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# What If Without the Conformal Prediction Method

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## Abstract

The abstract paragraph should be indented 1/2 inch (3 picas) on both left and right-hand margins. Use 10 point type, with a vertical spacing of 11 points. The word **Abstract** must be centered, bold, and in point size 12. Two line spaces precede the abstract. The abstract must be limited to one paragraph.

## 1 Introduction

In scientific, engineering, and everyday decision-making, obtaining a prediction is insufficient without also understanding its reliability through effective uncertainty quantification (UQ). Whether in autonomous driving, medical diagnosis, or financial risk assessment, relying solely on point estimates poses significant risks, as models are always imperfect and the world exhibits inherent noise. This challenge is formalized in classical decision theory, where optimal decisions require not only an expected outcome but a complete characterization of uncertainty.

Formally, consider a decision problem where we observe data  $x \in \mathcal{X}$  and must choose an action  $a \in \mathcal{A}$ . The consequence of this action depends on an unknown state  $y \in \mathcal{Y}$ , and is quantified by a loss function  $L : \mathcal{A} \times \mathcal{Y} \rightarrow \mathbb{R}$ . In the Bayesian decision theory, the optimal decision minimizes the *posterior expected loss*:

$$a^*(x) = \arg \min_{a \in \mathcal{A}} \mathbb{E}_{y \sim p(y|x)} [L(a, y)] = \arg \min_{a \in \mathcal{A}} \int_{\mathcal{Y}} L(a, y) p(y|x) dy, \quad (1)$$

where  $p(y|x)$  is the posterior distribution of  $y$  given  $x$ . As shown in (1), the optimal action  $a^*$  depends not merely on a point estimate (such as the posterior mean), but on the entire posterior distribution. A poor characterization of  $p(y|x)$  can lead to suboptimal decisions even with an accurate predictive model. Thus, robust and interpretable decision-making fundamentally requires well-calibrated uncertainty estimates. Consequently, a central challenge in modern machine learning, particularly for complex black-box models like deep neural networks, is to provide rigorous and reliable uncertainty measures for predictions. Without such measures, deploying these models in high-stakes domains remains risky.

To address this challenge, a variety of UQ methods have been developed, each with its own set of limitations that restrict practical applicability. **Parametric models**, for instance, often rely on strong distributional assumptions (e.g., normality) that are rarely justified in complex, real-world data settings. **Asymptotic theories**, while providing theoretical guarantees under ideal conditions, require sample sizes that are often unattainable in practice, and their convergence may not be guaranteed for finite or moderate datasets. Within the Bayesian paradigm, the choice of a **prior distribution** can be subjective and difficult to justify, while the computation of the **posterior distribution** is frequently intractable for high-dimensional or non-conjugate models, necessitating approximate inference schemes that may themselves introduce error. Among more recent machine learning approaches, **ensemble methods** (e.g., deep ensembles) can yield well-calibrated uncertainty estimates but at a prohibitive computational cost, as they require training and maintaining multiple models—a significant burden for large datasets and complex architectures. Techniques like **Monte Carlo**

**Dropout** offer a more lightweight alternative by approximating Bayesian inference within neural networks, yet they impose specific architectural constraints (e.g., dropout layers) and require careful tuning of training regimes. Lastly, **generative models** (e.g., variational autoencoders or normalizing flows) can model complex data distributions but are notoriously expensive to train and may be challenging to scale to high-dimensional problems. In summary, existing methods are often constrained by strong assumptions, high computational demands, or a lack of finite-sample guarantees, highlighting the need for a framework that is both model-agnostic and theoretically rigorous.

## 2 General formatting instructions

The text must be confined within a rectangle 5.5 inches (33 picas) wide and 9 inches (54 picas) long. The left margin is 1.5 inch (9 picas). Use 10 point type with a vertical spacing of 11 points. Times New Roman is the preferred typeface throughout. Paragraphs are separated by 1/2 line space, with no indentation.

Paper title is 17 point, initial caps/lower case, bold, centered between 2 horizontal rules. Top rule is 4 points thick and bottom rule is 1 point thick. Allow 1/4 inch space above and below title to rules. All pages should start at 1 inch (6 picas) from the top of the page.

For the final version, authors' names are set in boldface, and each name is centered above the corresponding address. The lead author's name is to be listed first (left-most), and the co-authors' names (if different address) are set to follow. If there is only one co-author, list both author and co-author side by side.

Please pay special attention to the instructions in section 4 regarding figures, tables, acknowledgments, and references.

## 3 Headings: first level

First level headings are lower case (except for first word and proper nouns), flush left, bold and in point size 12. One line space before the first level heading and 1/2 line space after the first level heading.

### 3.1 Headings: second level

Second level headings are lower case (except for first word and proper nouns), flush left, bold and in point size 10. One line space before the second level heading and 1/2 line space after the second level heading.

#### 3.1.1 Headings: third level

Third level headings are lower case (except for first word and proper nouns), flush left, bold and in point size 10. One line space before the third level heading and 1/2 line space after the third level heading.

## 4 Citations, figures, tables, references

These instructions apply to everyone, regardless of the formatter being used.

### 4.1 Citations within the text

Citations within the text should be numbered consecutively. The corresponding number is to appear enclosed in square brackets, such as [1] or [2]-[5]. The corresponding references are to be listed in the same order at the end of the paper, in the **References** section. (Note: the standard B<sub>I</sub>B<sub>T</sub>E<sub>X</sub> style `unsrt` produces this.) As to the format of the references themselves, any style is acceptable as long as it is used consistently.

As submission is double blind, refer to your own published work in the third person. That is, use "In the previous work of Jones et al. [4]", not "In our previous work [4]". If you cite your other papers

Table 1: Sample table title

PART	DESCRIPTION
Dendrite	Input terminal
Axon	Output terminal
Soma	Cell body (contains cell nucleus)

that are not widely available (e.g. a journal paper under review), use anonymous author names in the citation, e.g. an author of the form “A. Anonymous”.

## 4.2 Footnotes

Indicate footnotes with a number<sup>1</sup> in the text. Place the footnotes at the bottom of the page on which they appear. Precede the footnote with a horizontal rule of 2 inches (12 picas).<sup>2</sup>

## 4.3 Figures

All artwork must be neat, clean, and legible. Lines should be dark enough for purposes of reproduction; art work should not be hand-drawn. The figure number and caption always appear after the figure. Place one line space before the figure caption, and one line space after the figure. The figure caption is lower case (except for first word and proper nouns); figures are numbered consecutively.

Make sure the figure caption does not get separated from the figure. Leave sufficient space to avoid splitting the figure and figure caption.

You may use color figures. However, it is best for the figure captions and the paper body to make sense if the paper is printed either in black/white or in color.

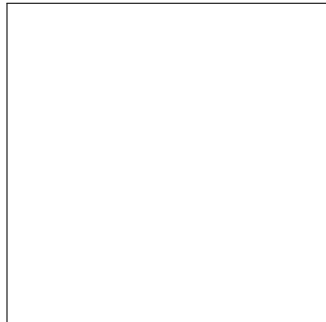


Figure 1: Sample figure caption.

## 4.4 Tables

All tables must be centered, neat, clean and legible. Do not use hand-drawn tables. The table number and title always appear before the table. See Table 1.

Place one line space before the table title, one line space after the table title, and one line space after the table. The table title must be lower case (except for first word and proper nouns); tables are numbered consecutively.

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<sup>1</sup>Sample of the first footnote

<sup>2</sup>Sample of the second footnote

## 5 Final instructions

Do not change any aspects of the formatting parameters in the style files. In particular, do not modify the width or length of the rectangle the text should fit into, and do not change font sizes (except perhaps in the **References** section; see below). Please note that pages should be numbered.

## 6 Preparing PostScript or PDF files

Please prepare PostScript or PDF files with paper size “US Letter”, and not, for example, “A4”. The `-t letter` option on `dvips` will produce US Letter files.

Fonts were the main cause of problems in the past years. Your PDF file must only contain Type 1 or Embedded TrueType fonts. Here are a few instructions to achieve this.

- You can check which fonts a PDF file uses. In Acrobat Reader, select the menu `Files>Document Properties>Fonts` and select `Show All Fonts`. You can also use the program `pdf fonts` which comes with `xpdf` and is available out-of-the-box on most Linux machines.
- The IEEE has recommendations for generating PDF files whose fonts are also acceptable for NIPS. Please see <http://www.emfield.org/icuwb2010/downloads/IEEE-PDF-SpecV32.pdf>
- LaTeX users:
  - Consider directly generating PDF files using `pdflatex` (especially if you are a MiKTeX user). PDF figures must be substituted for EPS figures, however.
  - Otherwise, please generate your PostScript and PDF files with the following commands:

```
dvips mypaper.dvi -t letter -Ppdf -G0 -o mypaper.ps
ps2pdf mypaper.ps mypaper.pdf
```

Check that the PDF file only contains Type 1 fonts.
  - `xfig` “patterned” shapes are implemented with bitmap fonts. Use “solid” shapes instead.
  - The `\bbold` package almost always uses bitmap fonts. You can try the equivalent AMS Fonts with command

```
\usepackage[psamsfonts]{amssymb}
```

or use the following workaround for reals, natural and complex:

```
\newcommand{\RR}{\mathbb{R}} %real numbers
\newcommand{\Nat}{\mathbb{N}} %natural numbers
\newcommand{\CC}{\mathbb{C}} %complex numbers
```
  - Sometimes the problematic fonts are used in figures included in LaTeX files. The `ghostscript` program `eps2eps` is the simplest way to clean such figures. For black and white figures, slightly better results can be achieved with program `potrace`.
- MSWord and Windows users (via PDF file):
  - Install the Microsoft Save as PDF Office 2007 Add-in from <http://www.microsoft.com/downloads/details.aspx?displaylang=en&familyid=4d951911-3e7e-4ae6-b059-a2e79ed87041>
  - Select “Save or Publish to PDF” from the Office or File menu
- MSWord and Mac OS X users (via PDF file):
  - From the print menu, click the PDF drop-down box, and select “Save as PDF...”
- MSWord and Windows users (via PS file):
  - To create a new printer on your computer, install the AdobePS printer driver and the Adobe Distiller PPD file from <http://www.adobe.com/support/downloads/detail.jsp?ftpID=204> *Note:* You must reboot your PC after installing the AdobePS driver for it to take effect.

- To produce the ps file, select “Print” from the MS app, choose the installed AdobePS printer, click on “Properties”, click on “Advanced.”
- Set “TrueType Font” to be “Download as Softfont”
- Open the “PostScript Options” folder
- Select “PostScript Output Option” to be “Optimize for Portability”
- Select “TrueType Font Download Option” to be “Outline”
- Select “Send PostScript Error Handler” to be “No”
- Click “OK” three times, print your file.
- Now, use Adobe Acrobat Distiller or ps2pdf to create a PDF file from the PS file. In Acrobat, check the option “Embed all fonts” if applicable.

If your file contains Type 3 fonts or non embedded TrueType fonts, we will ask you to fix it.

## 6.1 Margins in LaTeX

Most of the margin problems come from figures positioned by hand using `\special` or other commands. We suggest using the command `\includegraphics` from the `graphicx` package. Always specify the figure width as a multiple of the line width as in the example below using `.eps` graphics

```
\usepackage[dvips]{graphicx} ...
\includegraphics[width=0.8\linewidth]{myfile.eps}
```

or

```
\usepackage[pdftex]{graphicx} ...
\includegraphics[width=0.8\linewidth]{myfile.pdf}
```

for `.pdf` graphics. See section 4.4 in the graphics bundle documentation (<http://www.ctan.org/tex-archive/macros/latex/required/graphics/grfguide.ps>)

A number of width problems arise when LaTeX cannot properly hyphenate a line. Please give LaTeX hyphenation hints using the `\-` command.

## Acknowledgments

Use unnumbered third level headings for the acknowledgments. All acknowledgments go at the end of the paper. Do not include acknowledgments in the anonymized submission, only in the final paper.

## References

References follow the acknowledgments. Use unnumbered third level heading for the references. Any choice of citation style is acceptable as long as you are consistent. It is permissible to reduce the font size to ‘small’ (9-point) when listing the references. **Remember that this year you can use a ninth page as long as it contains *only* cited references.**

[1] Alexander, J.A. & Mozer, M.C. (1995) Template-based algorithms for connectionist rule extraction. In G. Tesauro, D. S. Touretzky and T.K. Leen (eds.), *Advances in Neural Information Processing Systems* 7, pp. 609-616. Cambridge, MA: MIT Press.

[2] Bower, J.M. & Beeman, D. (1995) *The Book of GENESIS: Exploring Realistic Neural Models with the GEneral NEural Simulation System*. New York: TELOS/Springer-Verlag.

[3] Hasselmo, M.E., Schnell, E. & Barkai, E. (1995) Dynamics of learning and recall at excitatory recurrent synapses and cholinergic modulation in rat hippocampal region CA3. *Journal of Neuroscience* **15**(7):5249-5262.