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Civic Statistics and iNZight: Illustrations of Some Design Principles for Educational Software

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subgroups within data, using multiple representations, analysing and reanalysing, and telling stories grounded in evidence. Often with complex social/civic datasets it is necessary to explore changes over time, and to explore spatial patterns. Here, we describe software features that facilitate data exploration for naïve users that include both direct guidance and hooks to encourage engagement and further learning, and also features for advanced users, such as the automatic generation of R code for documentation and software reuse. Software for analyzing data is evolving rapidly to accommodate new sorts of data, new techniques for analysis, and new methods to present data. Therefore, the chapter concludes by describing developments to iNZight that are in progress.

Keywords: Software design, Multivariate data; Multiple representations; Disaggregation; Complexity reduction, Complex survey designs

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Book Overview: J. Ridgway (Ed.). (2023). *Statistics for Empowerment and Social Engagement: Teaching Civic Statistics to Develop Informed Citizens*. Springer.

Effective citizen engagement with social issues requires active participation and a broad understanding of data and statistics about societal issues. However, many statistics curricula are not designed to teach relevant skills nor to improve learners' statistical literacy.

This book offers practical approaches to working in a new field of knowledge - Civic Statistics - which sets out to engage with, and overcome well documented and long-standing problems in teaching quantitative skills. The book includes 23 peer-reviewed chapters, written in coordination by an international group of experts from ten countries. The book aims to support and enhance the work of teachers and lecturers working both at the high school and tertiary (university) levels. It is designed to promote and improve the critical understanding of quantitative evidence relevant to burning social issues – such as epidemics, climate change, poverty, migration, natural disasters, inequality, employment, and racism.

Evidence about social issues is provided to the public via print and digital media, official statistics offices, and other information channels, and a great deal of data is accessible both as aggregated summaries and as individual records. Chapters illustrate the approaches needed to teach and promote the knowledge, skills, dispositions, and enabling processes associated with critical understanding of Civic Statistics presented in many forms. These include statistical analysis of authentic multivariate data, use of dynamic data visualisations, and deconstructing texts about the social and economic well-being of societies and communities. Chapters discuss ideas regarding the development of curricula and educational resources, use of emerging technologies and visualizations, preparation of teachers and teaching approaches and sources for relevant datasets and rich texts about Civic Statistics, and ideas regarding future research, assessment, collaborations between different stakeholders, and other systemic issues.

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Chapter 10

Civic Statistics and *iNZight*: Illustrations of Some Design Principles for Educational Software

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Abstract

The PCS project has made good use of *iNZight* in exploring topics such as migration, gender inequality, childhood malnutrition, and natural disasters. Further examples of Civic Statistics topics that have been addressed using *iNZight* are provided here, along with a range of examples of creative ways to display data. The chapter outlines the advantages of technology enhanced statistics education and software requirements; maps some analyses which are central to Civic Statistics and shows how these can be conducted using *iNZight*. Examples include working with multivariate data, exploring subgroups within data, using multiple representations, analysing and reanalysing, and telling stories grounded in evidence. Often with complex social/civic datasets it is necessary to explore changes over time, and to explore spatial patterns. Here, we describe software features that facilitate data exploration for naïve users that include both direct guidance and hooks to encourage engagement and further

learning, and also features for advanced users, such as the automatic generation of R code for documentation and software reuse. Software for analyzing data is evolving rapidly to accommodate new sorts of data, new techniques for analysis, and new methods to present data. Therefore, the chapter concludes by describing developments to iNZight that are in progress.

Keywords: software design, multivariate data; multiple representations; disaggregation; complexity reduction, complex survey designs

10.1 Introduction

Readers of this book will already be aware of the explosive growth in the availability and importance of data in understanding and managing almost all aspects of our society. The buzz words come in and fade away, e.g., the data deluge, big data, open data. Some (like open data) have lasting value because they describe something unique. Others just convey a sense of progress, urgency, opportunity, and sometimes alarm and dread.

Things we never knew could be considered as data are now very successfully being mined for insights and predictive value – sources such as text, images, sound files, and network data. The [International Data Science in Schools Project](http://www.idssp.org/) is proposing that much of this should be part of the high school curriculum. Different data types and structures demand different ways of thinking and looking. Accompanying the rapid expansion of the data universe has been an explosion of new and improved ways to visualize and analyze data. The barriers to participation are becoming ever lower. There is a steady stream of wonderful new visualization functions and packages becoming available in *R*, *Python* and *JavaScript* doing away with the need for low-level programming.

While technology is making it easier to perform specific tasks, it is also rapidly expanding the spectrum of things that non-specialists can do. Because each new data-type or graphic-type demands new ways of conceptualizing data and interacting with software, the universe of possibilities that are accessible to non-specialists is rapidly expanding in size and complexity.

¹ <http://www.idssp.org/>

While this stream of new opportunities is exciting, users can become overloaded cognitively – “It is all just too much. I just can’t get my head around it”. Strategies are needed which enable everyone to ride the wave of progress while managing individual expanding mental universes.

An important complexity-reducing factor comes from the advance of technology. Many of the mechanical procedures underpinning important concepts are no longer worth mastering. Any particular mechanical skill tends to be death-dated because software is continually automating these procedures. Creating histograms by hand offers an obvious example; one can argue that some hand-crafting is useful pedagogically, but not that this is an essential process for exploratory data analysis. The most important capabilities for the long term are an awareness of what is possible, thinking skills (such as imagining/question posing/interpreting/critiquing/concluding) and communication skills; in contrast to the mechanical procedures that were such a focus in the past. There are clear advantages to learners from not having to master so many technical procedures. However, these gains are insufficient to compensate for the explosive growth in the data world. We need more complexity-reduction strategies to enable representative citizens to engage effectively with evidence.

In Chapter 7, Trostianitser, Teixeira and Campos outline some uses of *iNZight* contained in lesson plans accessible via CivicStatMap², namely, the use of *iNZight* for exploring:

- The migration data for Nigeria taken from the UN 2015 Millennium Development Goals.
- The IPUMS Gender Equity data set for 2000 and 2005 for Brazil and the USA.
- Data on malnutrition in children from the Hunger and Commitment Index (Hanci).
- Data on natural disasters from the Center for Research on the Epidemiology of Disasters – Emergency Events Database (EM-DAT).
- Data from the OECD Program for the International Assessment of Adult Competencies (PIAAC).

² <https://iase-web.org/islp/pcs/>

In this chapter, further examples are given, which illustrate ways in which software can be used to support the sorts of analysis essential for wrangling with evidence relevant to Civic Statistics. The intention is not to provide a tutorial on the use of a particular package (tutorials can be found embedded in PCS lesson plans); rather it is to point to some principles of software design and implementation that are of general interest.

10.1.1 Design Principles for Educational Software

A seminal paper by Biehler (1997; see also 2019) discussed the criteria by which software to support learning statistics and doing statistics should be judged. Implicitly, this sort of analysis serves as a guide for future software developments. McNamara (2019) built on Biehler's (1997) work, and set out eight desirable features of educational software, which have been built into *iNZight*. These are:

- **Accessibility** - software should be affordable, work with a variety of operating systems, and should be easy to install.
- **Easy entry for novice users** - novice users should be able to see how to use the software, and what it does; using the software, users should receive immediate gratification i.e. an intelligible and immediate response to commands.
- **Data as a first-order persistent object** - Software should be able to access data presented in common formats (e.g. flat files, hierarchically ordered data, using APIs). There should be a good and transparent workflow for cleaning data. Users should always be able to view their raw data.
- **Support for a cycle of *exploratory and confirmatory analysis*** - to use Tukey's (1977) words. Biehler (1997) referred to *draft results*. Essentially, software should support activities such as question posing, critique, interpreting, concluding, and imagining.
- **Flexible plot creation** - there should be a facility to plot data in a variety of ways.
- **Support for randomisation** - software should support tools such as randomisation tests, and visual representations of uncertainty e.g. via bootstrap.
- **Interactivity at every level** - Biehler (1997) argued the case for direct manipulation rather than modifying a script, and that software tools should support graphs as an interface to the data. Another desirable aspect of interactivity is access to multiple coordinated views – so (say) highlighting an element in one display leads to relevant changes in every display.

- **Inherent documentation** - there is a need to show the pathway of any analysis, and also the logic of what has transpired - *Jupyter notebooks* (Toomey, 2017) provides an example. Biehler (1997) criticised the absence of inherent documentation in Velleman's (1989) *DataDesk* – the latest version generates *R* code from user actions.
- **Simple support for narrative publishing, and reproducibility** - communication is an essential aspect of any analysis. Users need to be able to share code and analyses, to say what was done, and to be able to use the same analysis on a new data set. Tools for exporting graphics and analyses should be provided.

Implicit in McNamara's and Biehler's analyses is the need to provide sophisticated tools for experienced users (and that this collection of tools will be extensible). Both authors comment that there are few if any examples of packages that satisfy all the design criteria, and support both learners and practitioners, although some - such as *Fathom*³ - fulfilled many of these essential criteria.

iNZight satisfies all these criteria; in addition, *iNZight* sets out to entice users to learn more about data exploration and analysis. Users might not know quite what they want to do, or the opportunities available to facilitate exploration and analysis; *iNZight* suggests relevant data visualisations and analyses. *iNZight* has many interesting features, and is free to use; we think it is legitimate to devote a whole chapter of this book to this tool, to demonstrate software design principles and their implementation. Moreover, the features that *iNZight* shows can also be seen as necessary and valuable for many data explorations in Civic Statistics - so these features can also be seen as illustrations of norms and requirements for future software that combines easy access for beginners with substantial data analytic capacities. In our examples we also use data from *Gapminder*, to show that *Gapminder* analyses can be supported by *iNZight* and expanded because of the richer data analytical environment.

³ <https://fathom.concord.org>

10.1.3 What is *iNZight*?

[iNZight](https://inzight.nz/)⁴ (Elliott et al., 2021; Wild et al., 2021) is a free, [open-source](#), data visualization and analysis tool that can be used by people at any stage of statistical development. It is a tool for beginners in the sense that it makes simple things very easy to do – it started off life as a tool for school children. However, it is also possible to do sophisticated things very rapidly, such as creating dynamic and interactive displays, wrangling with data, and doing complicated statistical modelling. Some capabilities are directly relevant to Civic Statistics, such as the ability to represent data from complex sample-surveys properly, and to deal with multiple response data (i.e. data from surveys where respondents can select as many answer-options to a question as they please).

iNZight comes in two versions, a desktop version that needs to be installed on a computer and an online version (called [iNZight Lite](#)⁶) that runs in a web browser when users are connected to the internet. Many parts of *iNZight* also make the underlying *R* code available. This has three major advantages: first, as an audit trail – audit trails are particularly important for seeing if, when and how the data itself has been modified (e.g. by removing outliers); second as a reproducibility, sharing and work-efficiency aid – a sequence of analysis steps can be shared or repurposed and re-implemented almost instantly simply by running the code; and third as a useful tool for those learning to program in *R* – viewing system-generated code can be a useful productivity-aid enabling people to find out quickly how to do things in *R*.

10.2 Key Software Functionality for Civic Statistics

In this section, we describe some of the functionality essential for working with Civic Statistics.

10.2.1 Easy Exploration of Multivariate Data

It is important for users to engage in multivariate data exploration easily, and to experience “Aha” moments. In *iNZight*, as soon as you choose to look at a variable, or a relationship between variables, *iNZight* will offer a graph. Users can refine the choices made to create new displays.

⁴ <https://inzight.nz/>

⁵ <https://github.com/iNZightVIT>

⁶ <https://lite.docker.stat.auckland.ac.nz/>

10.2.2 Minimizing Cognitive Load

Most statistics packages are driven via a graphical user interface (GUI). GUI-based tools typically assume that users know the names of the desired graphics and forms of analysis they want to use. This can be a significant barrier to participation and access for novices; they cannot explore data unless they know and remember the name of a procedure and how it is used. *iNZight* takes account of the data being explored, and offers default presentations and analyses (and, of course, provides the ability to look at alternatives and make changes).

10.2.3 Provoking Learning

An advantage of a GUI-based system is that when the system recognizes it is in a particular situation, the interface can then change to offer up choices corresponding to useful things that can be done, or looked at, in that situation. When confronted with controls it is a natural human impulse to ask, “I wonder what that does?” So a good interface can act as a prompt for doing more, or finding out what more can be done, to draw the user into learning more. Linking “I wonder what that does?” to a good help system facilitates discovery and just-in-time learning.

10.2.4 Offering *R*-code: Reproducibility and a Bridge from GUIs to Coding

GUI systems often fail to create audit trails of what has been done during an analysis. It is especially important to have records of where data has been changed for some reason (e.g., by deleting outliers) and what predates or follows such changes. GUI systems can also be bad at enabling others to reproduce an analysis that has been done, or allowing users to quickly re-run all the steps of an analysis, for example because the data has been updated or corrected since the original analysis. Saving the underlying *R*-code solves these problems. It also offers a useful aid to learning *R*, and a useful productivity-aid for people to find out quickly how to do things in *R* when they want to write *R* code (at the time of writing this is limited to all of the basic *iNZight* operations including data wrangling, and amongst the advanced modules, to the statistical-modelling module - but extensions are underway). For a fuller discussion of many of these issues, and in particular of the comparative strengths of GUIs and coding; see Wild (2018), Burr et al. (2021).

When the *show editable code boxes* feature is switched on in *iNZight*, the graphics, summary and inferential statistics features in basic *iNZight* show the code that created the current display and allow this code to be stored or modified and rerun. In addition to changing the output, the interface choices are also instantly repopulated to match the code instructions. The learning strategies being implemented include: “the code that makes it”: code is always in view to foster learning by osmosis; and the mappings between GUI settings, argument values of the function calls and output are direct and immediate in order to foster seeing the relationships between them.

10.2.5 Specific Support for Civic Statistics

Civic Statistics often engages with survey data. Survey data from authoritative sources is collected using complex survey designs involving features such as the oversampling of some (usually small but important) subgroups, stratified sampling and cluster sampling. Graphics and analyses that do not take these sample-design factors into account should always raise credibility red-flags, as they can be very misleading. With *iNZight*, the program will take account of any sample-design information provided (Elliott et al., 2021).

10.3 Illustrating *iNZight*

This section provides examples of the functionality of *iNZight* as a tool for engaging with Civic Statistics.

10.3.1 Making Simple Things Really Simple

Here, a small set of workforce data is explored. In its basic mode, *iNZight* requires data with a standard, rectangular, cases/units (rows) by variables (columns) structure. Initially, only the left-hand window in Fig. 10.1 is populated (the lower right-hand window has not yet been created). The display shows the data and various command capabilities. These command actions are initiated by the variables that have been selected in the boxes at the lower left of Fig. 10.1 and determined by variable type (either numeric or categorical).

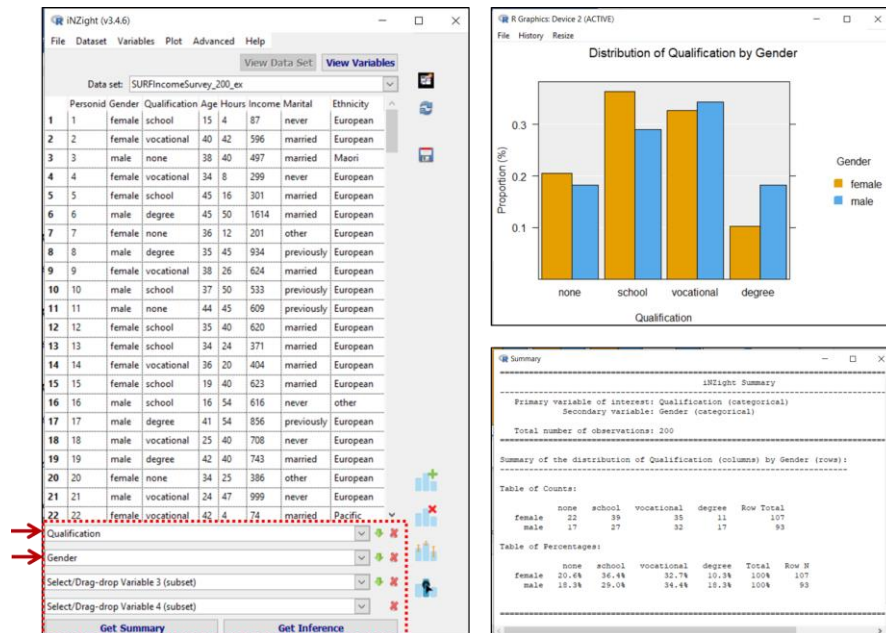


Fig. 10.1 Basic operation of *iNZight*

As soon as we select *Qualification* (a categorical variable) in the first box, a bar chart of the *Qualification* distribution appears. When we also select *Gender* (another categorical variable) in the second box the display changes to the side-by-side bar chart at the upper right to display the relationship between *Qualification* and *Gender*.

Pressing the **Get Summary** button at the bottom left creates a window of summary statistics (here the cross-classification between these two categorical variables presented both in terms of counts and proportions). Similarly, clicking **Get Inference** pops up a window of inferential information. For two categorical variables, the latter gives things like Chi-square test results and confidence intervals for differences in proportions. This epitomizes the cycle of exploration for *iNZight* at its most basic. When variables are selected, a relevant graph is created. **Get Summary** and **Get Inference** deliver just what they say.

If the variable chosen had been numeric (e.g. *Income*), then a different type of plot and different types of information would have been given (e.g., extremes, quartiles, medians, means, and standard deviations as summary information; and as inferential information: *t*-tests or an analysis of variance, tests and confidence

intervals for differences between group means or medians). There are options for changing default behaviour. In general, *iNZight* decides what to deliver instantly using the variable-types of the combination of variables selected - however, it also gives users options for changing the default behaviour.

Users have to know enough to be able to read and interpret the computer output, and to know whether what has been produced is sensible. However, users' efforts are focused on making meaning – in contrast to fighting software to get output.

10.3.2 Facilitating Exploration

In this Section, we illustrate ways in which software can facilitate exploration by offering a variety of ways to display data, and via the creation of interactive displays.

The **Add to Plot** facility (see Fig. 10.2) allows users to scroll through the types of graph applicable for the currently-chosen variables via the *Plot type* box. The options offered are taken from the relevant graphs from the [Financial Times Visual Vocabulary](https://www.vizwiz.com/2018/07/visual-vocabulary.html)⁷ with some additions.



Fig. 10.2 Default plot for *Income* by *Gender* plus the **Add to Plot** control panel

To illustrate, we explore the relationship between *Income* and *Gender* in the Workforce data set. For this small data set (up to about 3,000 observations) the default is side-by-side dot plots with boxplot summaries underneath them, as in Fig. 10.2. If we ask for **Add to Plot** the right-hand control panel is replaced by

⁷ <https://www.vizwiz.com/2018/07/visual-vocabulary.html>

the lower panel in Fig. 10.2. We can use the *Plot type* selection box to choose the name of a plot type we know we want, or we can scroll through all the alternative representations (here, those in Fig. 10.3); graphs can be oriented either horizontally or vertically.

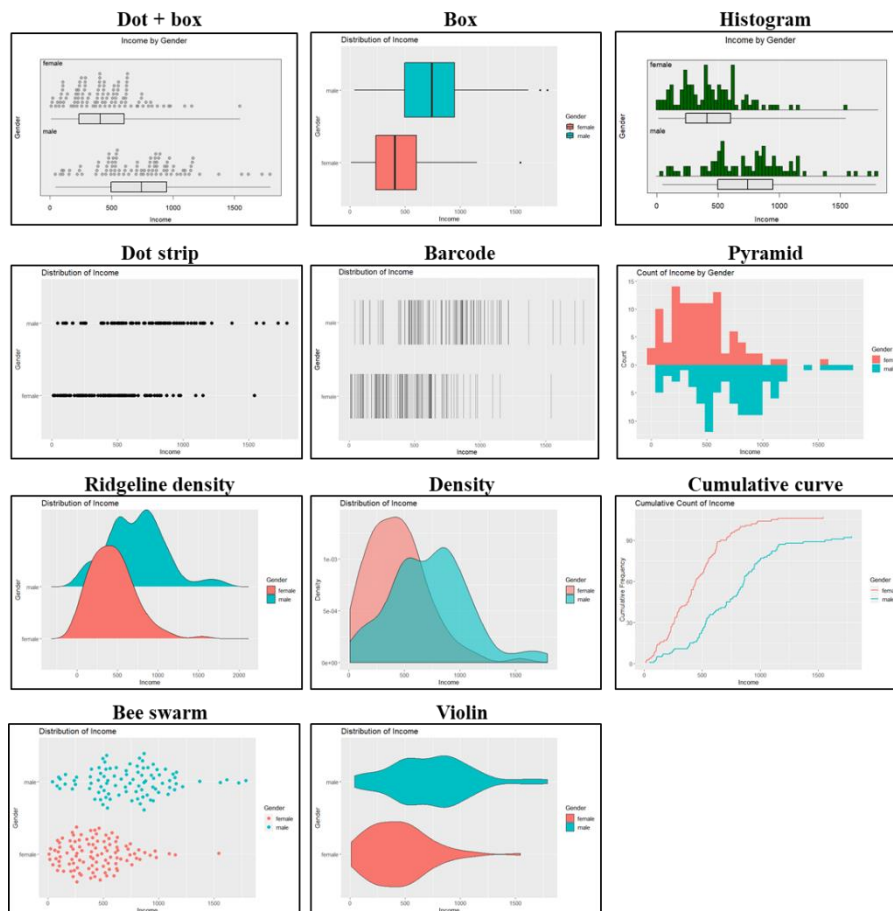


Fig. 10.3 Plot type options for relationship between a numeric and categorical variable

Interactive plots are particularly useful because of the ability they give the viewer to query or relate features in a plot or set of plots. Such plots can be both more engaging and more informative than static plots. Fig. 10.4 is a static image from the interactive version of the graph shown in Fig. 10.1. It shows the graph and the two-way table it was produced from. In the interactive plot, hovering the mouse over a bar gives information about the bar (as shown). But there is also

interactivity between the graph and the table. For example, clicking on the legend colour-square for females fades the data for males, thus highlighting the female distribution, and also highlights the corresponding percentages in the female row in the table. This shows, among other things, that the female percentages add to 100%, which is important for understanding the plot.

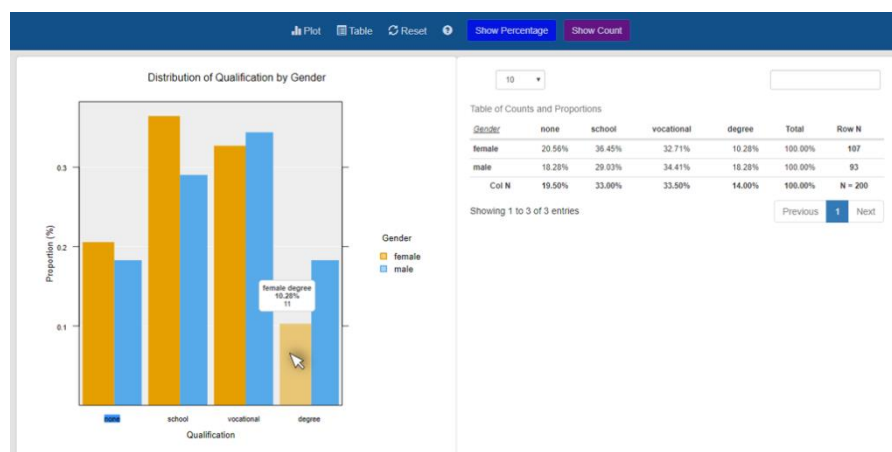


Fig. 10.4 Static image from the interactive version of the graph in Fig. 10.1

Fig. 10.5 shows something a little more sophisticated – an interactive graph from *iNZight*'s maps module. The data is 4-yearly, country-level data from *Gapminder*⁸. The left-hand graph shows the life expectancies over time for the countries as little time-series positioned on each country. The right-hand graph shows all of the time series for all of the countries in detail. Clicking on a country on the map highlights its time series on the right-hand plot. Clicking on an interesting looking time series, such as the one for Rwanda (blue) which shows a big dip in life expectancies in the 1990s, highlights the country it came from on the map. In this case, the dip in life expectancy reflects deaths in the Rwandan civil war and the genocide against the Tutsi. Hovering over a series shows the country name, year and the life expectancy value at the mouse-pointer location.

⁸ <https://www.gapminder.org/data/>

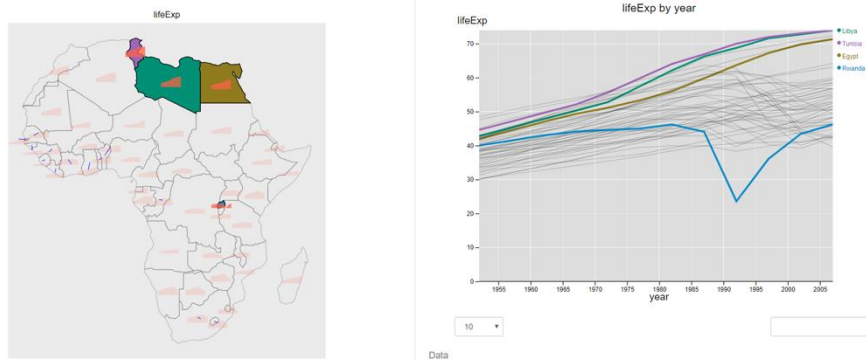


Fig. 10.5 Interactive graphs showing changes in average life expectancy over time for African countries

Here, the interactive graphics work entirely independently of the system that produced them, and so can be saved as html files and embedded in webpages (or given to someone else).

10.3.3 Disaggregation: Exploring Subgroups with Static and Dynamic Graphs

Here we will use a data set of about 10,000 cases from the NHANES⁹ survey of the US population. Fig. 10.6 shows the relationship between having smoked marijuana regularly at some point and having smoked cigarettes seriously (*has smoked over 100 cigarettes*) for everyone in the data set who answered the questions. It can be seen that cigarette smokers are much more likely to have smoked marijuana than nonsmokers. But is this relationship true for different subgroups?

⁹ <https://www.cdc.gov/nchs/nhanes/index.htm>



Fig. 10.6 Marijuana smoking by cigarette smoking (whole data set)

Selecting *AgeDecade* in the 3rd variable slot in the lower left panel produced Fig. 10.7 - the same sort of graph, but for each age-decade group separately. The operation of disaggregation is sometimes called facetting (here we have “facetted by the variable *AgeDecade*”). This allows us to see that the marijuana-cigarette relationship is very similar regardless of age group. In general, facetting is good for investigating whether, or in what way, a pattern changes over subgroups determined by some variable such as ethnicity, education level, or sex (here *AgeDecade*).

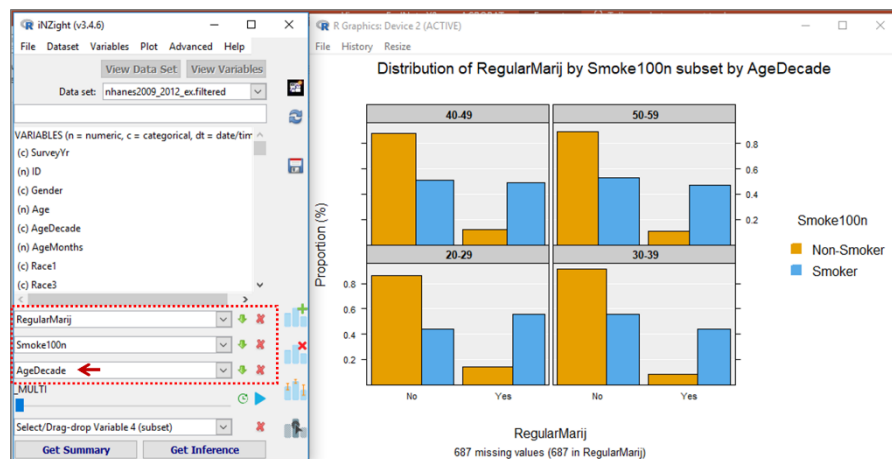


Fig. 10.7 Marijuana smoking by cigarette smoking faceted by *AgeDecade*

Fig. 10.8 goes a step further and also facets by *Race* (American for *Ethnicity*). Mostly the relationship looks similar regardless of age or race. However, having chopped up the data set into 20 subgroups, some of the sample sizes are small and so one would not be surprised to see differences attributable to random variation.

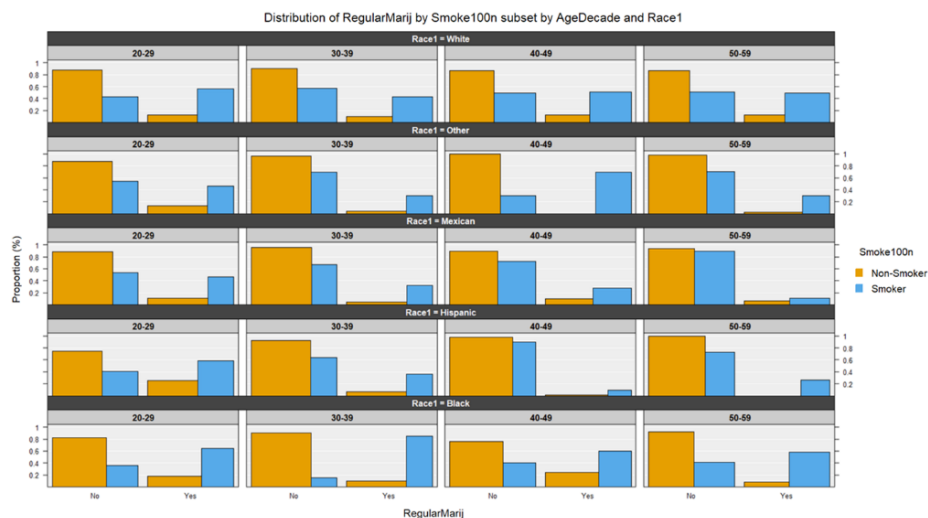


Fig. 10.8 Marijuana smoking by cigarette smoking facetted by *AgeDecade* and *Race*

Fig. 10.9 shows a more sophisticated example, where disaggregation leads to important insights. It shows *Fertility* by *Infant mortality* for the world's countries facetted by *Year*. The years increase from the bottom left. It is hard to see the changes over time, but if you play the images one at a time from oldest to most recent (e.g. using *iNZight*'s play button) you get a version of the famous Hans Rosling bubbles motion chart¹⁰, which plays like a movie (see Chapter 8 for examples of classroom uses of *Gapminder* from Kovacs, Kazar, and Kuruczleki). Here the changes become obvious. This is just the cartoonist's-

¹⁰ [https://www.gapminder.org/tools/#\\$chart-type=bubbles&url=v1](https://www.gapminder.org/tools/#$chart-type=bubbles&url=v1)

sketchbook effect, or any regular movie, i.e. a played sequence of still images. This can be done for any type of plot.

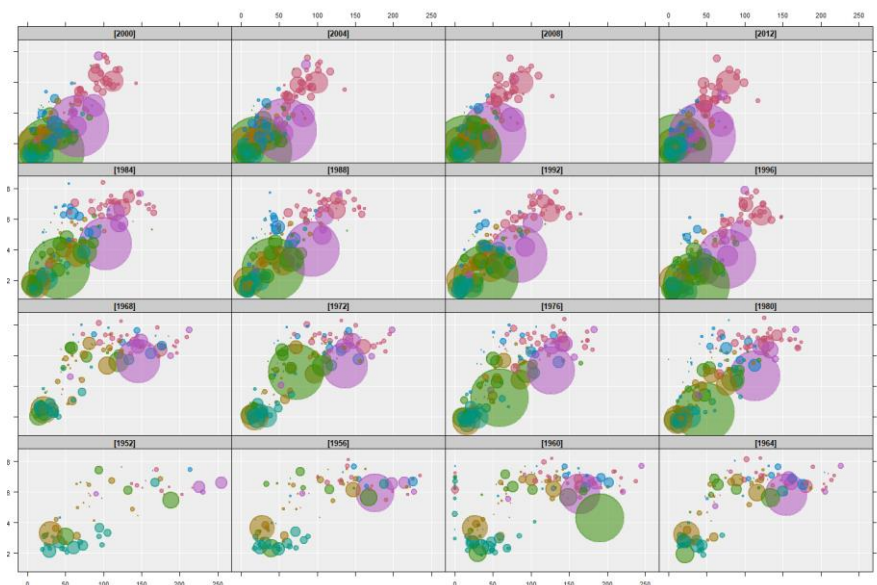


Fig. 10.9 *Fertility by Infant mortality* for the world's countries faceted by Year

10.4 Essential Analyses for Civic Statistics

Here, we give examples of analyses that are essential tools in the repertoire of anyone engaged with Civic Statistics. We illustrate analysis of multiple response data, time series data, and spatial data.

10.4.1 Multiple Response Data

How do young people spend their time online? Fig. 10.10 shows a small segment of data from a 2011 student survey¹¹. Highlighted is the data from a multiple-response question that asked *In the last seven days, which of these online activities have you done? (You may tick more than one)*. This 'single question' elicits responses that need to be coded on many variables, one for each activity chosen. It was asked as a single item because these are a set of things that "belong together". The fact that the resulting data has multiple variables,

¹¹ <https://new.censusatschool.org.nz/>

however, can make it hard to get an overview of the results. *iNZight*'s Multiple Response module was developed to address this problem.

	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG
1	techconsc	technone	cellmonth	onlinemusic	onlinevideo	onlinegame	onlinefriend	onlineschool	onlineother	onlinenone	bedtime
2	yes	no	12	yes	yes	no	yes	yes	no	no	11:45:00
3	yes	no	1	yes	yes	no	yes	no	no	no	12:30:00
4	yes	no	NA	yes	yes	yes	yes	yes	no	no	10:00:00
5	yes	no	36	yes	yes	no	yes	no	no	no	10:00:00
6	no	no	10	no	no	no	no	no	no	no	11:30:00
7	yes	no	12	no	no	yes	yes	yes	no	no	10:00:00
8	yes	no	1	no	yes	yes	yes	no	no	no	9:00:00

Fig. 10.10 Some multiple-response data

In Fig. 10.11 we have told the program to treat a set of these variables together by selecting them jointly in the control panel. A graph pops up at the right giving all the proportions of positive responses for each variable in one picture.

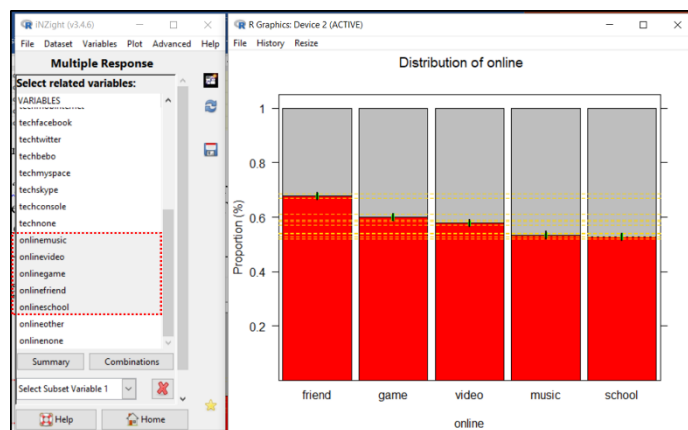


Fig. 10.11 Proportions of students reporting various sorts of activity online

As argued earlier, disaggregation is an essential activity if data are to be understood. Here, the data get a lot more interesting when faceted by *age* and *gender* as in Fig. 10.12. We see interesting (apparent) age trends such as the dropping off in participation in playing games online by older students, with the fall being steeper and further for girls than boys. Girls appear to take to music and socializing more than, and earlier than, boys. There is an important statistical issue for the software to address, namely that with multiple-response data, tests and confidence intervals for differences in proportions need to take account of the (differing) correlations between them.

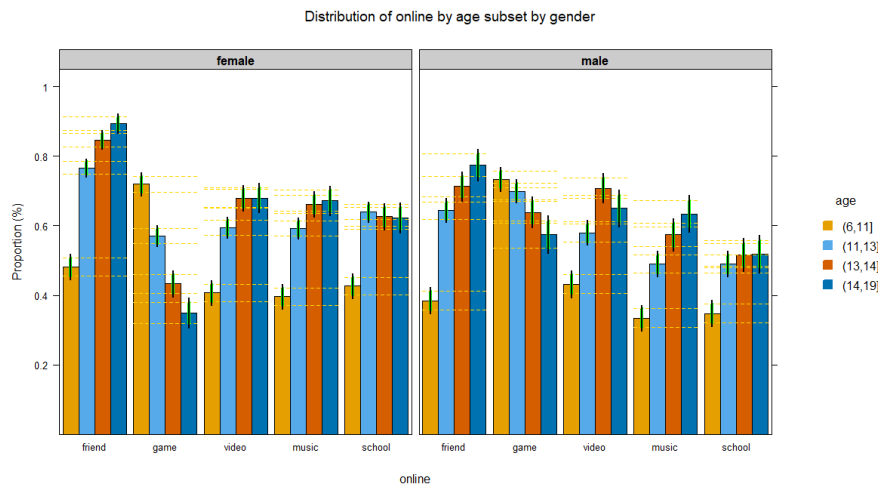
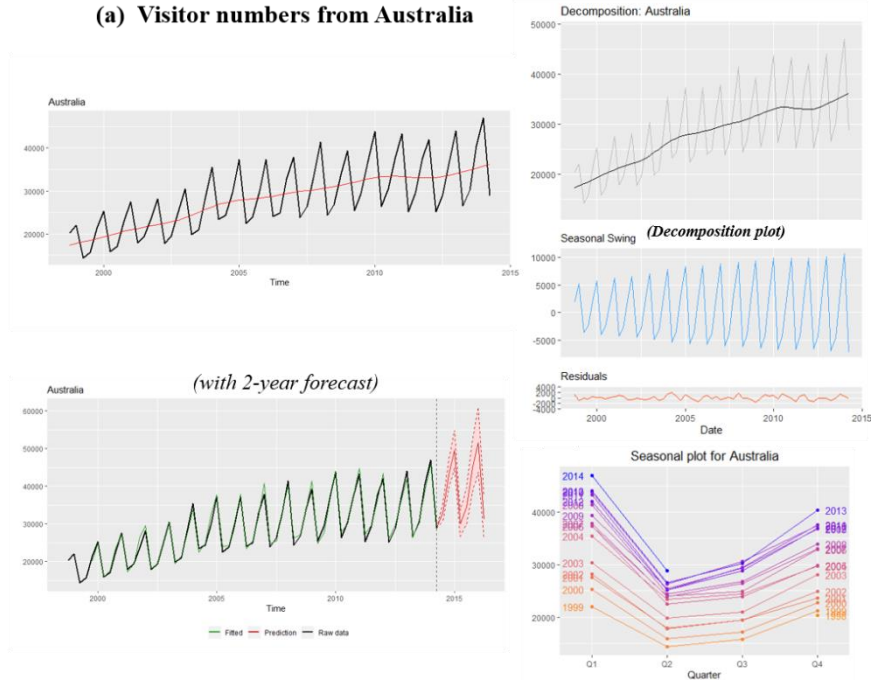
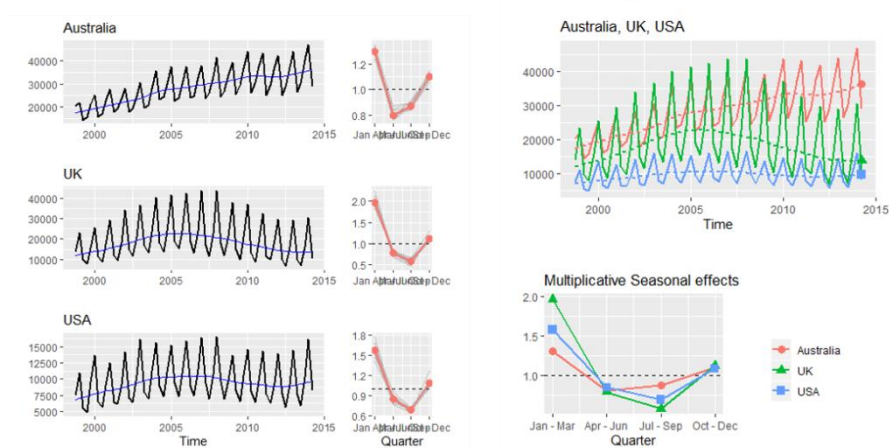


Fig. 10.12 Online-activity responses facetted by *age* and *gender*

10.4.2 Time Series

Fig. 10.13 shows time series graphs of quarterly data on the average visitor numbers in New Zealand from Australia, the UK and the US in the period 1998-2014¹². *iNZight*'s time-series module takes data from a single series or compares several series and supports additive and multiplicative methods for seasonal series, including forecasts. Visitor numbers are clearly very heavily seasonal with considerably larger numbers in the January-March quarter and lower in July-September – except for Australian visitors for whom the lowest numbers are in April-June. For the UK, there are over twice as many visitors in the southern summer than the southern winter. There are also some very noticeable differences in the time trends – with Australia climbing relatively steadily but the UK and the US numbers tipping into a decline – probably attributable to the global financial crisis (though the US numbers show recovery towards the end of the time period). Again, these displays show the importance of being able to represent data in different ways, and that disaggregated data does not always show the same patterns as aggregated data.

¹² <http://infoshare.stats.govt.nz/infoshare/>

(a) Visitor numbers from Australia**(b) Comparing visitor numbers from Australia, UK and USA****Fig. 10.13** Average numbers of visitors present in New Zealand, 1998-2014

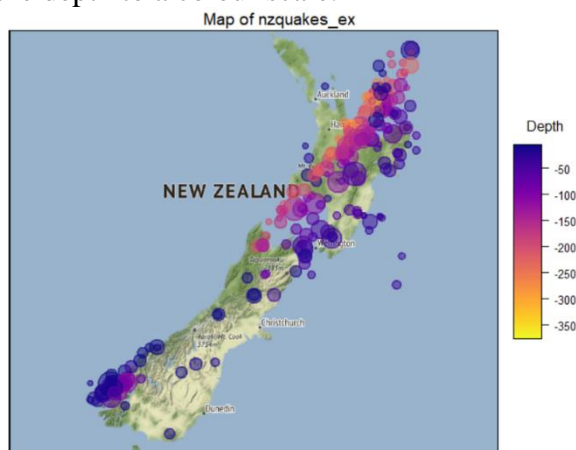
10.4.3 Maps

Data most commonly plotted on maps relates to either location or region. Here, we give an example of the use of each, starting with *location*. The commonest way of specifying a location is by its latitude and longitude. Additional variables give information about what happened there. Fig. 10.14 shows a fragment of data on earthquakes in New Zealand in the year 2000¹³; we have information about where the epicenter of the quake was (latitude and longitude), how deep underground it was, how strong it was, when it occurred, and several other variables.

Order	Latitude	Longitude	Depth	Felt	Magnitude	RMS	NorMidSt	Month	Day	Hour	Minute
1	-39.14347	174.8942	-218	N	4.289	0.19	North	1	3	11	53
2	-37.70441	177.2514	-65	Y	4.454	0.21	North	1	4	18	44
3	-40.25043	173.57	-196	N	4.035	0.247	North	1	6	19	19
4	-38.14048	176.3235	-158	N	4.479	0.205	North	1	7	12	30
5	-36.86741	177.0199	-212	N	4.049	0.183	North	1	7	15	30

Fig. 10.14 An example of location data: earthquakes in New Zealand in 2000

As is typical for location data, we start by plotting the locations of the earthquakes onto a suitable map – but that just tells us where things were, nothing else about them. There are many ways of coding more information on to these points. Fig. 10.15 codes the intensity of the earthquake to point-size, and the depth to a colour scale.



¹³ <https://www.gns.cri.nz/>

Fig. 10.15 Earthquakes in New Zealand in 2000

In New Zealand, there are about 15,000 earthquakes each year, all are related to the movement of tectonic plates. In Fig.10.15 we see a strong, roughly 45 degree pattern of quake locations - unsurprising, given that associated volcanoes created the islands. The deepest epicentres occurred in the South Island (a subduction zone) and the shallowest epicentres occur in the North Island, where the opposite flow of plates occurs.

Our second example illustrates the use of data plotted by region. By ‘region’ we mean entities such as countries of the world or states/counties/electoral districts within a country. The associated variables usually give summary measures for each region.

Fig. 10.16 shows a fragment of data from *Gapminder*¹⁴ on different countries of the world which includes: the year the data relates to, average life expectancy, population size, and GDP per capita. Fig. 10.17 offers so-called “choropleth plots” of the average fertility levels (*children per woman*) and average life expectancies for the countries in Africa in 2012. This is the most commonly used plot-type for regional data. Values of the variable are coded by a colour scale which is then used to colour the regions on the map. In Fig. 10.17 the most obvious feature is the very low fertility rates in the north and the south of Africa compared with the central regions. This is pattern is partially reversed for the life expectancies with higher life expectancies in the north.



country	continent	year	lifeExp	pop	gdpPercap
Algeria	Africa	2007	72.301	33333216	6223.367
Angola	Africa	2007	42.731	12420476	4797.231
Argentina	Americas	2007	75.32	40301927	12779.38
Australia	Oceania	2007	81.235	20434176	34435.37
Austria	Europe	2007	79.829	8199783	36126.49
Bahrain	Asia	2007	75.635	708573	29796.05

¹⁴ <https://www.gapminder.org/data/>

Fig. 10.16 A fragment of data on the world's countries from *Gapminder*

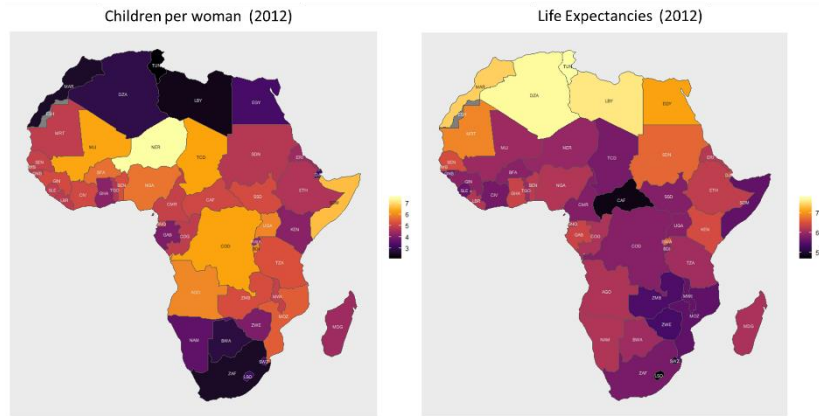


Fig. 10.17 Fertilities and Life Expectancies in Africa in 2012

With choropleth plots, large regions are visually prominent. This is problematic when large (rural) regions with small populations are presented alongside small (urban) regions with large populations. This is less pronounced with African countries than with American (US) states, where choropleth plots of election results give a very misleading impression (dominated by large, sparsely-populated states in the middle of the country). Fig. 10.18 shows some of the methods people have devised to try to get around this problem.

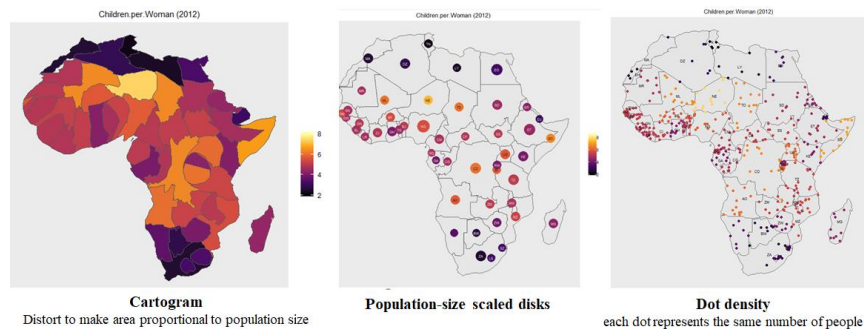


Fig. 10.18 Three methods that attempt to overcome conflation of area with number

10.4.4 Communicating by Customizing: Making Aesthetic Changes and Adding Information to Plots

An essential aspect of Civic Statistics is the ability to communicate effectively. Here, we show how a standard output can be customized so that findings can be interpreted more readily by others. Country-level data has been downloaded from *Gapminder* for 2016; we are exploring the relationship between the average number of children each woman in a country has, and the life expectancy of the population in that country. Once relevant variables have been chosen, *iNZight* creates a scatterplot (Fig. 10.19) – the default for a relationship between two numeric variables.

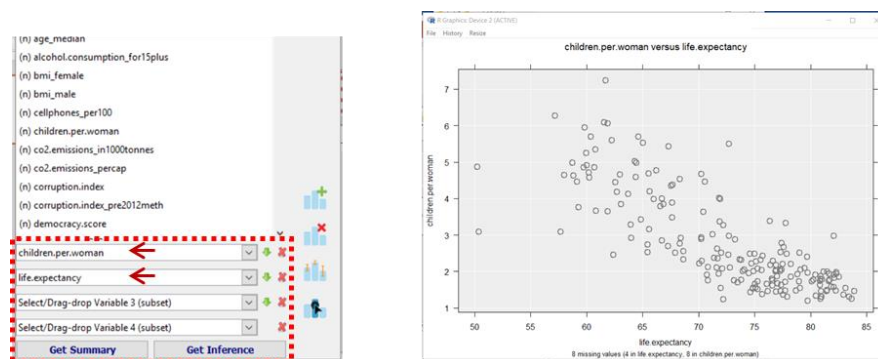


Fig. 10.19 Relating *Children per woman* to *Life Expectancy* for countries in 2016

Fig.10.20 shows the results of using some of the facilities of **Add to Plot** – the command panel controlling some of this is shown on the left. The plotted symbols have been sized to show the *population size* of the country; the points have been coloured according to the *Region* of the world to which the country belongs; country-name labels have been placed by some of the very big countries and by some of the outlying countries; “rugs” have been added alongside the axes to show the positions of the X-values and Y-values of the points; a smooth trend-curve has been added (solid blue line) together with about 20 bootstrapped smooths (dashed lines).

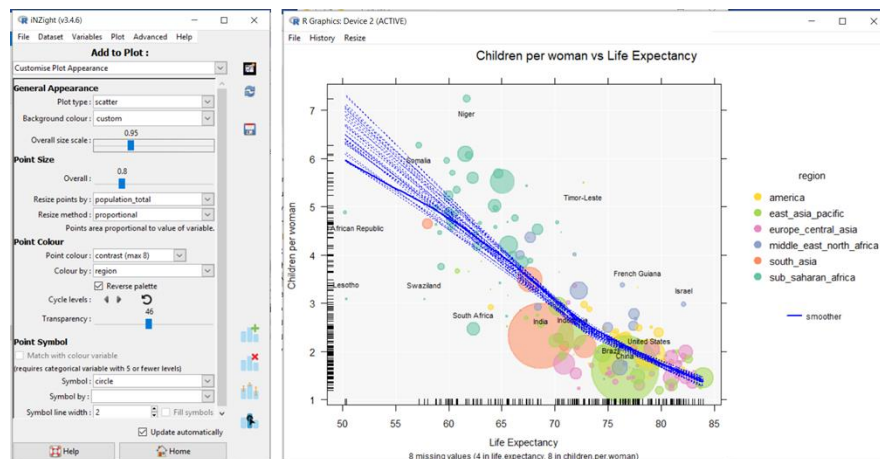


Fig. 10.20 Augmenting the scatterplot in Fig. 10.19

Some of the aesthetic changes are as follows: the title and X- and Y-axis labels have been changed from the default (which simply picks up the variable names from the data set) into something that reads better; the background has been lightened; the points (disks) have been made semi-transparent and colored according to a chosen palette; and the overall sizes of things have been reduced somewhat.

10.4.5 Give Me the *R* Code for That

It is important that analyses of data can be reproduced, and (if necessary) re-used on other data sets. This is problematic if data are modified during the processes of exploration and analysis – for example, if outliers are removed, or some values are interpolated. In *iNZight*, the *R* code that implements user actions is automatically stored, and the stored code is made available to the user – both to provide an audit trail of changes made to the data and for possible use in *R* programs to automate such changes in the future. (To give more internal detail, when a user asks for a data-wrangling operation to be performed, the system first constructs the *R* code to do it, and then both executes and stores that code).

In addition, the controls for the plot types shown in Fig. 10.3 have buttons for storing and displaying the *R*-code that produced them. Fig. 10.21 shows a stored-code display window containing saved plots. Clicking on a plot thumbnail

regenerates the plot in the graphics window. The code can be copied for external use and even modified and re-run in the current *iNZight* session.

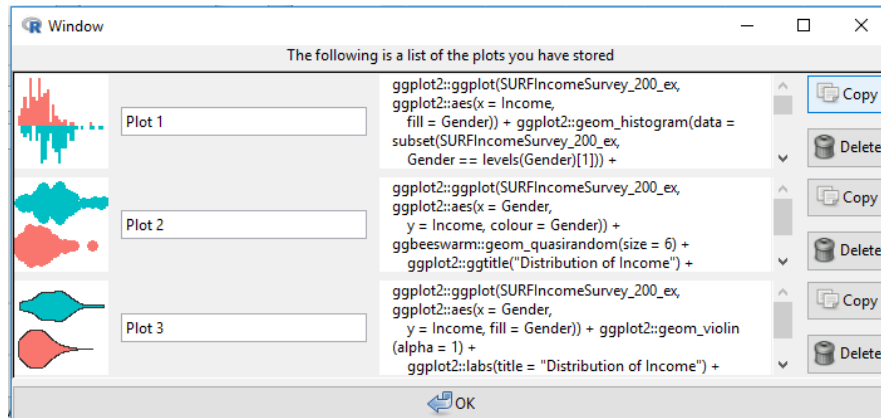


Fig. 10.21 Stored *R*-code displayed for three plots

10.5 Future-proofing Software

A book chapter is a snapshot in time whereas a software project is always a work in progress. By the time you read this, whatever you gleaned about the capabilities of *iNZight* will now be out of date. So we will conclude by briefly describing some of the things that are under development. The guiding principles are to develop the software environment in a principled way, and also to monitor important developments in the field, and to implement them in *iNZight*.

In the Advanced Modules space, the *iNZight* project is working on modules for text harvesting and text analytics, network data, longitudinal data and small-area estimation. All of these are directly relevant to Civic Statistics.

Work is also underway on extending graphical displays to include multivariate graphics (in the sense of multiple *Y*-variables), and to provide much greater functionality for exploring and analysing time series data.

New modules for analysing hierarchical data, and data from designed experiments are under development.

We are also working on modules for supervised learning (predictive modelling) and unsupervised learning (primarily cluster analysis).

In the code-writing space we intend to increase the number of *iNZight* functions that write *R* code. We have prototypes of parts of *iNZight Lite* writing shell *R*-

Markdown documents, which combine text and executable *R*-code and are a good way to write documents that combine discussion and analysis. The shell document delivered by *iNZight* can then be further refined independently of *iNZight* (but in conjunction with *R*). We hope also to close the loop between *iNZight Lite* and coding using cloud implementations of *R*.

The *iNZight* project's source code can be found in the Github repository¹⁵. We welcome collaborators.

10.6 Conclusions

We began by describing some desirable features of software to support learning and doing statistics, then set out to show how these features have been implemented in *iNZight*. A key message is the importance of engaging users and fostering their skills in statistical enquiry skills whatever their level of statistical knowledge. *iNZight* is particularly well suited to the analysis of data relevant to Civic Statistics, by facilitating multiple representations, handling multivariate data that can be dynamic, spanning time and places, collected in a variety of ways. Wrangling with Civic Statistics data requires analysis, reanalysis and reflection; tools to record analyses and data moves are essential for successful analysis. We are living in interesting times, and face new challenges in understanding an increasingly connected and complex world characterised by new artefacts, events, new sorts of data, new kinds of analysis, and new ways of communicating with each other. Tools to support our intellectual development must continue to evolve, and to be accessible to both naïve and sophisticated users.

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¹⁵ <https://github.com/iNZightVIT>

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