Overview of the Sheffield Elicitation Framework (SHELF, v4)

An "Off the Shelf" package for eliciting probability distributions

Why SHELF?

Elicitation is the process of capturing expert knowledge about one or more uncertain quantities in the form of a probability distribution. Expert knowledge elicitation is an important tool to provide understanding of uncertain phenomena, and as input to decision-making processes. There has been a steadily growing demand for elicitation in many fields – throughout industry, government and science. Yet there is little practical help available for those wishing to use elicitation. SHELF is a response to that need.

Elicitation can be done informally, but when the expert judgements are sufficiently important it is necessary to employ a formal procedure in the interests of quality and defensibility. The SHELF protocol is such a formal procedure for elicitation.

But SHELF is more than this. Good elicitation generally requires a facilitator who has expertise in the process of elicitation. The facilitator guides the expert(s), manages the process and at the end delivers the elicited probability distribution. SHELF provides not only the tools for a facilitator but also copious advice on their use.

The developers of SHELF are co-authors of one of the leading textbooks in the field:

> "Uncertain Judgements: Eliciting Experts' Probabilities", by A. O'Hagan, C. E. Buck, A. Daneshkhah, J. R. Eiser, P. H. Garthwaite, D. J. Jenkinson, J. E. Oakley and T. Rakow. Published in 2006 by Wiley. ISBN: 978-0-470-02999-2.

SHELF has drawn extensively on this book's research and conclusions for best practice, but is also updated to reflect our innovations and experience over the intervening 10 years.

Experienced practitioners of elicitation employ a variety of frameworks. The SHELF developers also participated in writing a guidance document for the European Food Safety Authority which identified SHELF as one of three methods that represent best practice in elicitation:

> "Guidance on Expert Knowledge Elicitation in Food and Feed Safety Risk Assessment." *EFSA Journal 2014*;12(6):3734. Available from http://www.efsa.europa.eu/en/efsajournal/pub/3734.htm

By using SHELF, the facilitator can say that the elicitation has been conducted in an open and well-structured way that accords with best practice in the field. The SHELF name is a mark of quality.

What's in SHELF?

The SHELF package is delivered as a zip file containing the following components:

1. This **SHELF Overview** document, which should be read carefully before using SHELF, and five folders containing additional files as follows
2. **Advice** for coordinators and facilitators of SHELF elicitation workshops
    a. Pre-elicitation
    b. Evidence Dossier
    c. Definitions
    d. SHELF Methods
    e. Multivariate Elicitation
    f. Facilitator Skills
    g. Discrete Quantities
    h. Extension
    i. Many Quantities of Interest
3. PowerPoint **slide sets** to guide experts in making accurate judgements
    a. Plausible Limits
    b. Median
    c. Quartiles
    d. Tertiles
    e. Roulette
    f. RIO
    g. Quadrant Probabilities
    h. Conditional Range
4. Blank **templates** for recording SHELF elicitations, and the same templates with added notes
    a. SHELF 1
    b. SHELF 1 with notes
    c. SHELF 2
    d. SHELF 2 with notes
    e. SHELF 3 Copula

f. SHELF 3 Copula with notes
g. SHELF 3 Dirichlet
h. SHELF 3 Dirichlet with notes
i. SHELF 3 Discrete
j. SHELF 3 Discrete with notes
k. SHELF 3 Extension
l. SHELF 3 Extension with notes

5. **Sample** documents for use in expert briefing and for illustration
   a. SHELF Expert Briefing
   b. Expert Enquiry
   c. External Expert Enquiry
   d. Sample Evidence Dossier
   e. Sample SHELF 1
   f. Sample SHELF 2
   g. Sample SHELF 3 Extension

Supporting software is also available, which can be freely obtained separately, and is described below.

What's new in version 4?

SHELF version 4 is a significant development from version 3, featuring:

- Additional advice for organising and conducting SHELF elicitation workshops, in the form of new documents covering discrete quantities, the new extension method and how to handle many quantities of interest.
- Two new SHELF 3 templates. One is designed for eliciting judgements about a discrete quantity of interest. The other is for the extension method, which can be used to elicit judgements about a single quantity by conditioning on another quantity, or to elicit a joint distribution for two or more quantities that are not judged to be independent.
- A new PowerPoint slide set to assist with the extension method.
- Supporting software for implementing the extension method.
- An example of a completed SHELF 3 Extension template.

The essential elements of SHELF

Any application of the SHELF protocol will be distinguished by a number of essential elements.

1. *Individual elicitation – discussion – group elicitation.* Serious elicitation almost always requires using a group of experts in order to capture their combined knowledge. SHELF elicits a single distribution from the group but begins by eliciting judgements from each expert independently. This is followed by the experts discussing their differences, to share their expertise, opinions and interpretations of the evidence. Then group judgements are elicited and the result of the elicitation is a "consensus" distribution fitted to these judgements. This combination of individual and group elicitations is the most important distinguishing feature of SHELF.
2. *The SHELF workshop.* The discussion and group elicitation phases require that the experts come together in what is called a SHELF workshop. Typically, they are physically together in a room, although SHELF can be used with other arrangements, including video-conferencing.
3. *The rational impartial observer (RIO).* Even after discussing and debating, SHELF does not expect the experts to reach complete agreement (such that they now have the same knowledge and beliefs about an uncertain quantity, represented by the same probability distribution). Instead they are asked to judge what a rational impartial observer, called RIO, might reasonably believe, having seen their individual judgements and listened to their discussion. By taking the perspective of RIO, experts can reach agreement on a distribution that represents a rational impartial view of their combined knowledge.
4. *The facilitator.* The SHELF workshop is led by a facilitator, who has expertise in the process of eliciting expert knowledge, and in particular is familiar with SHELF. The facilitator works with the experts to obtain accurate judgements of their knowledge, manages the group discussion and leads them in applying the RIO perspective. The facilitator's role may also be found in other elicitation protocols, but it is particularly important in SHELF.
5. *SHELF templates.* The SHELF 1, 2 and 3 templates play a dual role. First, they organise the progress of the workshop through a predefined series of steps. In particular, SHELF 2 directs both the individual elicitations and the group elicitation through controlled sequences of judgements. The entire process and the elicitation sequences used are based on research into the psychology of judgement, and on extensive experience in practical elicitation. The templates are an essential element of a SHELF elicitation. Second, the templates serve to document a SHELF workshop, such that conduct of the workshop and the development of each elicited distribution is clearly set out.

Provided that all these essential elements are properly followed, an elicitation may claim to have been conducted according to SHELF.

Advice and guidance

The SHELF package includes copious advice and guidance on conducting elicitations according to SHELF, based on the authors' extensive experience in implementing and teaching the SHELF method. Whilst it is not essential to follow the advice, it is strongly recommended, particularly for those who are less experienced.

The document "Pre-elicitation" covers all the tasks that are needed in preparing for a SHELF workshop. Good preparation is very important to ensuring an effective and trouble-free workshop.

Three additional documents deal in more depth with some of those tasks, "Definition" of the quantity or quantities of interest, the creation of an "Evidence Dossier" and how to manage "Many Quantities of Interest".

In the workshop itself, a SHELF elicitation with a group of experts always involves the experts making individual judgements, followed by discussion and then group judgements. However, depending on the nature of the quantity or quantities of interest, there are a variety of different judgements that they may be asked to make.

In most cases, the quantity of interest can take any value in some range; for instance if X is the size of something then it could in principle take any positive value, while if X is a percentage it can take any value between 0 and 100. Such a quantity is referred to as *continuous*. SHELF allows the facilitator a degree of choice in the methods to be used for the individual and group elicitations for a continuous quantity. Different methods ask for different sequences of judgements from the experts. The document "SHELF Methods" explains the different methods and provides guidance on choosing between them.

A quantity of interest that can only take one of a set of distinct values is referred to as *discrete*. An example might be the number of years in the next decade when a country's GDP falls (relative to the previous year), which can only take values 0, 1, 2, …, 10. An event which either happens or does not happen can be considered as a 'quantity' that can only take two discrete values. The document "Discrete Quantities" explains the judgements to be made when eliciting a discrete distribution, and various other issues around discrete quantities.

One of the most challenging issues in elicitation is how to elicit a joint probability distribution for a group of uncertain quantities that are not independent. Another document, "Multivariate Elicitation", discusses this problem. It explains a technique known as elaboration which can often by-pass the issue, and also describes two kinds of multivariate elicitation for which SHELF 3 templates are provided – the Dirichlet and copula elicitations.

A particularly useful form of elaboration is known as extending the argument, which also has an important role in multivariate elicitation. A separate document, "Extension", explains the various ways in which this technique can be used.

Finally, the most challenging task of all when first embarking on elicitation is the role of the facilitator, which is both important and demanding. Advice and tips for the facilitator are offered in the document "Facilitator Skills".

The slide sets

Unless experts have taken part previously in a SHELF workshop, they will almost certainly be unfamiliar with making the judgements that will be required. It is therefore important to train experts in the ideas of probability and in making the specific judgements that the facilitator will ask for.

But even after training has been given, experience shows that experts still benefit from frequent reminders, in particular by being given a clear explanation of each judgement as it is requested. This is not easy for the less experienced facilitator, so SHELF provides a short PowerPoint presentation for each of the different kinds of judgement. Even an experienced facilitator may find these useful aids to support his/her explanations in the workshop.

Software

The SHELF protocols require distributions to be fitted, distributions to be plotted and feedback data to be computed in real-time. It is essential that the facilitator (or another member of his/her team) has access to suitable software, and is fluent in its use. We have produced an R package `SHELF`, which can be installed from R with the command

```
install.packages("SHELF")
```

(You may need to update your version of R to install the package). For examples and tutorials ("vignettes") to get started, after installing the package, type the commands

```
library(SHELF)
?SHELF
browseVignettes("SHELF")
```

The reference manual and vignettes are also available at

https://cran.r-project.org/web/packages/SHELF/index.html

The R package includes (shiny) apps for implementing most of the methods. These apps are also available online from

http://www.jeremy-oakley.staff.shef.ac.uk/project/elicitation/

Other suitable software may of course be used (i.e. use of our R package is not one of the five essential elements of SHELF). In particular, another web-based implementation of some of the code within the `SHELF` R package, the MATCH Uncertainty Elicitation Tool, is available at

http://optics.eee.nottingham.ac.uk/match/uncertainty.php

Using SHELF with one expert

Although a formal and careful elicitation process such as SHELF is generally used for elicitation from several experts, it is straightforward to adapt the SHELF materials for use with a single expert. The discussion and group elicitation stages are skipped and corresponding fields in SHELF forms may be left blank.

About SHELF

This is the fourth version of the Sheffield Elicitation Framework. SHELF will continue to evolve in response to the experiences of people using it and according to the wish of its developers to extend its capabilities.

Comments are welcomed by Tony O'Hagan (shelf@tonyohagan.co.uk) and Jeremy Oakley (j.oakley@sheffield.ac.uk).

We would particularly welcome offers of additional materials, suggested amendments or any other ideas for improving SHELF.

The SHELF package is available from the website

http://tonyohagan.co.uk/shelf/

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b) amended documents have headers removed and titles/contents edited to remove any implication that they are SHELF documents;

c) you acknowledge the extent to which your materials are based on those of SHELF.

The appropriate form of citation in published work is:

Oakley J. E. and O'Hagan, A. (2019). SHELF: the Sheffield Elicitation Framework (version 4). School of Mathematics and Statistics, University of Sheffield, UK. (http://tonyohagan.co.uk/shelf)