SOCR Bivariate Normal Distribution

Settings

ρ = 0

μ_x=0 μ_y= 0

σ_x=2 2 σ_y=1 1

Use WebGL

Controls

-2 < X < 2 -2 < Y < 2

Marginal of X | Marginal of Y

Conditional of X|Y = -2 | Conditional of X|Y = 2

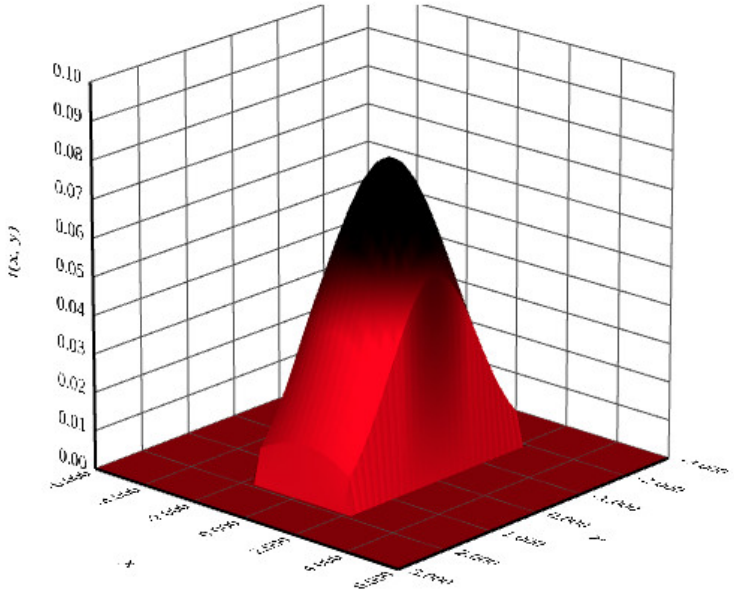
Conditional of Y|X = -2 | Conditional of Y|X = 2

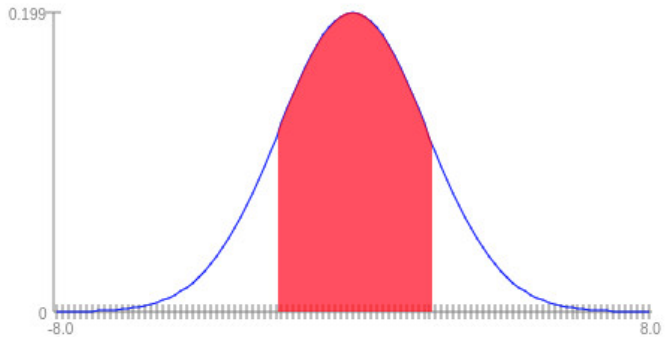
Probability Results

```
P(-2 < Y < 2 | X = 2) = 0.954
P(-2 < X < 2 | Y = 2) = 0.683
```

Instructions

- **Requirements** - modern web-browser with HTML and JavaScript support. The 3D view of the bivariate distribution requires WebGL support.
- See the SOCR Bivariate Normal Distribution **Activity**.
- Use the **Settings** to initialize the web-app. To activate new input settings click outside the component.
- In the **Control** panel you can select the appropriate bivariate limits for the X and Y variables, choose desired *Marginal* or *Conditional* probability function, and view the 1D Normal Distribution graph. Use any non-numerical character to specify infinity (∞).
- You can rotate the bivariate normal distribution in 3D by clicking and dragging on the graph.
- **Probability Results** are reported in the bottom text area.





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Christou, N., & Dinov, I.D. (2010). "A study of students' learning styles, discipline attitudes and knowledge acquisition in technology-enhanced probability and statistics education." Journal of online learning and teaching, 6(3).

Identify learning styles:

1. Information processing: active / passive
2. Information perception: sensory / intuitive
3. Sensory channel: visual / auditory
4. Understanding process: sequential / global

Findings:

1. Marginal but consistent effect of TEL
   → improved satisfaction and quantitative performance
2. Dependent on learning style

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bokeh

Histogram | Crossfilter

Advantages:

- Relatively simple to use
- Default style is often sufficient

Drawbacks:

- Backward compatibility is not always maintained
- Specific functions for plots ($\neq$ `matplotlib`, $\sim$ `ggplot`)

Some example:

- Normal likelihood with unknown mean
- Kalman filter

Accessibility:

Alternative with R: Shiny (Thank you Martyn)

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Disclaimer

The following poorly-commented code is for illustration purposes only

Example

Initialisation

```
# True parameter
mu = 2
sig_default = 1.0

# Number of points to plot the p.d.f.s (reduce this number of speed)
N = 250

x = np.linspace(-5, 5, N)
y = normal_pdf(x, 0.0, 1.0)
N0 = ColumnDataSource(data=dict(x=x, y=y))
N1 = ColumnDataSource(data=dict(x=x, y=y))

y = normal_pdf(x, mu, sig_default**2)
N2 = ColumnDataSource(data=dict(x=x, y=y))

# Function regenerating the observations
max_n_obs = 10
obs_root = np.random.randn(max_n_obs)

y_obs = np.array((0,0.2))
```

Example

Plot

```
# Set up plot
plot = figure(plot_height=400, plot_width=800, title="Prior, posterior and
                                        sampling distributions",
            tools="crosshair,pan,reset,save,wheel_zoom",
            x_range=[-5, 5], y_range=[0, 1.1])

plot.line('x', 'y', legend='prior', source=N0, line_width=3, line_alpha=0.6)
plot.line('x', 'y', source=N1, line_width=3, line_alpha=0.6, legend='
                                        posterior', line_dash='dashed')
plot.line('x', 'y', source=N2, line_width=3, line_alpha=0.6, legend='sampling
                                        ', color='firebrick')

obs_data_list = []
obs_plot_list = []
for i in range(max_n_obs):
    obs = obs_root[i]*sig_default + mu
    x_obs = obs*np.ones(2)
    obs_data_list.append(ColumnDataSource(data=dict(x=x_obs, y=y_obs)))
    obs_plot_list.append(plot.line('x', 'y', source=obs_data_list[i],\
        color='firebrick', line_width=3, line_alpha=0.6))
```

Example

Widgets

```
# Set up widgets
button = Button(label="Regenerate observations")
mu_0 = Slider(title="mu_0", value=0, start=-5, end=5, step=0.1)
sigma_0 = Slider(title="sigma_0", value=1, start=0.01, end=5, step=0.1)
sigma = Slider(title="sigma", value=sig_default, start=0.01, end=5, step=0.1)
n_obs = Slider(title="n", value=0, start=0, end=max_n_obs, step=1)
```

Example

Update plot I

```
# Update data frames
def update(attrname, old, new):
    mu_0_val = mu_0.value
    var_0 = sigma_0.value**2
    n = n_obs.value
    var = sigma.value**2
    loc_obs = obs_root * sigma.value + mu
    for i in range(max_n_obs):
        x_obs = loc_obs[i]*np.ones(2)
        vis = (i < n)
        obs_data_list[i].data = dict(x=x_obs, y=y_obs)
        obs_plot_list[i].visible = vis

    obs = 0
    if n > 0:
        obs = np.mean(loc_obs[:n])

    mu_post = (n * var_0 * obs  + var * mu_0_val) / (n * var_0 + var)
    var_post = (var_0 * var) / (n * var_0 + var)
    N0.data = dict(x=x, y=normal_pdf(x, mu_0_val, var_0))
    N1.data = dict(x=x, y=normal_pdf(x, mu_post, var_post))
    N2.data = dict(x=x, y=normal_pdf(x, mu, var))
```

Example

Update plot II

```
# Function regenerating the observations
def reg():
    global obs_root
    obs_root = np.random.randn(max_n_obs)
    update('value', 1, 1)

button.on_click(reg)
mu_0.on_change('value', update)
sigma_0.on_change('value', update)
sigma.on_change('value', update)
n_obs.on_change('value', update)

# Set up layouts and add to document
inputs = widgetbox(button, mu_0, sigma_0, sigma, n_obs)

curdoc().add_root(row(inputs, plot, width=800))
curdoc().title = "Normal likelihood: unknown mean"
```

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In general:

- Gentle introduction to programming
- Accessible even with little knowledge of Python/R
- Suitable environment for active learning

Jupyter notebooks:

- Intuitive environment
- Can be run online with the GitHub + Binder solution
- Example

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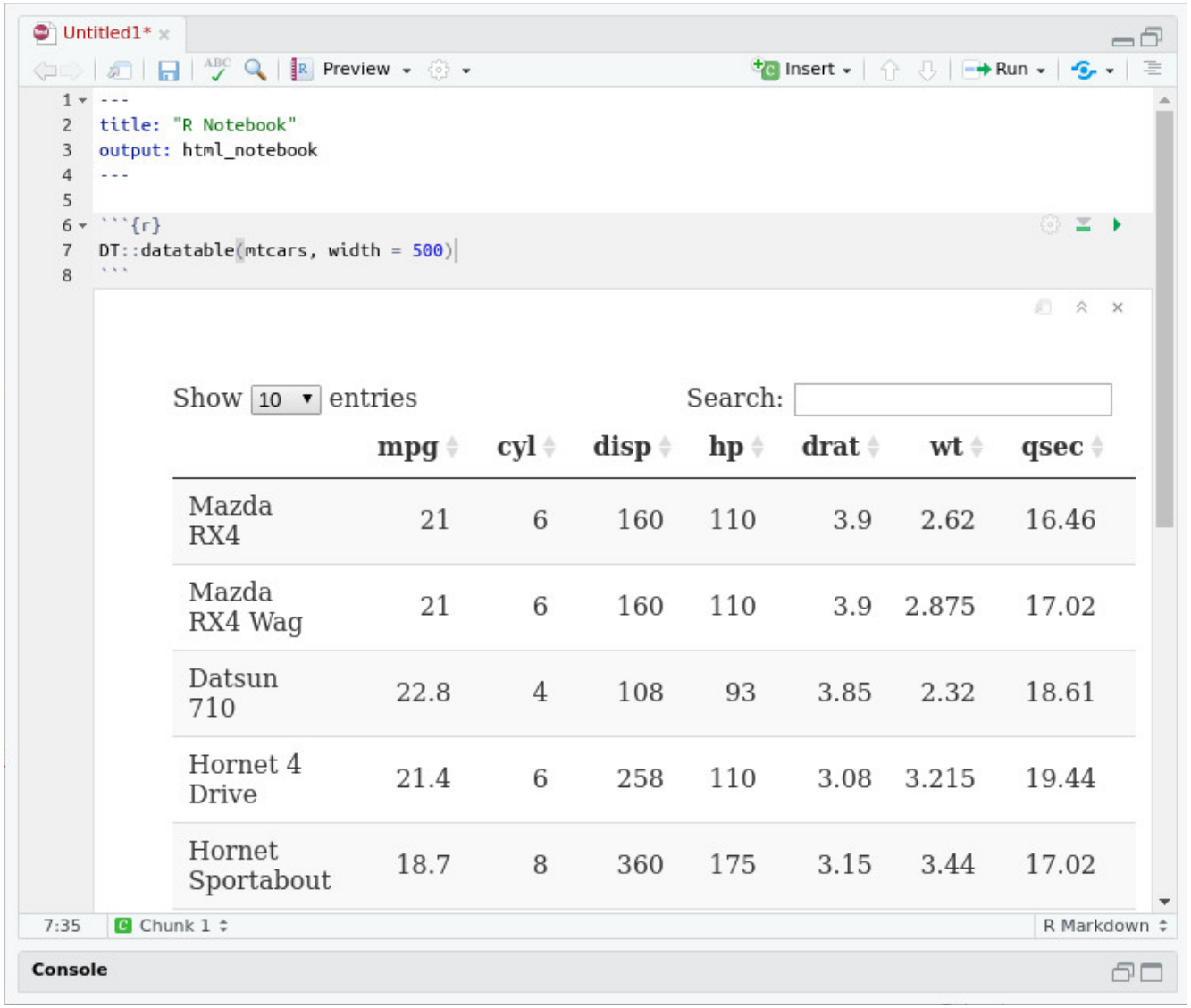
Untitled1*
Preview
Insert
Run
1 ---
2 title: "R Notebook"
3 output: html_notebook
4 ---
5
6 ```{r}
7 DT::datatable(mtcars, width = 500)
8 ```
Show 10 entries
Search:
mpg cyl disp hp drat wt qsec
Mazda RX4 21 6 160 110 3.9 2.62 16.46
Mazda RX4 Wag 21 6 160 110 3.9 2.875 17.02
Datsun 710 22.8 4 108 93 3.85 2.32 18.61
Hornet 4 Drive 21.4 6 258 110 3.08 3.215 19.44
Hornet Sportabout 18.7 8 360 175 3.15 3.44 17.02
7:35
Chunk 1
R Markdown
Console

Concluding remarks

- There is an opportunity for quantitative and qualitative enhancement
  - → Interactive plots for engagement
  - → Notebooks for active learning
- Gradual increase in students' degrees of freedom
- Happy to help if anyone wants to try bokeh

What do **you** think?

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Comparative Judgement

Over to you, Ian.