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Software update

Update (1.2) to ANDURIL and ANDURYL: Performance improvements and a graphical user interface

Guus Rongen [a,b,*], Cornelis Marcel Pieter 't Hart [a,c], Georgios Leontaris [a,d], Oswaldo Morales-Nápoles [a]

[a] Civil Engineering and Geosciences, Delft University of Technology, The Netherlands
[b] HKV consultants, The Netherlands
[c] Tunnel Engineering Consultants (TEC), Amersfoort, The Netherlands
[d] Vattenfall, The Netherlands

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ABSTRACT

This is an update to PII: S2352711018300608 and S2352711019302419 In this paper, we present three main improvements of ANDURIL and its python version ANDURYL. First the MATLAB version ANDURIL is brought to the Python version standard by implementing (i) user defined quantiles and (ii) the possibility to deal with missing values. Second, the computational engines of both ANDURIL and ANDURYL were significantly improved making calculation time lower and improving further accuracy. Finally a standalone Graphical User Interface is presented which we believe will make the software more accessible to practitioners of Cooke's method.

Software metadata

Current code version	ANDURYL v1.2
Permanent link to code/repository used for this code version	GitHub (peer review version)
Legal Code License	GNU General Public License
Code versioning system used	GitHub
Software code languages, tools, and services used	Python, PyQt5, Numpy, Matplotlib
Compilation requirements, operating environments & dependencies	Python version 3.6+
If available Link to developer documentation/manual	Available from GUI and Github
Support email for questions	g.w.f.rongen@tudelft.nl

Code metadata

Current code version	Code: ANDURYL v1.2, Paper v1.2
Permanent link to code/repository used for this code version	GitHub (peer review version)
Legal Code License	GNU General Public License
Code versioning system used	None
Software code languages, tools, and services used	Python, PyQt5, Numpy, Matplotlib
Compilation requirements, operating environments & dependencies	Python version 3.6+
If available Link to developer documentation/manual	Available from GUI and Github
Support email for questions	g.w.f.rongen@tudelft.nl

1. Motivation and significance

Software implementing Cooke's classical model [1] for structured expert judgment was presented in [2] and [3]. The earlier

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* Corresponding author at: Civil Engineering and Geosciences, Delft University of Technology, The Netherlands.
E-mail address: g.w.f.rongen@tudelft.nl (G. Rongen).

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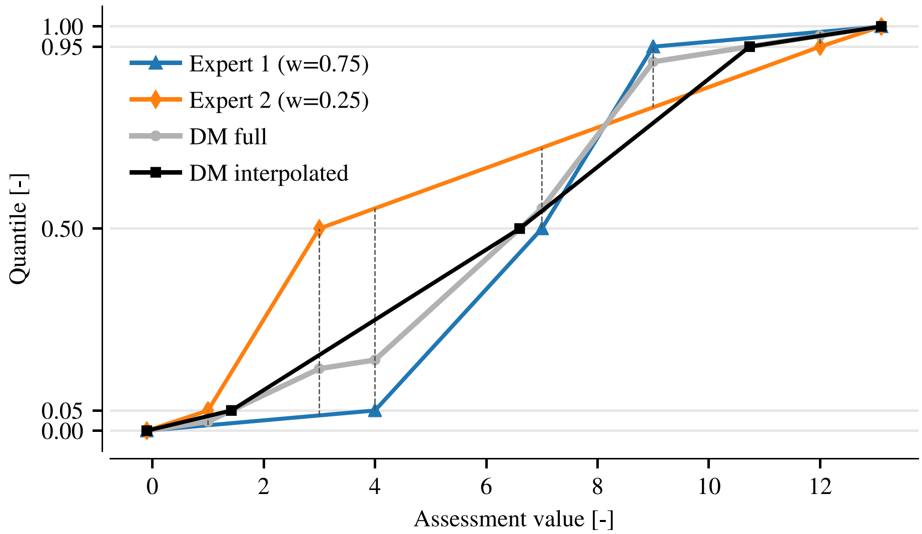

Fig. 1. Illustration of decision maker interpolation.

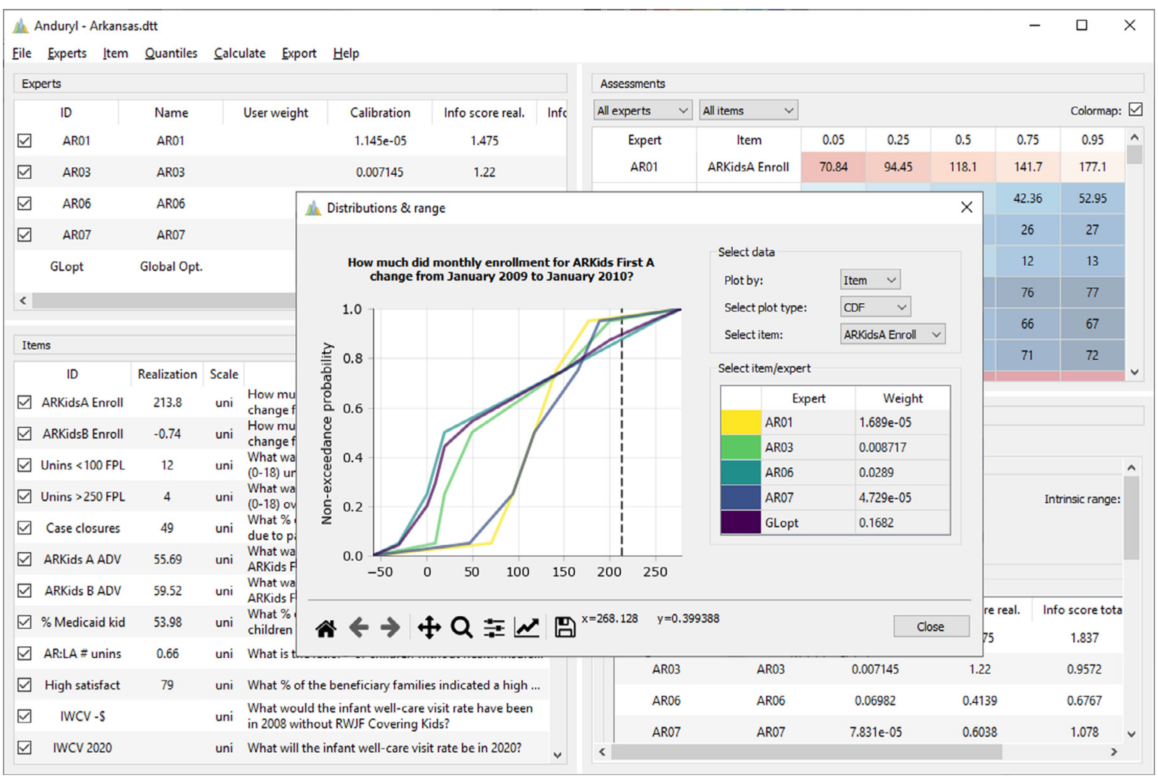

Fig. 2. Overview of the ANDURYL GUI, with on the background the main window and on the foreground the CDF of each expert and the DM for a specific question.

Table 1
Computational times of different version of AI and AY in robustness analysis. Up to four items left out at a time, global weights, no optimization.

AI v1.0	AY v1.1	AI v1.2	AY v1.2
15 min	60 s	30 s	4 s

MATLAB version is named ANDURIL (AI) while the Python version is ANDURYL (AY).

In this update:

1. ANDURIL is brought to the Python version standard by implementing: (i) user defined quantiles and (ii) the possibility to deal with missing values. These features will not be discussed further. The reader is referred to [3] for an explanation of the main features now also available in AI v1.2 (ANDURIL version 1.2).
2. The code of both ANDURIL and ANDURYL was significantly improved, reducing the calculation time. The calculation times on a PC with an Intel Core I5-5300U CPU of 2.3 GHz for robustness analysis (global weights without optimization) for the study presented in [5] are shown in Table 1. Up to 4 of the 13 calibration questions at a time were excluded, resulting in 1092 combinations of excluded items. The MATLAB version AI v1.2 is 30 times faster than AI v1.0 for the study under consideration. Similarly AY v1.2 is a factor 15 faster than AY v1.1 and approximately 220 times faster than AI v1.0.

Table 2
Comparison of results presented in Table 1 of [4] (CC) and calculations with AI (AI) and AY (AY). Note that only the 7 studies that had or still have differences are shown. The other 26 studies have no differences in the outcomes.

Study	#E	#S	Equal Weight			Global No Op.			PW Global			PW Item			Best Expert		
			Sa	In	Co	Sa	In	Co	Sa	In	Co	Sa	In	Co	Sa	In	Co
CDC ROI (CC)	20	10	0.23	1.23	0.29	0.39	1.35	0.52	0.72	2.31	1.66	0.72	2.31	1.66	0.72	2.31	1.66
CDC ROI* (AI 1.0)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CDC ROI (AY 1.1)	20	10	0.23	1.23	0.29	0.39	1.35	0.52	0.72	2.30	1.66	0.72	2.30	1.66	0.72	2.30	1.66
CDC ROI (AI 1.2)	20	10	0.23	1.23	0.29	0.39	1.35	0.52	0.72	2.30	1.66	0.72	2.30	1.66	0.72	2.30	1.66
CDC ROI (AY 1.2)	20	10	0.23	1.23	0.29	0.39	1.35	0.52	0.72	2.30	1.66	0.72	2.30	1.66	0.72	2.30	1.66
CWD (CC)	14	10	0.47	0.93	0.44	0.47	0.94	0.45	0.49	1.22	0.60	0.68	1.33	0.90	0.31	2.19	0.69
CWD (AI 1.0)	14	10	0.47	0.93	0.44	0.47	0.94	0.45	0.49	1.21	0.60	0.68	1.33	0.90	0.31	2.19	0.69
CWD (AY 1.1)	14	10	0.47	0.93	0.44	0.47	0.94	0.45	0.49	1.21	0.60	0.68	1.33	0.90	0.31	2.19	0.69
CWD (AI 1.2)	14	10	0.47	0.93	0.44	0.47	0.94	0.45	0.49	1.21	0.60	0.68	1.33	0.90	0.31	2.19	0.69
CWD (AY 1.2)	14	10	0.47	0.93	0.44	0.47	0.94	0.45	0.49	1.21	0.60	0.68	1.33	0.90	0.31	2.19	0.69
Gerstenberger (CC)	12	14	0.64	0.48	0.31	0.35	0.61	0.21	0.93	1.10	1.02	0.76	1.20	0.91	0.54	1.74	0.93
Gerstenberger* (AI 1.0)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Gerstenberger (AY 1.1)	12	14	0.64	0.48	0.31	0.35	0.61	0.21	0.93	1.09	1.02	0.76	1.09	0.82	0.54	1.74	0.93
Gerstenberger (AI 1.2)	12	14	0.64	0.48	0.31	0.35	0.61	0.21	0.93	1.09	1.02	0.76	1.20	0.91	0.54	1.74	0.93
Gerstenberger (AY 1.2)	12	14	0.64	0.48	0.31	0.35	0.61	0.21	0.93	1.09	1.02	0.76	1.20	0.91	0.54	1.74	0.93
Goodheart (CC)	6	10	0.55	0.28	0.15	0.47	0.35	0.16	0.71	0.96	0.68	0.71	0.96	0.68	0.71	0.96	0.68
Goodheart (AI 1.0)	6	10	0.55	0.28	0.15	0.47	0.35	0.16	0.47	0.35	0.17	0.68	0.64	0.43	0.71	0.96	0.68
Goodheart (AY 1.1)	6	10	0.55	0.28	0.15	0.47	0.35	0.16	0.47	0.35	0.17	0.68	0.64	0.43	0.71	0.96	0.68
Goodheart (AI 1.2)	6	10	0.55	0.28	0.15	0.47	0.35	0.16	0.71	0.96	0.68	0.71	0.96	0.68	0.71	0.96	0.68
Goodheart (AY 1.2)	6	10	0.55	0.28	0.15	0.47	0.35	0.16	0.71	0.96	0.68	0.71	0.96	0.68	0.71	0.96	0.68
Hemopilia (CC)	18	8	0.25	0.20	0.05	0.31	0.27	0.08	0.31	0.49	0.15	0.31	0.46	0.14	0.85	1.07	0.91
Hemopilia* (AI 1.0)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hemopilia (AY 1.1)	18	8	0.25	0.20	0.05	0.31	0.27	0.08	0.31	0.30	0.09	0.31	0.15	0.05	0.85	1.07	0.91
Hemopilia (AI 1.2)	18	8	0.25	0.20	0.05	0.31	0.27	0.08	0.31	0.29	0.09	0.31	0.39	0.12	0.85	1.07	0.91
Hemopilia (AY 1.2)	18	8	0.25	0.20	0.05	0.31	0.27	0.08	0.31	0.30	0.09	0.31	0.41	0.13	0.85	1.07	0.91
IceSheets (CC)	10	11	0.49	0.52	0.25	0.62	0.70	0.43	0.40	1.55	0.62	0.62	1.04	0.64	0.40	1.55	0.62
IceSheets (AI 1.0)	10	11	0.49	0.52	0.25	0.37	0.66	0.25	0.40	1.55	0.62	0.62	1.04	0.64	0.40	1.55	0.62
IceSheets (AY 1.1)	10	11	0.49	0.52	0.25	0.37	0.66	0.25	0.40	1.55	0.62	0.62	1.04	0.64	0.40	1.55	0.62
IceSheets (AI 1.2)	10	11	0.49	0.52	0.25	0.37	0.66	0.25	0.40	1.55	0.62	0.62	1.04	0.64	0.40	1.55	0.62
IceSheets (AY 1.2)	10	11	0.49	0.52	0.25	0.37	0.66	0.25	0.40	1.55	0.62	0.62	1.04	0.64	0.40	1.55	0.62
Topaz (CC)	21	16	0.63	0.92	0.58	0.31	1.12	0.34	0.41	1.46	0.60	0.41	1.46	0.60	0.41	1.46	0.60
Topaz (AI 1.0)	21	16	0.63	0.92	0.58	0.31	1.12	0.34	0.41	1.45	0.60	0.41	1.45	0.60	0.41	1.45	0.60
Topaz (AY 1.1)	21	16	0.63	0.92	0.58	0.31	1.12	0.34	0.41	1.45	0.60	0.41	1.45	0.60	0.41	1.45	0.60
Topaz (AI 1.2)	21	16	0.63	0.92	0.58	0.31	1.12	0.34	0.41	1.45	0.60	0.41	1.45	0.60	0.41	1.45	0.60
Topaz (AY 1.2)	21	16	0.63	0.92	0.58	0.31	1.12	0.34	0.41	1.45	0.60	0.41	1.45	0.60	0.41	1.45	0.60

The new code led also to improved accuracy of both AI and AY. That is, both solutions are closer to EXCALIBUR (CC). The differences between CC and AI and AY for the 7 studies where differences were observed, are shown in Table 2. This will be elaborated further below.

3. A standalone Graphical User Interface of ANDURYL is presented. A screen shot of the GUI is presented in Fig. 2

2. ANDURYL and ANDURIL code improvement

The main improvement in speed and accuracy is the result of a different implementation for calculating the Decision Maker's (DM) cumulative distribution function (CDF). In version 1.0 and 1.1, the DM's CDF was calculated by integrating the probability density function (PDF) of the weighted DM's numerically (quadrature method) through an anonymous function. Solving this integral is numerically expensive and when the probability density of one or more expert are very concentrated in a range in relation to that of other experts, parts of the PDF were skipped in the discretization used in the numerical integration.

In the new (AY v1.2 and AI v1.2), the old implementation of the integral is replaced by an interpolation of the CDF. As long as the PDF between the given quantiles is uniform (or log-uniform), this gives the same results as solving the integral, but much quicker and without inaccuracies due to the discretization of the integral. Fig. 1 illustrates the process of interpolation for the decision maker.

Note that the DM quantiles ("DM full" in the figure) are determined by interpolating each of the (two in this case) experts' answers (following the dashed lines). This results in the full detailed CDF of the decision maker. This can subsequently be interpolated at the percentiles of interest (which is EXCALIBUR's output). Note that the interpolation is not carried out over the quantile direction.

3. ANDURYL GUI

The main improvement for the Python version is the graphical user interface. This interface, programmed with the Python module PyQt5, is compiled with PyInstaller (for Windows), such that it is a stand-alone executable. This makes ANDURYL accessible to non-Python users. The layout of the user interface consists of 4 overviews, for the experts, items, assessments and results, as shown in Fig. 2.

The following list gives an overview of the functionalities that the stand-alone GUI offers:

- Assessments per expert or item can be plotted as a PDF, CDF, survival function or range. The CDF option is shown in Fig. 2 on the foreground.
- Because of the improvements in computational performance, it is now less demanding to do a robustness analysis for excluding multiple experts or items. The results of the robustness analysis can be shown in box plots.
- The program has options for saving the project in EXCALIBUR format or a more common JSON format.
- Separate DM's results, such as the full CDFs, can be exported or copied to clipboard.

- The AY code is separated between calculation and user interface functionalities so that the Python-module can also be used from a script or Jupyter notebook. For research purposes this is a useful functionality.
- The fact that AY is still significantly faster than AI, as shown in Table 1, is due to differences in implementation. In AI several expensive operations are re-calculated for different iterations. In AY the amount of data that is re-calculated is minimized.

4. Comparing with previous studies

In [4], 33 post-2006 studies using Cooke's classical method are presented using CC. We use these data to compare output from AY and AI to both CC, the MATLAB implementation AI of the v1.0 paper [2] and the Python implementation of the paper [3].

The differences are smaller compared to the results from the last code version. For two studies, "Hemophilia" and "Ice sheets" the differences are still significant. For four other studies the results seem to be due to rounding errors. Of the remaining 26 studies, the majority have equal results. Table 2 shows the differences for the studies where differences are still observed.

5. Conclusions

The Python module named ANDURYL (AY) has been extended with a graphical user interface and is available as stand-alone executable. The MATLAB toolbox named ANDURIL (AI) for combining expert judgments applying Cooke's method has been further extended by adding functionalities for user defined quantiles and handling missing values. The stand-alone GUI enables practitioners and researchers that have no Python or MATLAB experience to apply Cooke's method with ANDURYL. For users that are more familiar with programming, the MATLAB toolbox and Python GUI are a means to perform or analyze expert elicitations in a reproducible way. The improved speed and accuracy contribute to this cause. Both codes are open source to encourage usage and further development.

CRediT authorship contribution statement

Guus Rongen: Methodology, Software, Writing - original draft. **Cornelis Marcel Pieter 't Hart:** Methodology, Validation. **Georgios Leontaris:** Methodology. **Oswaldo Morales-Nápoles:** Conceptualization, Writing - review & editing, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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