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iNZight: A Graphical User Interface for Data Visualisation and Analysis through R

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Abstract

Visualisation, exploration, and analysis of data is often inaccessible to many due to high up-front costs of learning the necessary coding skills to get started. Graphical user interfaces (GUIs) have often been used to provide inexperienced users with access to these underlying, complex systems without the need for coding. Yet, with respect to R GUIs, many still require some degree of experience with R. **iNZight** is a GUI-based tool written in R that provides researchers and students with the opportunity to interact with and explore data without the need for code. The tool is designed to be easy to use, with intuitive controls and clever defaults. **iNZight** also provides more complex features for manipulation and analysis of data, and includes some code-writing capabilities for researchers to efficiently generate reproducible outputs, or as a pathway for newcomers to learn the basics of the R programming environment.

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

1. Introduction

The open source statistical programming environment R (R Core Team 2020) is used throughout statistics and data science, and is supported by a repository of thousands of free packages allowing users to access the latest statistical techniques and graphics, and perform many other essential tasks. Amongst these packages are several graphical user interfaces (GUIs) providing point-and-click methods for interacting with R to create graphs, test hypotheses, and access a range of other statistical methods, with two prominent examples: R Commander (Fox 2005) and **Deducer** (Fellows 2012). R Commander includes a full interface which displays, writes, and runs R code, while **Deducer** extends the R console with additional menus to open window interfaces for a range of methods. These tools let users perform known procedures using point-and-click interfaces without needing to remember function and argument names. They do, however, require that users not only install R and the necessary packages, but also have a general understanding of the underlying methods and how to use them. This excludes many users new to statistics from the benefits of a GUI.

An alternative design is to let users choose the variables, and have the software present a selection of applicable methods (or use a good default). This approach is used by **iNZight**, a GUI built in R to allow non-coders to explore, visualise, and analyse data. Designing the GUI with "variable-first" concepts makes it more approachable and gives the software an exploration-focus, with a special emphasis on graphics. **iNZight** encourages users to explore the variables in their dataset without worrying about variable types, and then producing summary statistics and inference information using designated buttons. These summaries and inferences display information relevant to the chosen variables, which means users do not need to know in advanced that the test used to compare the means of two groups is a t-test: the software provides a list of applicable tests. This concept is used throughout the program, making it ideal for both beginners new to statistics as well as researchers who may need to perform simple tasks on an infrequent basis. Additionally, it makes performing some data analysis tasks more accessible to organisations who would otherwise need to train individuals within their organisation, or hire specialists—both of which require time and money.

Like other GUIs, there is a code component to **iNZight**. R Commander provides a place for users to enter R code, while **Deducer** sits on top of the R console using the environment as-is. With **iNZight**, however, code is evaluated "behind the scenes", and is not directly editable by users. Every action the user makes calls one or more R functions, and the code is added to the *code history* for users to review, save, and share. Users can generate an R script unique to their data and later edit and run the code manually in R, quickly generating a reproducible methodology for research oganisations. Additionally, the script can be used as a stepping stone for learning to code in R. [1]

Not only has **iNZight** been adopted throughout New Zealand's statistical education program, the combination of **iNZight**'s simplicity and powerful tool set make it a popular choice for research (and other)[2] organisations. Students are introduced to basic statistical concepts using **iNZight** in their final year of high school, and thus as future researchers will be familiar with it for their professional projects. This paper provides an overview of **iNZight**'s main features, technical details of its development, an introduction to the *add-on* system, and a description of the install process.

`Into still needs work, especially last 2 paras.`

2. A tour of iNZight's features

Originally designed as a tool for teaching statistical concepts to students, **iNZight** lends itself well to use as an rapid research development tool for community and government research groups. The interface is minimal and provides instant feedback from user actions, making it intuitive to use so users can easily start exploring their data. This paradygm makes it easy to learn new statistical concepts—such as hypothesis testing—by focusing on the output first, and consequently makes it very easy to pick up after a period of non-use, typical of critical but seldomly performed tasks within organisations. Ease-of-use is achieved through familiar controls such as *drag-and-drop*, *drop-down* selection, and *slider bars*. Additionally, **iNZight** uses a *variable-first* approach, where users choose the variables they are interested in and the

[1] Drop this paragraph in favour of one for student vs research?
[2] some examples from Andrew?

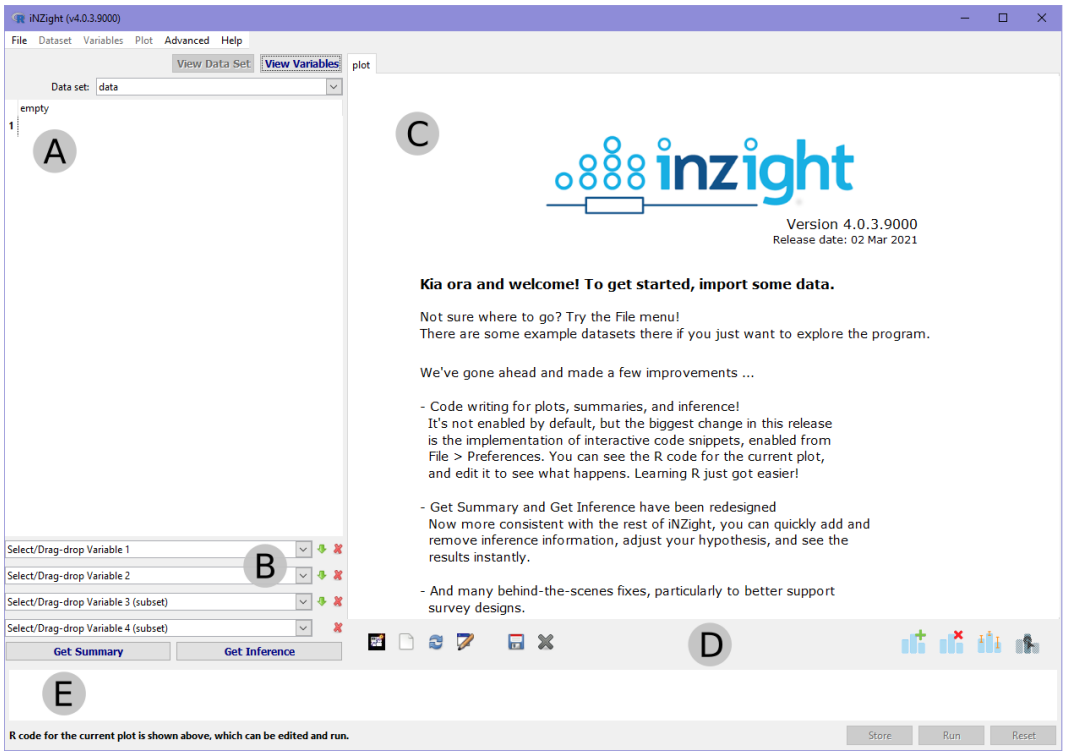

Figure 1: The **iNZight** GUI landing page presents users with a few controls. The labeled areas are: (A) the active data set is displayed prominently; (B) variable control boxes provide users either drag-and-drop from (A), or select from dropdowns; (C) graphs are displayed in the graphics window; (D) plot controls, most importantly the plot configuration controls (left); (E) if enabled, code for the active plot is shown here and can be edited by the user.

software decides on the best option of provides a small set of choices. The best way to explore **iNZight**'s features is by demonstration.

2.1. Loading data

Datasets come in a wide range of formats, some of which are traditionally software-dependent (for example Excel, Microsoft Corporation 2018, stores files in Excel (.xlsx) format). Fortuately, there are 1000's of R packages on the Comprehensive R Archive Network (CRAN), amongst which are some dedicated to importing most of the common (and indeed many uncommon) file formats. Usually, R users would need to first recognise or look up the file extension, find an appropriate package, then recall the function name and arguments (often by reading the documentation) to import an unusual file. **iNZight** provides a simple Load Data window from which users only need select the file to import: the software detects the

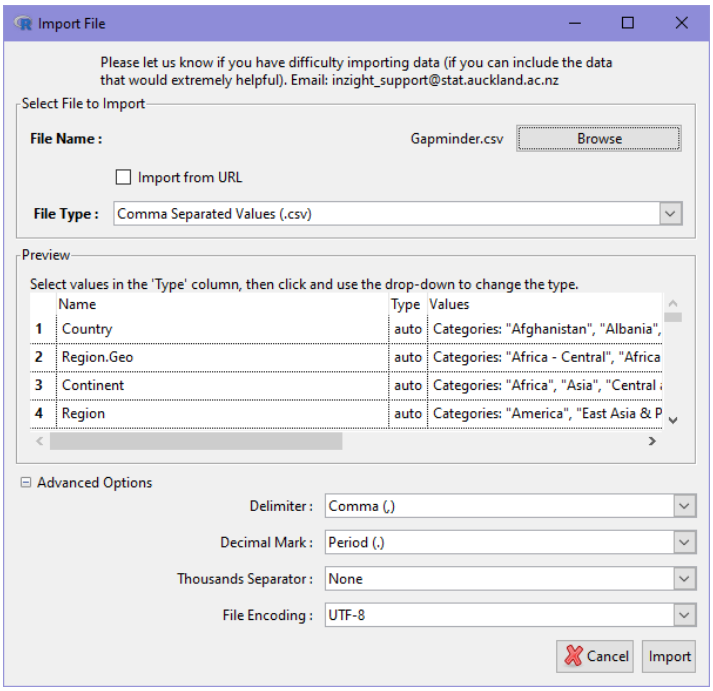

Figure 2: Load Data window, showing the chosen file, the File Type (guessed from the extension), and a preview of the data.

file type from the file extension and reads the file if the format is supported. Currently, **iNZight** supports files in comma separated values (CSV), tab-delimited, Excel, SAS, Stata, SPSS, R-data, and JSON formats. If the file is readable by **iNZight**, a preview is displayed for the user to check before proceeding with the import, as demonstrated in Figure 2 which shows the Load Data window for a CSV file.

In addition to the preview, **iNZight** also has an Advanced Options section for some specific formats. Currently only delimited files have advanced options, where users can override the default delimiter, for example in European countries where the semi-colon (;) is used (the comma is reserved as the decimal separator), or to choose between different encoding formats. The preview is updated when these options are changed, so users can use trial-and-error if they are not sure what the necessary inputs are. This is particularly useful for encoding, which is difficult to find out manually.

Lastly, the data preview allows users to override the default variable types. This is particularly userful when importing a dataset with coded factors (e.g., values $1, 2, 3$ instead of "A", "B",

"C"). Currently, **iNZight** handles numeric, categorical, and date-time formats.

2.2. Creating graphs

Grahpics are the core of **iNZight**'s user experience; indeed, the very first prototype of **iNZight** was simply a drag-and-drop of variables onto slots to create a graph—everything else came later. Behind the scenes, **iNZight** uses variable types (numeric, categorical, or a date-time) to determine the appropriate graph. For example, a single numeric variable produces a dot plot, while a categorical variable produces a bar chart. While this may seem obvious to experienced statisticians, beginners cannot be expected to immediately grasp the concept of a "numeric" variable, and why a dot plot is used instead of a bar chart. By taking away this step, teaching and learning focus can switch to "why does this variable produce this graph" instead. It also lets even experiences users quickly look at graphs without the hassle of first figuring out the data types.

The control panel (**B** in Figure 1) is where users can choose up to four variables: the first of these (*Variable 1*) specifies the *Primary Variable of Interest* (or *Outcome Variable*). The remaining three variable boxes are for exploring what variables influence the primary variable. For example, 'height' might be the primary variable, so selecting it will produce a *dot plot* of height. If a secondary variable is chosen, for example 'ethnicity', then we will be shown a dot plot of height for each ethnicity, stacked vertically. Importantly, if a *numeric* variable, such as 'age', is chosen as the secondary variable, we are shown a graph of height versus age: variable 1 (height) becomes the y-variable in the scatter plot. 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 and interactions.

For a deeper exploration of variable relationships, 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 (boxed in red in Figure 3). From here, users can choose from a selection of alternative plot types for the type of variable(s) selected, as well as choose a colour variable, sizing variable, plot symbols, trend lines, change axis labels and limits, and much more. The possible choices are presented in an interactive format such that the graph

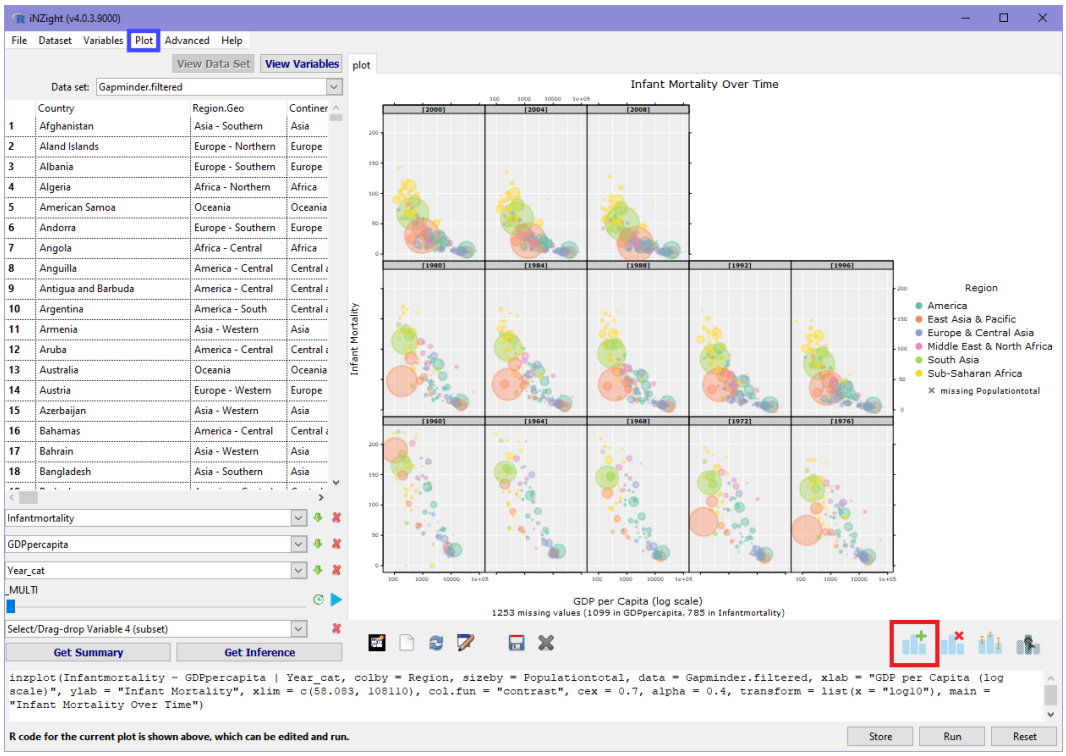

Figure 3: Demonstration of plot modifcations available from **iNZight**'s ADD TO PLOT menu. The ADD TO PLOT button, highlighted in red, opens a panel giving user control over colours, size, shape, labels, and much more. This can also be accessed from the plot menu, boxed in blue.

updates whenever the user changes input values, allowing them to explore "what happens if . . . ", and "what does this do?". This way, beginners can learn about the software while they explore the data: they are not limited by a lack of knowledge or coding skill, while researchers can quickly generate visualisations before starting their analysis. Figure 3 shows a graph produced by **iNZight** exploring the relationship between infant mortality and (log) GDP, region (colour), population (point size), and year (faceting).

2.3. Summaries and inference

To supplement the visual graphics, **iNZight** provides two textual output modes: *summary* and *inference*, accessed from the GET SUMMARY and GET INFERENCE buttons, respectively, below the control panel. Summary information includes basic statistics about the graph, and so similarly depend on the variable type(s) chosen. Dot plots produce summaries of

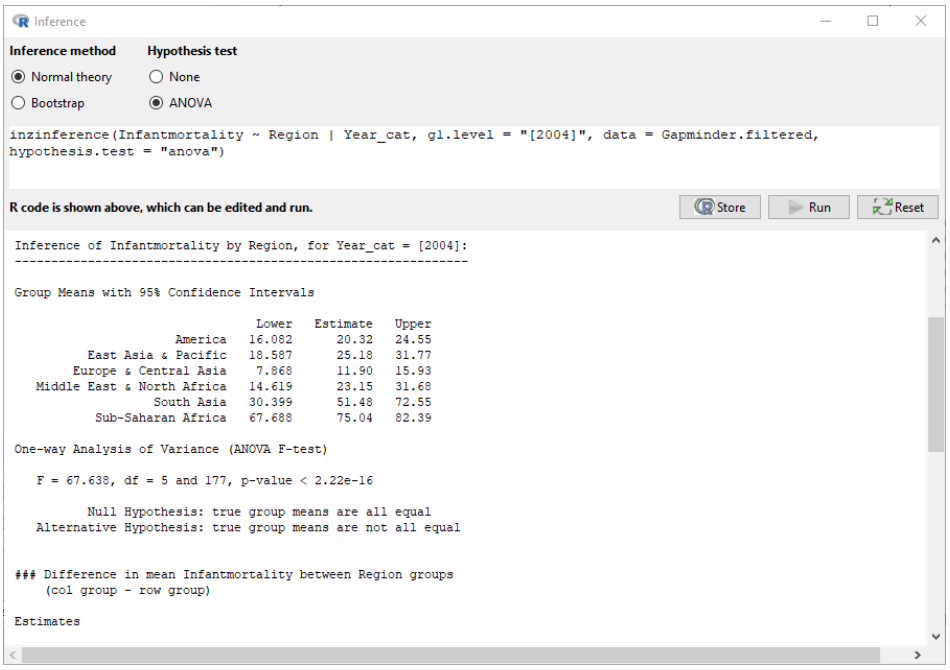

Figure 4: The INFERENCE window provides a selection of hypothesis tests for the chosen variables. In this case, these are `Infantmortality` (a numeric variable) and `Region` (categorical with six levels), so **iNZight** provides an ANOVA test.

means, standard deviations, and quantiles, while bar charts produce a table of counts and percentages. Scatter plots come with the formula for any fitted trend lines, as well as the correlation between the variables.

The inference information includes estimates, confidence intervals, and any applicable p-values for quantities such as means and proportions, and includes a simple interface for performing hypothesis tests. **iNZight** displays a set of tests applicable to the chosen variable(s), as shown in Figure 4. The full list of tests available are given in Table 1. Inference information can either be calculated using Normal theory or bootstrap methods (using the **boot** package, Canty and Ripley 2020), with work on-going to add Bayesian inference methods.

2.4. Data wrangling

Researchers typically start a new analysis by creating a set of exploratory graphs, as described in Section 2.2. However, it is often not possible to get the correct graphs from the raw data, which might not be in the correct format. Often, data transformations are required before

Table 1: iNZight hypothesis test options.

Variable 1		Variable 2			
		NULL	numeric	2 level cat	2+ level cat
numeric		t-test[1]	–	t-test[3]	ANOVA
categorical	2 levels	single proportion	t-test[3]	χ^2-test[4,5]	χ^2-test[4,5]
	2+ levels	χ^2-test[2]	ANOVA	χ^2-test[4]	χ^2-test[4]

[1] One-sample
[2] Equal proportions
[3] Two-sample
[4] Equal distributions
[5] Additionally includes epidemiological output such as odds and risk ratios.

any useful analysis can begin (for example converting numeric codes to categorical variables) or to explore from a different perspective. **iNZight** contains two *data manipulation* menus: Data and Variables, for manipulating the full dataset and individual columns (variables), respectively.

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. **iNZight** provides a GUI interface to these (often complex) methods, so users can quickly and easily filter by value, convert from *wide* to *long* form, or merge two related datasets together. In most cases, the interface evolves from top-to-bottom as the users first chooses, for example, the variable, with subsequent inputs tailored to previous choices. At the bottom of many windows is a preview of the data after transformation, as demonstrated in Figure 5. A full list of available methods is given in Appendix B.1.

The Variable menu houses 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 new variables based on existing ones, as well as renaming and deleting variables. In most cases, **iNZight** creates a *new* variable, for example converting `Year` to categorical yields the variable `Year_cat`, which makes the experience more exploration-friendly. Appendix B.2 gives a list of available variable manipulation methods.

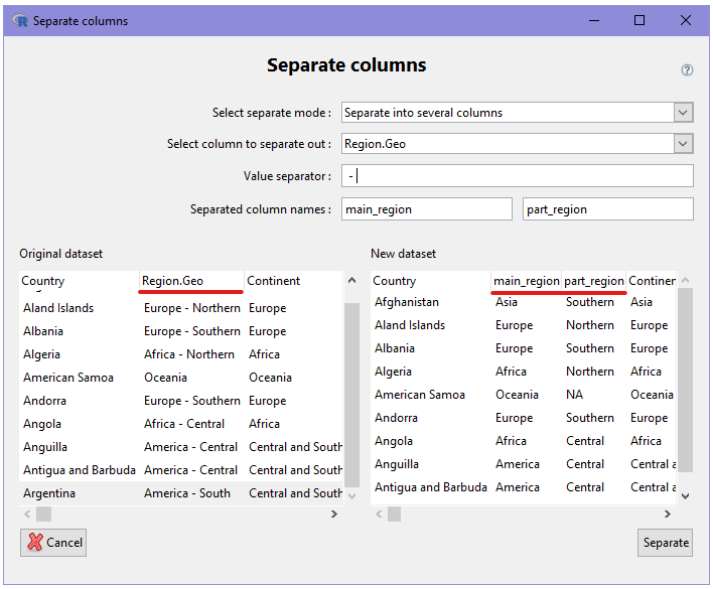

Figure 5: Here, the user is separating a column to create two new variable, with the preview displayed in the bottom-right. The relevent column names are underlined in red. The preview uses the first few rows of the data, and updates in real-time, reacting to changes the user makes, allowing them to experiment easily.

2.5. Special data types

Many data sets that beginners are exposed to are in 'tidy' format (Wickham and Grolemund 2017, chapter 12), such that rows are individual records and columns observations. However, there are some unique data types that are common for beginners to encounter, or form a core component of statistical anlysis. These data sets require special graphics or different handling to explore correctly, a task which **iNZight** has been extended to perform. Some examples are described here.

Complex survey designs

One of the more important data types for official statistics and population researchers are complex surveys, which require information about the survey's structure to provide valid graphs, summaries, and inferences. **iNZight** handles survey designs behind the scenes, requiring the user to specify the structure either manually (Figure 6) or by importing a special *survey design* file which can be distributed with the data. Once specified, the user can forget about the survey design and use **iNZight** as normal: survey weights are incorporated correctly

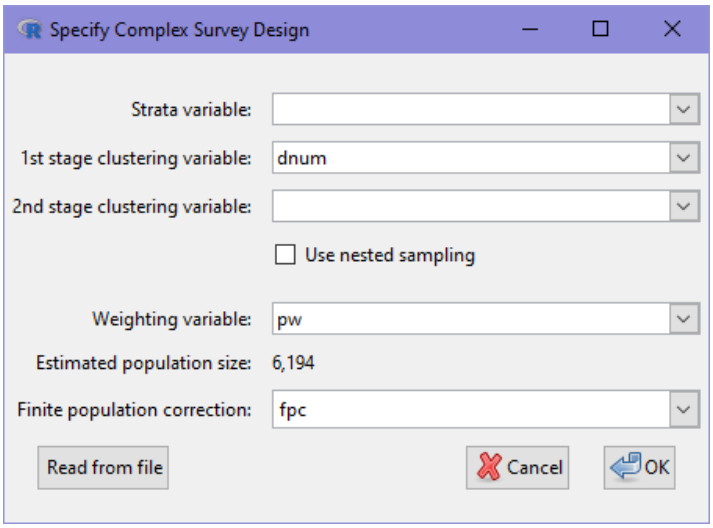

Figure 6: Users can specify survey design information manually by filling in the fields. These will then be used throughout the session.

into graphs, summaries, and data manipulation functions using the **survey** (Lumley 2004) and **srvyr** (Freedman Ellis and Schneider 2020) packages behind the scenes.

iNZight handles stratified, one- and two-stage cluster surveys. Instead of exposing the strata and cluster information in the dataset, some surveys provide this information using *replicate weights*, allowing variance estimation without exposing this information (Lumley 2010). **iNZight** provides an interface for specifying replicate weight designs in that case. Additionally, **iNZight** provides functionality to calibrate surveys with data from other sources to reduce the estimated variances (**?**). Once again, this is performed once by the user and the used continually throughout the rest of **iNZight**.

The types of graphs available differ for survey data. For a single numeric variable, a *histogram* is displayed by default instead of a dotplot. For two numeric variables, a *bubble plot* is used, which is effectively a scatter plot with points sized by the respective weights of observations; alternatively, this can be displayed as a *hex* plot. Bar plots are still used for surveys. Summaries display the same information as before (Section 2.3), but provide estimates and standard errors of the population values, as shown in Figure 7. Similarly, inferences and hypothesis tests are performed for the population, and thus include additional uncertainties from the survey design.

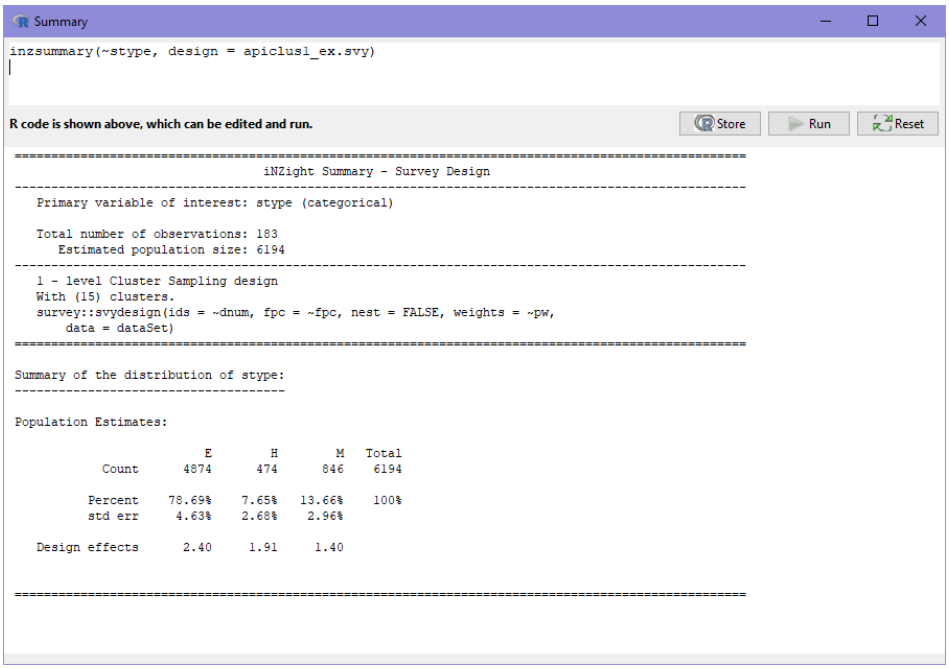

Figure 7: The SUMMARY window window provides simple summary statistics and, in the case of survey data, standard errors of these population estimates.

Time series

Another important data type is *time series* in which the variable of interest is observed changing over time. Time information can be specified to **iNZight** either in a specially formatted column in the data, or manually by the user within the module itself. Then one or more variables can be displayed on the y axis versus time, typically connected by lines. Currently **iNZight** only supports time series with equally spaced and non-missing values.

iNZight's time series module provides capabilities for users to graph one or more time series on a graph, and automatically overlays a smoother (controlled by a slider) on each. Additionally, the series can be decomposed to show the trend, seasonal, and residual components (using seasonal-trend decomposition using LOESS (STL)). Animations are available to help with understanding how the various components combine to form the final series, and a Holt-Winters' forecast can be obtained by choosing the *forecast* plot type (Holt 2004; Winters 1960).

Figure 8 shows the time series module with quarterly visitor arrivals data for several countries

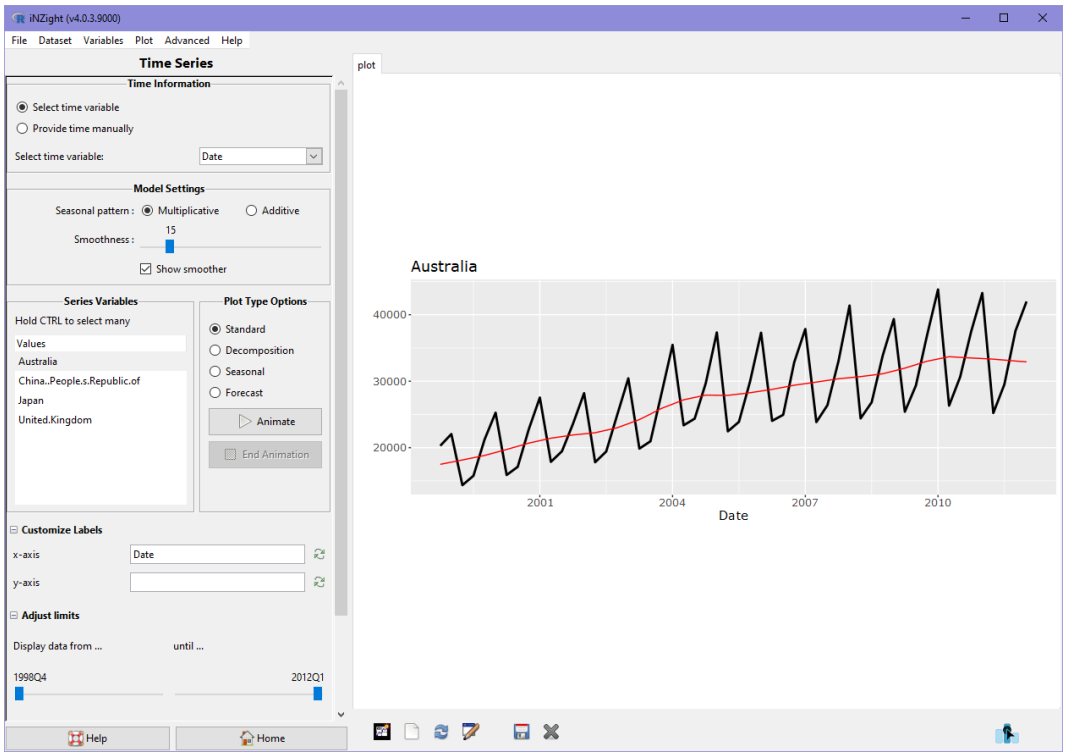

Figure 8: The time series module.

loaded. The software automatically detects the `Time` column ("Date") when loaded, and draws the displayed graph without any user interaction. Users have a choice between *additive* and *multiplicative* models, and a slider to control the smoothness of the LOESS smoother (in red). From the SELECT VARIABLE list, one or more variables may be chosen, while the graph type is selected from the list on the right ('Plot type Options').

Maps

Geographical data is particularly important for looking at regional effects or differences, or for seeing the distribution of location-based events; however, it can be difficult to create appropriate graphs. **iNZight** features a *Maps* module for exploring two types of geographical data: point-based data, in which observations are associated with latitude and longitude locations (for example earthquakes); and regional maps for exploring data for specific regions which may be countries or areas within countries (regions, states, and so on). The functionality within the maps module call wrapper functions from the **iNZightMaps** package (Barnett and

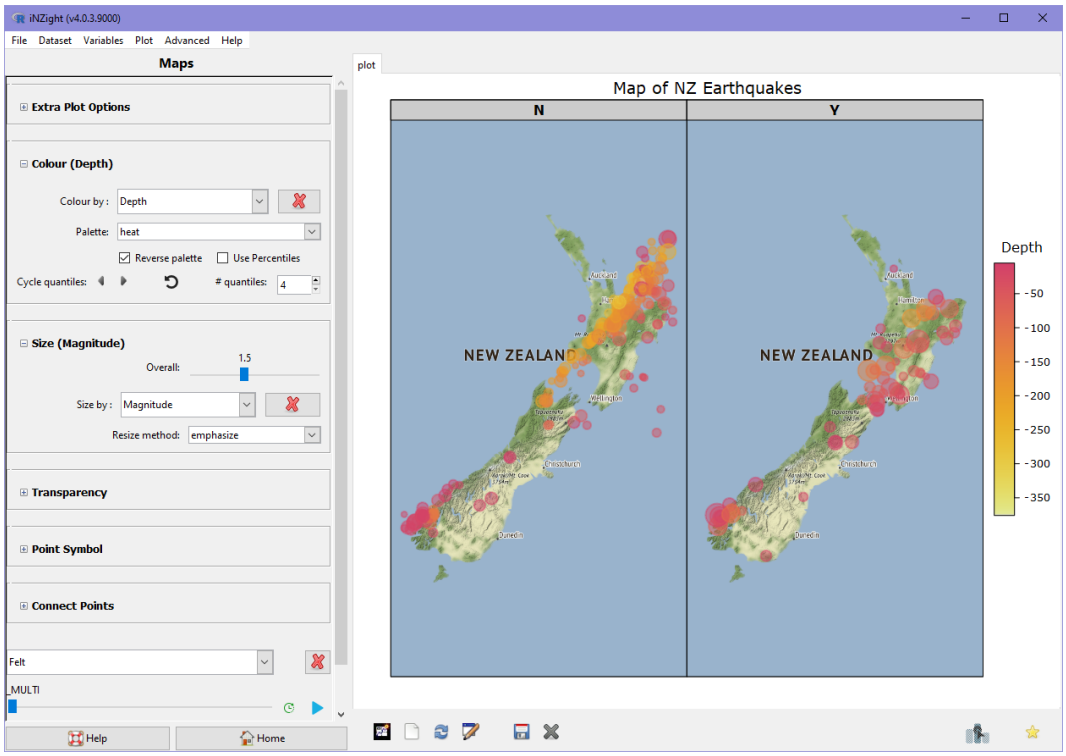

Figure 9: The maps module showing New Zealand earthquakes sized by magnitude, coloured by depth, and subset by whether or not they were felt.

Elliott 2020).

For point-based observations, the points are overlayed on a map obtained using the **ggmap** package (Kahle and Wickham 2013). The maps module in **iNZight** lets users explore other variables in the dataset using size, colour, and transparency, as well as through faceting, again using the same interface controls as the base program. A demonstration of this module using New Zealand earthquake data is shown in Figure 9, where points are coloured by depth, sized by magnitude, and faceted by whether or not they were felt.

Regional data has the added complexity of *shape files*, needed to describe the boundaries of areas. An example of this is country data, which requires shape files for countries in the dataset describing the world map. **iNZight**'s maps module lets users choose the type of map they need for the data, and proceeds to match labels between the two datasets using several matching techniques: countries may be coded using full names or a code ("New Zealand" versus "NZ" versus "NZL"). Once initial set-up is complete, users are free to pick variables to

graph, and regions of the map are coloured appropriately. Alternatively, if longitudinal data is provided, *spark lines* can be drawn showing how the value of a variable changes over time in various regions.

Other data types and features

Besides these few examples, **iNZight** supports several other special data types. *Multiple response* data arises from "Choose all that apply" type survey questions, and need their own method of graphics to explore adequately. There is also a multivariate data add-on module for performing principle components analysis and generating the appropriate graphs, such as a ? plot (**?**). The model fitting module allows users to fit complex linear and generalised linear regression models to data, including that from complex survey designs. The regression model output is provided reactively as users add and remove variables, and a range of residual plots are available to explore.

Besides those examples listed above, **iNZight** has an add-on system (Section 4) that allows developers to extend the interface to suit various type of data or to perform specific analyses. Individual package developers, or research groups, can create custom modules that are then shared either publically or privately with others.

2.6. Code writing for getting started with R

One feature prominent in the other R GUIs is the coding interface, which differs significantly from **iNZight**'s. R Commander provides a prominent "script" box into which code appears when using the command boxes, or users can enter their own code into. Below the script box is an output terminal. Meanwhile, **Deducer** is added onto the existing R Console, and similarly provides menu-driven commands to run code in the console. Each of these GUIs require some familiarity with R coding and an understanding of simple statistical terms and methods. **iNZight**, however, is completely separate from the R console, providing an interface-only experience for beginners and users not interested in the code. All of the code used by various actions is stored and available for users to review and run—with changes—in R manually.

The R script contains a history of all actions taken by the users from importing the data,

through transformations and manipulations, and any plots and summaries the user chose to save. The goal is to provide a record of what the user did, as well as something they can save to run in R themselves, editing where desired. This allows users to explore a dataset with a GUI tool to make a basic framework for an anlysis that can be used as the basis of a reproducible workflow.

A newer feature is the R code box at the bottom of the interface (see Figure 1). This displays the code used to generate the current plot and, more importantly, can be edited by the user and run, but very limited in functionality. The interface detects changes in the code and applies those changes to a GUI, providing a seamless way for users to begin experimenting with code whilst retaining the familiarity of the GUI. Users can also store the code for the current plot, adding it to the R script. A similar code box is displayed in the Get Summary and Get Inference windows, with plans to implement this behaviour throughtout **iNZight** in future.

The code used by **iNZight** uses a **tidyverse** (Wickham *et al.* 2019) workflow, as this provides an introduction to R with a simpler, verb-like syntax for data wrangling, and is used in the *R for Data Science* book (Wickham and Grolemund 2017). To demonstrate **iNZight**'s code-writing capabilities, Appendix A contains the script generated during the tour presented in this section.

3. Technical details

iNZight's interface is written with R using three main packages. **gWidgets2** (Verzani 2019) provide a simple widget-based application programming interface (API) to building a cross-platform interface with R, with wrappers for Tcltk, Qt, and GTK2. We choose GTK2, as it was the most feature rich and—at the time—had the best cross-platform support (see Section 5.1). The GTK2 binaries are access through R using the **RGtk2** package (Lawrence and Temple Lang 2010), and is translated from simple **gWidgets2** calls using the **gWidgest2RGtk2** package (Verzani 2020). Together, these packages provide a platform- and library-independent API for creating a GUI with R.

Figure 10: The reference class components of the **iNZight** interface, some of which are themselves made from several child objects.

The GUI for **iNZight** uses an object oriented programming (OOP) framework in R called *reference classes* (from the **methods** packages included with the base R distribution). The same framework is used by **gWidgets2** to describe individual components of the interface. Each piece of the GUI is a *class*, with individual buttons, methods (actions), and even smaller sub-components. OOP allows for *inheritance*, so developers can describe a general class which can be shared to several related components, but which may have different layouts or methods; this is what drives the add-on system (Section 4). Figure 10 shows the **iNZight** GUI with some of the major class components annotated.

In addition to these "visible" class components, others exist behind-the-scenes. The prominent one is the '`iNZDocument`' class which stores the state of the application, including the data set, variable selection, any survey design information, and plot settings. The '`iNZDataNameWidget`' component visible in the top-left of Figure 10 displays a list of documents the user can switch between. From the Data menu, several loaded datasets can be

merged together.

The structure of each class is, in most cases, a set of attributes that the user can control, stored as *properties* of the class. There is also a set of *methods* which can be used by the class to react to user input or perform actions. Most components have a main *action*[3] method, which performs the primary function of the component. For example, the '`iNZFilterData`' class contains a `filter_data()` method which takes the user's input and passes it to an appropriate *wrapper* functions. A skeleton example of the Filter Data window class is shown in Listing 1. [4] In this oversimplified example, the user is given a drop-down `gcombobox()` to choose a variable to filter on. When they click the Filter button, the data is filtered and passed back to the main GUI. Here, the method uses a `switch()` function to select the appropriate wrapper function within the **iNZightTools** package based on the user's chosen value of "type". The actual class for the Filter Data method is much more complicated, and includes reactive components so only the relevant inputs are displayed to the user.

Each major component has a similiar structure to Listing 1, with calls to various functions, many of which come from other **iNZight*** packages. Plots are generated by calls to `iNZightPlots::inzplot()`, while data import is handled by `iNZightTools::smart_read()`. This import function uses the file extension to guess the file type and load the data using the appropriate methods. The wrappers enforce separation of the interface and data logic so that the GUI is only concerned with the input values.

A second advantage of having components calling external functions is that the wrapper functions can include the lower-level R code used to generate the result, which the GUI can fetch from the returned data and attach to the script described in Section 2.6. Here is an example using `iNZightTools::smart_read()`:

```
R> library("iNZightTools")
R> data <- smart_read("nls.dta")
R> cat(code(data), sep = "\n")
```

[3] Find a better word.
[4] Include a figure of this window, too?

```
iNZFilterData <- setRefClass(
    "iNZFilterData",
    propoerties = list(
        GUI = "ANY",
        data = "data.frame",
        type = "ANY",
        variable = "ANY",
        operator = "ANY",
        value = "ANY",
        ...
    ),
    methods = list(
        initialize = function(gui) {
            initFields(GUI = gui, data = gui$getActiveData())
            # ... construct GUI inputs ...
            # e.g.,
            type <<- gradio(c("Numeric value", "Factor levels", "Random"))
            variable <<- gcombobox(colnames(data))
            okbtn <- gbutton("Filter", handler = function(h, ...) filter_data())
        },
        filter_data = function() {
            filtered_data <- switch(svalue(type, index = TRUE),
                iNZightTools::filterNumeric(
                    data,
                    var = variable,
                    op = operator,
                    num = value),
                ...
            )
            GUI$update_data(filtered_data)
        }
    )
)
```

Listing 1: Reference class definition for filter window example.

Table 2: iNZight R package family

Package	Description
iNZight	The main package for the GUI
iNZightModules	An additional GUI package providing additional modules for the main **iNZight** program.
iNZightPlots	Provides plot function `inzplot()` along with `inzsummary()` for descriptive statistics and `inzinference()` for inference and hypothesis testing.
iNZightRegression	Plots and summaries of regression models, including from `lm()`, `glm()`, and `survey::svyglm()` objects.
iNZightTS	Time series visualisation, decomposition, and forecasting.
iNZightMR	Visualisation and estimation of multiple response data.
iNZightTools	A suite of helper functions for data process and variable manipulation.

```
haven::read_dta("nls.dta")
```

The `iNZightTools::code()` function returns the R code attached to the resulting object, allowing a user to see that the **haven** package (Wickham and Miller 2020) was used to read this Stata file (`.dta`). Beginner R users need only learn the one function—`smart_read()`—but can easily dive into the underlying code and edit it as necessary to access advanced options.

While the GUI packages provide the structure of the visual GUI, it's the collection of R packages developed alongside **iNZight** that power the program. The main reason for creating separate packages was to force the separation of interface and data logic. However, it also allowed for the parallel development of a separate interface (Section 5.4) using the same wrapper functions. The collection of packages within the **iNZight** project are described in Table 2. Most of these packages have been designed with simple high-level interfaces that are both useful for connecting to the GUI, but also for beginners to use standalone.

3.1. Usage

At its core, **iNZight** is an R package that can be installed and run like any other, as covered in Section 5. Once installed, the main program can be started by calling the function of the same name:

```
R> library("iNZight")
R> iNZight()
```

This can optionally take a `data` argument, which will launch **iNZight** with the data loaded

and ready to explore. Another use-case of the data argument could be to include within an R script used by a research group where the data needs to be loaded in a specific way (for example from a secure database). Users need only source a script similar to the following.

```
library("DBI")
con <- dbConnect(...)
tbl_data <- dbGetQuery(con, "SELECT ...")
library("iNZight")
iNZight(data = tbl_data)
```

For development purposes, it is preferable to initialize the GUI object manually:

```
ui <- iNZGUI$new()
ui$initializeGui()
```

Users now have access to the 'iNZGUI' object to explore states and trigger actions for easier testing. In these next two commands, the first returns the dimensions of current data, while the second sets the first variable drop-down value to `height`.

```
R> dim(ui$getActiveData())

[1] 500  10

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

4. The add-on system

For most users, the main **iNZight** program will have all they need to explore, visualise, and perform simple analyses on their data. Some, however, may require access to special analyses not built in to the base program. Rather than requiring each new datatype or method to be manually coded into **iNZight** by the developers, we crafted an *Add on* system allowing anyone to create their own **iNZight** modules that can connect to new or existing R packages available on CRAN or elsewhere.

Installing existing add-ons is easy. From the MODULE MANAGER users can add, update, and remove modules from our add-on repository,[5] a custom URL, or a local file. In all cases, the file is downloaded to the `modules` directory; users can also place files there manually, if desired. All files in this directory are displayed in the ADVANCED menu of **iNZight**, and when opened have access to the **iNZight** interface, including the dataset imported by the user.

The module files themselves describe a single class object which inherits from '`CustomModule`'. This parent class provides several methods, including the initialization of the module panel in the left-hand-side of the **iNZight** interface. Additional properties and methods can be written by the developers of individual modules. This opens up possibilities for teachers, research groups, or even R package developers themselves to write custom modules to distribute to their desired audience.

As an example, Figure 11 shows a prototype for an upcoming Bayesian demographic modelling (Zhang *et al.* 2019) module which will be used by demographers to do small-area estimation. In the example, we have estimated life expectancies from death count data, which is traditionally a complicated ... [grab quote from other report]. Full details for this module will be published once the full version is complete.

5. Installation and availability

As an R package, **iNZight** may be installed manually from the R console like any other package. We have an R repository available at `https://r.docker.stat.auckland.ac.nz` which hosts the most up-to-date versions of our packages. Most of these are now on CRAN, and work continues to prepare the remainder. Since **iNZight** is a GUI, there are one or two additional system dependencies that need to be installed, with variations between operating systems, as discussed below.

5.1. Operating system-specific requirements

The GTK windowing system is a cross-platform project with libraries available on Windows,

[5] https://github.com/iNZightVIT/addons

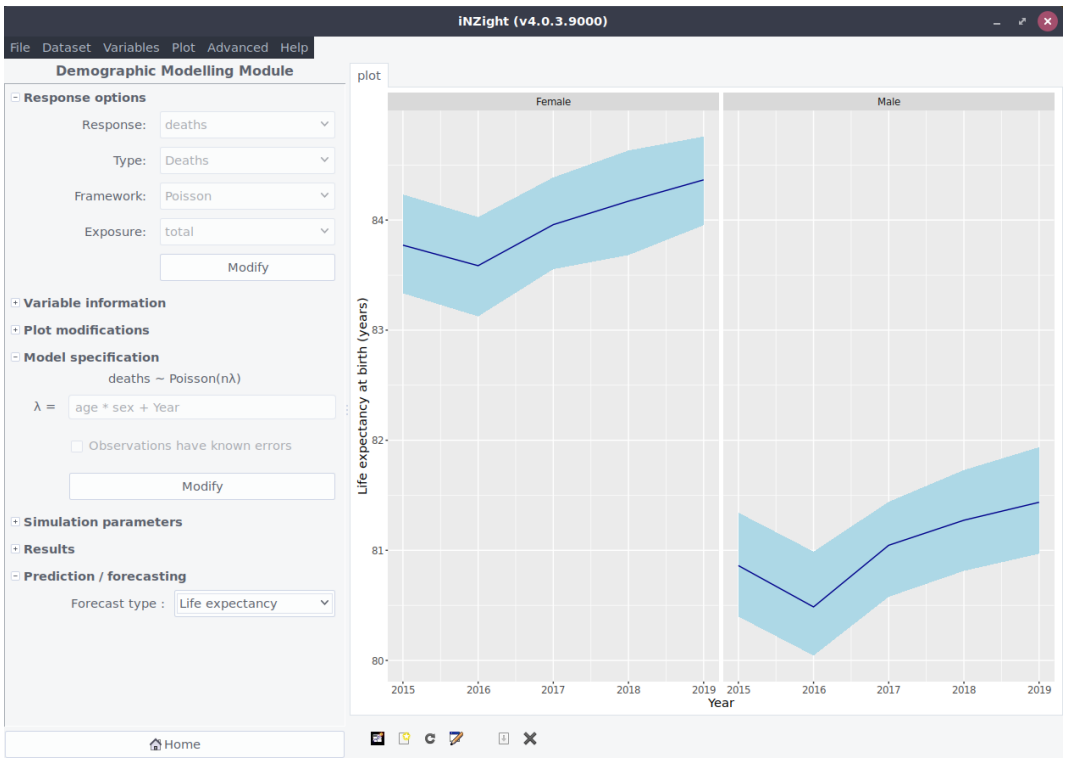

Figure 11: The prototype for a new Bayesian demographic modelling module for **iNZight**. In this example, life expectancy is estimated from death data.

macOS, and Linux. However, the install process varies between operating systems in both steps and complexity. On Windows, the necessary files are available in binary form, and can be installed *after* installing **iNZight**: the **RGtk2** package will prompt the user to download and install these binaries on the first run.

On macOS, users are required to install XQuartz and the GTK+ framework before manually compiling **RGtk2** themselves as, unfortunately, the binaries are no longer supported on CRAN. The complexity of this setup, and the lack of backwards compatibility of the macOS operating system, means we cannot officially support **iNZight** on macOS.

Finally, Linux comes in many flavours, each with different package managers and library names. However, the two main dependencies are `xorg` and `gtk`, which are typically installed using the system package manager. For example, on Ubuntu 20.04, users can install the libraries thus:

```
$ apt-get install xorg-dev libgtk2.0-dev
```

Users of other operating systems should use the search functionality of their package manager to find the requisite libraries, or compile them themselves. There are several other system dependencies which need to be installed for some features of **iNZight**. For the latest list, check `inzight.nz/install`.

5.2. Windows installer

A large audience for **iNZight** is students new to statistics, who are unlikely to have the computer literacy[6] required by other GUIs to install and run the software (including R). To improve the accessibility of **iNZight**, we have built a custom installer that is effectively a self-extracting `.exe` file which includes a copy of R and the package library, so once installed **iNZight** is ready to go. This is by default installed into the user's `Documents\\iNZightVIT` directory.

In addition to the binaries and packages, the installer includes several shortcuts which can be double-clicked to launch R in a specific directory. This directory contains a `.Rprofile` file

[6] another word, perhaps...

which automatically loads the **iNZight** package and launches the interface. It also hides the R console, so users are presented with just a GUI, as they will be most familiar with. When started from the script, R is passed a command to terminate the R session once the user has finished using **iNZight**.

The **iNZight** installer also includes an Update script to allow easy updating of the R packages. This allows novice users to update to the latest version without needing to use R or re-download the entire installer. Additionally, we include an Uninstaller which removes **iNZight** from the user's system if they so desire—since **iNZight** is standalone, this just deletes the folder and shortcuts.

5.3. Docker image

Docker is a development and deployment solution for developers to build, test, and share their projects (Merkel 2014). It allows developers to construct build chains with all dependencies included within a single image file which can be downloaded by users to run the program without installing a large set of dependencies. We have built a docker image for **iNZight**, allowing users of macOS and Linux to run the software without installing the system dependencies. The downside of this approach is that **iNZight** does not run as smoothly as it does natively, and also, as a GUI, requires a little more work from the user (particularly on macOS) to set up the necessary conditions for the app running in the container to access the host's graphical interface. More information can be found at `https://inzight.nz/docker`.

5.4. Online shiny version iNZight *Lite*

In recent years, many schools have adopted tablets or Chromebooks instead of Windows laptops, neither of which are capable of running R and, therefore, **iNZight**. To provide these students with equal opportunity, we created an online version of **iNZight** that uses **shiny** (Chang *et al.* 2021) as the GUI framework instead of GTK, named **iNZight** *Lite*.

Since most of the data-logic occurs in separate packages, porting **iNZight** to the web was simply a case of coding the interface elements and passing user inputs to the wrapper functions. This also means that the underlying code is the same between programs, so the *output* is the

same in both cases, making it easier for teachers and researchers to use one or the other. We attempted to keep the interfaces as similar as possible, but some differences are unavoidable due to the constraints of the individual GUI toolkits.

The online version runs inside its own docker container on a remote Amazon Web Services server. Interested users could run the container locally by installing docker. Most users, however, can access the web interface by heading to `https://lite.docker.stat.auckland.ac.nz` in a browser on a computer or tablet. There is a set of URL parameters which can be passed to the **iNZight** *Lite* instance, including a URL for a dataset to automatically load, so for examples it's possible to store datasets on a server with a list of URLs to launch Lite with the chosen data loaded. For example, `https://lite.docker.stat.auckland.ac.nz/?url=https://inzight.nz/testdata/nhanes.csv&land=visualize`. An example is this dataset index, `https://www.stat.auckland.ac.nz/~wild/data/Rdatasets/`.

Within the container, **shiny** (Chang *et al.* 2021) is used to create the visual controls and perform reactivity events. A user's data is stored on the server temporarily, and is only accessible from that user's session: it cannot be shared or accessed by other users. However, we still would not recommend users upload confidential or otherwise sensitive data; this would be better explored using either the desktop version or by running **iNZight** *Lite* locally. Research groups could host their own secure port of *Lite* with access to private data.

6. Summary and future work

Newcomers to statistics often need to learn both how to code using R whilst simultaneously learning the basic skills for data exploration, while many researchers need quick, easy methods to get new projects started. By providing an easy-to-use GUI, **iNZight** lets users focus on exploring and analysing data. Beginners can develop interpretation skills before embarking on the more challenging part of learning to code. The software is *variable first*, meaning users do not need to first know or remember complicated statistical terminology to get the most from their data: the software provides a list of applicable methods given their current variable selection(s).

Similarly, data manipulation techniques such as filtering, renaming levels of factors, and even specifying survey designs, are all presented in simple step-by-step windows, many of which provide previews that help users to tweak the inputs to get the correct output. Many users may want to learn to code with R, and **iNZight** includes some simple tools for helping that migration: code writing to a session script, and a reactive code panel for modifying and running code for the current plot.

Statistics and data science is an ever expanding field, with new R packages added to CRAN daily. **iNZight** has an add-on system that developers outside of the development team can use to create and share modules for users to install and use on top of **iNZight**'s existing feature set. Since **iNZight** is available as a standalone program on Windows, package developers have an opportunity to engage previously unreachable audiences.

6.1. Future Work

Many new features and functionality are planned for the future of **iNZight**, the foremost being the ability to interact with more complex datasets, particularly those saved within a database, with as much processing done within the database as possible to speed up the interface for large datasets. This, along with other advances, will make **iNZight** a useful tool for not only learners but researchers and organisations alike, including capabilities for the software to connect to secure databases behind a firewall and allowing researchers without coding skills access to it.

The main issue with **iNZight** at present is its reliance on GTK, which has been discontinued on macOS. Exploration into possible alternative frameworks is ongoing, with desire to develop a fully cross-platform application so users from all backgrounds can make use of the software.

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A. Code history

The R code history generated during the demonstration in Section 2 is copied here.

```
# iNZight Code History

## This script was automatically generated by iNZight v4.0.3.9000
## ------------------------------------------------------------------------ ##

## This script assumes you have various iNZight packages installed.
## Uncomment the following lines if you don't:

# install.packages(c('iNZightPlots',
#                    'magrittr',
#                    'readr',
#                    'dplyr',
#                    'tidyr',
#                    'survey'),
#     repos = c('https://r.docker.stat.auckland.ac.nz',
#               'https://cran.rstudio.com'))

## ------------------------------------------------------------------------ ##

library(magrittr)  # enables the pipe (%>%) operator
library(iNZightPlots)

Gapminder <-
    readr::read_csv("C:\Users\Tom\Downloads\Gapminder.csv",
        comment = "#",
        col_types = readr::cols(
```

```
            BodyMassIndex_M = "c",
            BodyMassIndex_F = "c",
            Cellphones = "c",
            Femalesaged25to54labourforceparticipationrate = "c",
            Forestarea = "c",
            Governmenthealthspendingperpersontotal = "c",
            Hightotechnologyexports = "c",
            Hourlycompensation = "c",
            Incomeshareofpoorest10pct = "c",
            Incomeshareofrichest10pct = "c",
            Internetusers = "c",
            Literacyrateadulttotal = "c",
            Literacyrateyouthtotal = "c",
            Longtermunemploymentrate = "c",
            Poverty = "c",
            Ratioofgirlstoboysinprimaryandsecondaryeducation = "c",
            Renewablewater = "c",
            Taxrevenue = "c",
            TotalhealthspendingperpersonUS = "c"
        ),
        locale = readr::locale(
            encoding = "UTF-8",
            decimal_mark = ".",
            grouping_mark = ""
        )
    ) %>%
    dplyr::mutate_at(
        c(
            "Country",
```

```
        "Region-Geo",
        "Continent",
        "Region",
        "Year_cat"
    ),
    as.factor
) %>%
dplyr::mutate_at(
    c(
        "BodyMassIndex_M",
        "BodyMassIndex_F",
        "Cellphones",
        "Femalesaged25to54labourforceparticipationrate",
        "Forestarea",
        "Governmenthealthspendingperpersontotal",
        "Hightotechnologyexports",
        "Hourlycompensation",
        "Incomeshareofpoorest10pct",
        "Incomeshareofrichest10pct",
        "Internetusers",
        "Literacyrateadulttotal",
        "Literacyrateyouthtotal",
        "Longtermunemploymentrate",
        "Poverty",
        "Ratioofgirlstoboysinprimaryandsecondaryeducation",
        "Renewablewater",
        "Taxrevenue",
        "TotalhealthspendingperpersonUS"
    ),
```

```
        as.numeric
    ) %>%
    dplyr::rename(Region.Geo = "Region-Geo")


Gapminder.filtered <-
    Gapminder %>%
    dplyr::filter(Year_cat %in% c(
        "[1960]",
        "[1964]",
        "[1968]",
        "[1972]",
        "[1976]",
        "[1980]",
        "[1984]",
        "[1988]",
        "[1992]",
        "[1996]",
        "[2000]",
        "[2004]",
        "[2008]"
    )) %>%
    droplevels()


inzplot(Infantmortality ~ GDPpercapita | Year_cat,
    colby = Region,
    sizeby = Populationtotal,
    data = Gapminder.filtered,
    xlab = "GDP per Capita (log scale)",
    ylab = "Infant Mortality",
```

```
    col.fun = "contrast",
    alpha = 0.4,
    transform = list(x = "log10"),
    main = "Infant Mortality Over Time"
)

inzinference(Infantmortality ~ Region | Year_cat,
    g1.level = "[2004]",
    data = Gapminder.filtered,
    hypothesis.test = "anova"
)

Gapminder.filtered.separated <-
    data %>% tidyr::separate(
        col = "Region.Geo",
        into = c(
            "main_region",
            "part_region"
        ),
        sep = " - ",
        extra = "merge"
    )

## Load example data set
data(apiclus2, package = 'survey')

## ------------------------------------------------------------------------ ##
## Exploring the 'apiclus1_ex' dataset
```

```
apiclus1_ex <- apiclus1


## create survey design object
apiclus1_ex.svy <- survey::svydesign(ids = ~dnum, fpc = ~fpc, nest = FALSE,
    weights = ~pw, data = apiclus1_ex)


inzsummary(~stype,
    design = apiclus1_ex.svy
)


## Load example data set
data(visitorsQ, package = 'iNZightTS')


## ------------------------------------------------------------------------ ##
## Exploring the 'visitorsQ_ex' dataset


visitorsQ_ex <- visitorsQ
```

B. Data wrangling methods

iNZight features the following methods for transforming and manipulating data.

B.1. Dataset

Transform, mutate, etc.

B.2. Variables

Create, rename, change, etc.

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