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iNZight: A Graphical User Interface for Visualisation and Exploration of Data with R

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Abstract

Getting started with data science is a daunting task, particularly when it requires a large amount of coding before you can even start looking at data. Graphical user interfaces (GUIs) have often been used as a way of proving novice users the ability to interact with complex systems without the need for coding. However, many of these themselves have steep learning curves to understand how to make the software do what's needed, and do not provide a pathway to more standard and flexible methods, such as coding. **iNZight** is a GUI based tool written in R that provides students of statistics and data science the opportunity to interact with data and explore without first learning to code. The tool is designed to be easy to use, with logical interactions and clever defaults. However, it also provides some more complex features to manipulate and analyse data, and further provides a code history of the actions performed, creating a pathway between GUI and learning to code for those interested in progressing into the more open and exciting world of data science.

Keywords: GUI, statistical software, statistical education, R.

1. Introduction

The R programming environment (R Core Team 2020) is used throughout statistics and data science due to it being open source, easy to learn, and backed by a huge package repository to solve even the most unique of problems.

- several graphical user interfaces (GUIs) have been developed over the years to ease access to advanced features of R: graphs, hypothesis tests, etc

- eg: Fox (2005), Fellows (2012)
- these tend to work by asking users to first choose an action, then fill in the fields (including variable choice)
- this requires some higher level of understanding to get useful information out (i.e., need to know what a "t-test" is)

An alternative approach is to work variable-first, such that users choose variables they are interested in, and then choose from an automatically curated list of options to perform. **iNZight** uses this approach, and presents users with a exploration-focussed interface.

- focus is on visualising, removing the need for any basic understanding of statistical procedures to get started with data visualisation
- like other GUIs, there's a code component: however, **iNZight**'s is more *behind-the-scenes*; useful for seeing a history of what you've done, with a little emphasis on editing a command to see how it changes things
- goal is to develop data exploration skills before moving them on to coding (high-level to low-level)

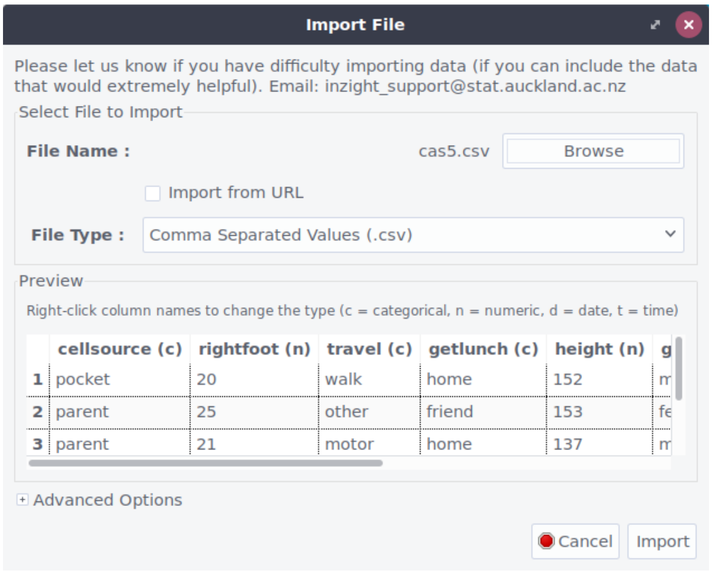
Due in part to its ease of use, **iNZight** has been adopted throughout New Zealand's statistical education program. Final year high school students are introduced to basic statistical concepts using **iNZight**, including a foray into time series analysis. Universities accross the country have also begun to use **iNZight** in both introductory and some advanced statistics courses. This paper provides an overview of some of the main features of **iNZight**, along with technical details, an introduction to its *Add-on* system, and description of the install process.

2. A tour of iNZight's features

The primary audience for **iNZight** are students of statistics and data science, but secondary groups include small research groups with small budgets and organisations which perform analyses infrequently. The simplicity of the interface means its easy to remember how to use the program after a period of non-use, unlike more specialised software which can cost time to relearn. We have done this by making the interface as intuitive as possible, with few self-explanatory controls using basic mechanisms such as drag-and-drop or selection from a drop-down box. **iNZight** also uses a *variable first* approach, meaning users choose the variables they are interested in, and the software displays relevant actions. The easiest way to demonstrate **iNZight**'s features is by demonstration. In this section, we take a tour through the software from simple to complex.

2.1. Loading data

Data comes in a wide range of formats, some of which are typically software-dependent (such as Excel files, Microsoft Corporation 2018). Thanks to being open source, there are 1000's of R packages on the Comprehensive R Archive Network (CRAN), amongst which are some



Please let us know if you have difficulty importing data (if you can include the data that would extremely helpful). Email: inzight_support@stat.auckland.ac.nz

File Name : cas5.csv

□ Import from URL

File Type : Comma Separated Values (.csv)

Right-click column names to change the type (c = categorical, n = numeric, d = date, t = time)

	cellsource (c)	rightfoot (n)	travel (c)	getlunch (c)	height (n)	g
1	pocket	20	walk	home	152	m
2	parent	25	other	friend	153	fe
3	parent	21	motor	home	137	m

Figure 1: Load Data window, showing the chosen file, the File Type (guessed from the extension), and a preview of the data.

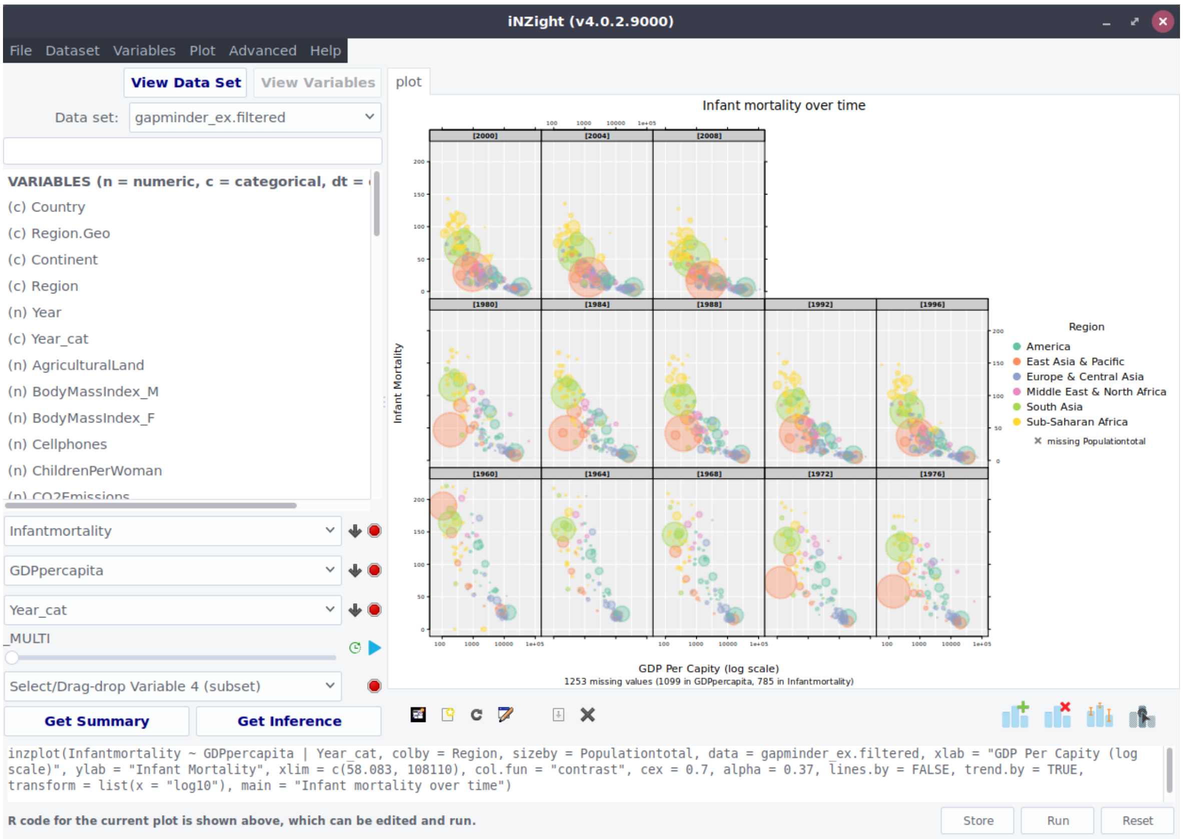
dedicated to reading specific file formats. However, users must still know the correct package and function for their files. **iNZight** provides a simple Load Data window from which they can select a file to import. The software detects the file type from the file extension and attempts to read the file. If successfull, a preview is displayed for the user to check before proceeding to import the file. Figure 1 shows the Load Data window, which has detected a comma separated values (CSV) file and used the appropriate function in the background. Currently, **iNZight** supports files in CSV, tab-delimited, Excel, SAS, Stata, SPSS, R-data, and JSON formats.

In addition to the preview, **iNZight** also has an *Advanced Options* section for some specific formats (currently only CSV files). Namely, this allows users to override the default delimiter, for example in European countries where the semi-colon (;) is used (the comma is reserved as the decimal separator), as well as different encoding formats. The preview is updated when these options are changed, meaning users do not have to know specifically what they need, and can quickly trial-and-error until the preview looks right.

2.2. Creating graphs

Within **iNZight**, graphics are at the core of the user experience. The very first prototype included a drag-and-drop of variables to create a plot, and that is how things have remained. Behind the scenes, **iNZight** detects the variable types (numeric, categorical, of a date-time) and draws an appropriate graph. For example, a single numeric variable produces a dot plot, while a categorical variable produces a bar chart. The user does not need to know what type of graph they want to create from a chosen variable, allowing them to freely explore the dataset by drag-and-drop of variables onto the Variable boxes (or using the drop down menus).

The first variable box is referred to as the *Primary Variable of Interest*. That is, this is the



```
inzplot(Infantmortality ~ GDPpercapita | Year_cat, colby = Region, sizeby = Populationtotal, data = gapminder_ex.filtered, xlab = "GDP Per Capity (log
scale)", ylab = "Infant Mortality", xlim = c(58.083, 108110), col.fun = "contrast", cex = 0.7, alpha = 0.37, lines.by = FALSE, trend.by = TRUE,
transform = list(x = "log10"), main = "Infant mortality over time")
```

R code for the current plot is shown above, which can be edited and run.

Figure 2: Demonstration of plot modifcations available from **iNZight**'s Add to Plot menu.

variable we want to know about, and how it is influenced by other variables. For example, if 'height' is chosen as Variable 1, and we want to know how 'height' changes with ethnicity or age. In the latter case, the result will be a scatter plot *with 'height' on the y-axis*. In addition to the first two variable slots, **iNZight** includes two Subset variables to quickly and easily facet the plot and explore more complex relationships.

Finally, there is an entire panel dedicated to plot modifications: Add to Plot. This is accessed either from the Plot menu, or from the button in the Plot Toolbar. From here, users can choose from a selection of alternative plot types (limited by the types of variables), as well as choose a colour variable, sizing variable, plot symbols, trend lines, changing axis labels and limits, and much more. The options are presented in an interactive format such that the graph updates whenever the user changes values, allowing them to explore "what happens if . . . ", and "what does this do?". The goal is to allow beginners to explore a dataset without being limited by having to learn how to do a wide range of actions. Figure 2 shows a graph produced by **iNZight** exploring the relationship between infant mortality and GDP, region, population, and year.

2.3. Summaries and inference

To supplement the visual graphics, **iNZight** also provides two textual output modes: *summaries* and *inference*, accessed from the Get Summary and Get Inference buttons respectively. Summary information includes basic information about the chosen variables, including mean, standard deviation, quantiles, and so on, acting as a quick reference for values that are likely estimable from the graph itself.

The inference information provides confidence intervals for quantities such as means and proportions, and additionally provides a simple interface for performing hypothesis tests. **iNZight** displays a selection of tests available for the chosen variable(s), as shown in TABLE. The inference information can either be calculated using Normal theory or bootstrap methods (using the **boot** package, Canty and Ripley 2020).

2.4. Data wrangling

Usually the first thing researchers want to do when they first begin exploring a dataset is to create a set of exploratory graphs. However, it is often not possible to get the correct graphs from the raw data alone. Applying transformations and other modifications to the data can allow researchers to explore the data correctly, or explore it from a different perspective. **iNZight** contains two *data manipulation* menus: Data and Variables. The former acts on the data set as a whole, while the later modifies individual columns.

In their book *R for Data Science*, Wickham and Grolemund (2017) describe many data manipulation methods including filtering, aggregation, and reshaping. They provide the **tidyverse** (Wickham *et al.* 2019) code for these actions, which **iNZight** uses behind-the-scenes to implement the behaviours. However, **iNZight** provides a GUI interface to these (often complex) methods, allowing users to quickly and easily filter by value, convert from *wide* to *long* form, or merge two related datasets together. In most cases, the interface allows users to fill out the fields which change according to previous selections, and at the bottom is a preview of what the data will look like, as demonstrated in FIGURE.

Supplementary to the dataset operations, the Variable menu provides a selection of variable transformation and modification actions. For example, numeric variables can be converted to categorical (a common example is `Year`), or categoric variable levels can be renamed, reordered, and combined. Users also have the option of creating custom variables using R code, as well as renaming and deleting entire variables. In most cases, **iNZight** creates a *new* variable, for example converting `Year` to categorical might yield the variable `Year.cat`, which makes the experience more exploration-friendly.

2.5. Special data types

- a lot of data is simple rows of individual observations
- most standard graph types offered by **iNZight** can cover the basic explorations
- some cases where either the data has unique features that *must* be incorporated (e.g., surveys) *or* the data has unique constructs and needs a specific exploration techniques (time series, multiple response)
- **iNZight** provides capabilities for some of each (plus extensibility for more)

Complex survey designs

- native handling of surveys: set and forget
- stratified/cluster surveys; replicate weight surveys; post-stratification/calibration
- design stored and used in place of dataset: graphs, summaries, transformations all use survey-specific functions from the **survey** package (Lumley 2004).

Time series

Maps

Other types

- multiple response data
- multivariate data (addon module, Section 4)
- frequencies
- extensible to others too

2.6. Code writing for getting started with R

- displays code for current plot (if enabled)
- can be edited -> GUI updates
- can be saved to 'script'
- **iNZight** keeps history of all actions as R code -> can copy and paste into R, edit manually, share, etc

[[show code history in Appendix for the demo session; note: plots not saved unless requested]]

3. Technical details

- based on **gWidgets2** (Verzani 2019) and **gWidgets2RGtk2** (Verzani 2020), which call to **RGtk2** (Lawrence and Temple Lang 2010); cross-platform
- like **gWidgets2**, we used reference classes to describe each component of the GUI [[FIGURE of GUI overlaid with object names?]]
- object oriented programming (OOP) makes sense for a GUI
  - panel has buttons, methods; belongs to another panel/window/GUI

  - inheritance: some windows have similar methods, just a few differences

- each major panel calls a single function from another packages
  - plots: `iNZightPlots::inzplot()`
  - import data: `iNZightTools::smart_read()`
  - filter: `iNZightTools::filterData()`

- wrappers: many custom-made packages in separate **iNZight*** packages; make easy interface between GUI and R (inputs = arguments)
  - enables code-writing: wrapper includes R code for its call

- describe sub-packages (TABLE: plots/regression/etc)

- diving deeper: data stored in *Documents*, each with a dataset/info about it; plots settings, variable choices, etc
  - users can switch between documents (data sets)
  - or merge them

3.1. Usage

- its an R package

- GUI is a single reference class object, ‘`iNZGUI`’

```
R> library(iNZight)
R> ui <- iNZGUI$new()
R> ui$initializeGui()
```

- however, include a wrapper to make easier startup:

```
R> iNZight()
```

- For development, first option is better since it provides direct access to the objects:

```
R> ui$getActiveData()
R> ui$ctrlWidget$V1box$set_value("height")
```

4. The add-on system

- **iNZight** comes with several “advanced” modules

- also a (newer) add-on system allowing anyone to install new addons from a 3rd party (or from our repo)

- a single file (currently) with a single refernence class object inheriting from ‘`CustomModule`’

- **iNZight** lists all modules installed to a specific modules directory on user's computer (either using manager or manually) in the ADVANCED menu
- when opened, shows up in the left-hand panel; has access to data, graphics device, menu items (can change these)
- developer can use their own methods, controls, etc
- Demo: Bayesian demographic modelling module (under development)

5. Installation and availability

- can install as an R package from combination of our repository and CRAN (still working towards publishing final few packages to CRAN)

5.1. Operating system specific requirements

- windows: will be prompted to install GTK binaries on first run
- macOS: very difficult, need to install XQuartz, gtk2+ framework, and compile **RGtk2** manually ...
- Linux: install system dependencies, then install as usual

5.2. Windows installer

- difficult to expect novice users/students to install R, etc
- we have a bundled version which comes as a `.exe` installer, unpackaging into chosen directory (default `Documents`
  `iNZightVIT`) which includes a copy of R and package library
- also some shortcuts to launch R in a subdirectory containing a `.Rprofile` which loads **iNZight** and launches the GUI

Updating

- updater included with installer: makes it easy for non-R users to update packages periodically

5.3. Docker image

- Docker (**?**) lets developers bundle apps for distribution
- containiner based on Linux and works for Linux and macOS hosts
- less speedy (performance) but doesn't require huge install; currently the only way to run **iNZight** on macOS without manually compiling lots of things
- still requires a little work from the user to enable X11 forwarding (so the interface windows display on the host screen)

5.4. Online shiny version iNZight Lite

- for users who can't install (e.g., macOS, tablet)
- most of the same functionality, separate but parallel development
- call to same packages: same results across systems
- runs on Amazon Web Services (AWS) server: some performance issues

6. Summary and future work

- **iNZight** provides an easy-to-use GUI to simple exploration and visualisation tasks for statistics and data science students/beginners
- variable-first: doesn't require knowledge of techniques beforehand
- data manipulation techniques and other advanced data-specific features (e.g., surveys)
- code writing for those interested in migrating towards learning to code in R
- add-on system for easy expansion by course coordinators/researchers/R package maintainers who want to provide a simple interface to their package
- available on Windows and Linux

6.1. Future Work

- database connections (for larger datasets, including surveys, with database calculations where possible)
- translation system (flexible for any other languages)
- exploration of alternative GUI frameworks (gtk alternative) with better cross-platform support (i.e., macOS)

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