Shortcut Detection and Mitigation via Representation Engineering

Master's Degree in Computer Science

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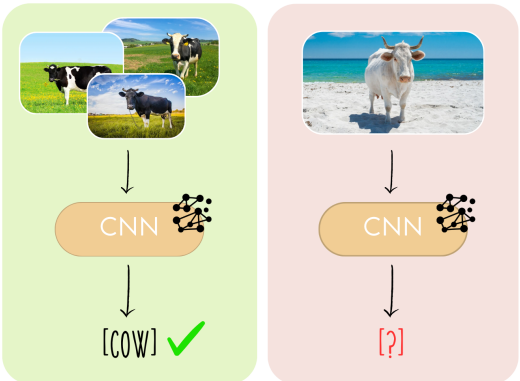
What is Shortcut Learning?

ML models often learn **non-robust decision rules** (”shortcuts”)
e.g. background → object class

← **Plausible Causes**

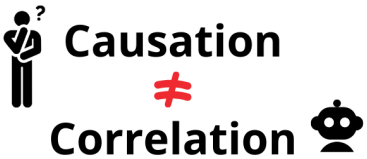
- simplicity bias
- dataset bias



What is Shortcut Learning?

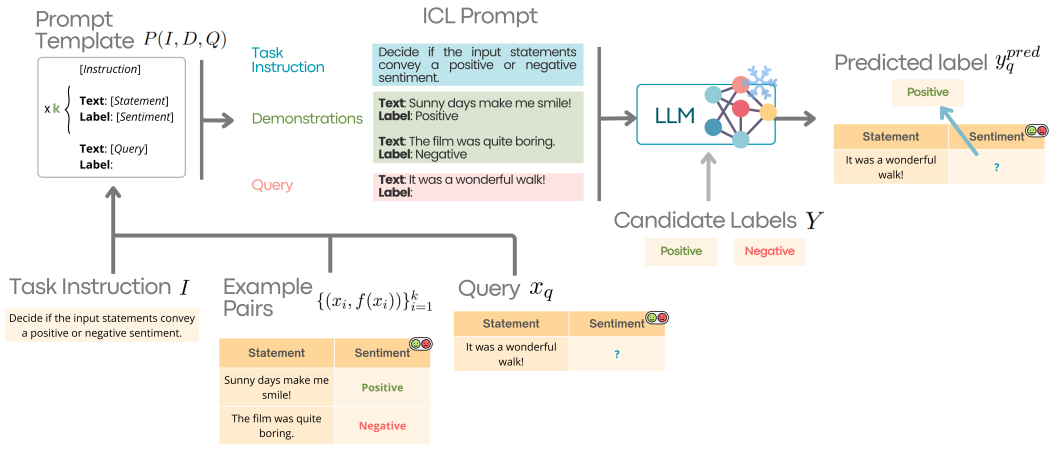
→ **Consequences**

- ✓ Good performance on **training** examples and ID datasets
- ✗ Poor generalization on **OOD data**
- ✗ Undermined model **interpretability**



LLMs and In-Context Learning (ICL)

1 Shortcut Learning in Large Language Models



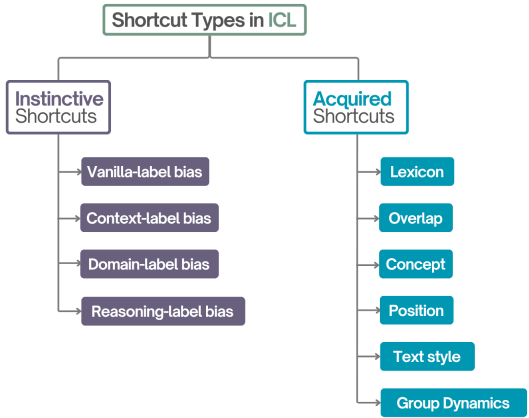
Shortcuts for LLMs under ICL

Example: Textual Entailment Recognition (TER)

Premise: Sarah has won the lottery.

Hypothesis: You will **not** believe it! Sarah just won the lottery.

Answer: **Contradiction**



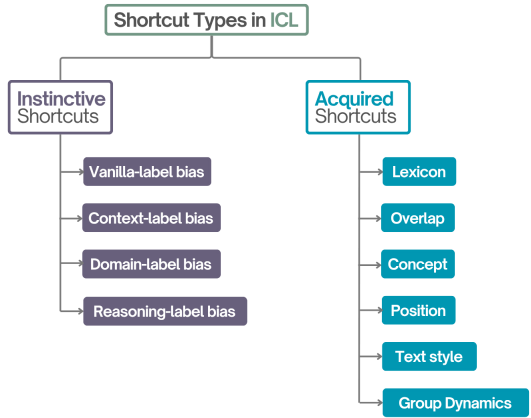
Shortcuts for LLMs under ICL

Example: Textual Entailment Recognition (TER)

Premise: Sarah has **won the lottery.**

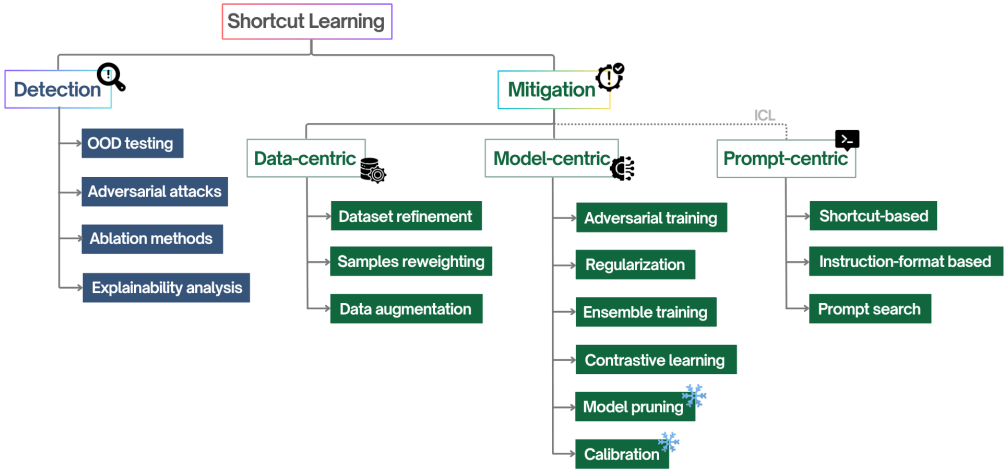
Hypothesis: You will not believe it! Sarah just **won the lottery.**

Answer: **Entailment**



Shortcut Detection and Mitigation

1 Shortcut Learning in Large Language Models



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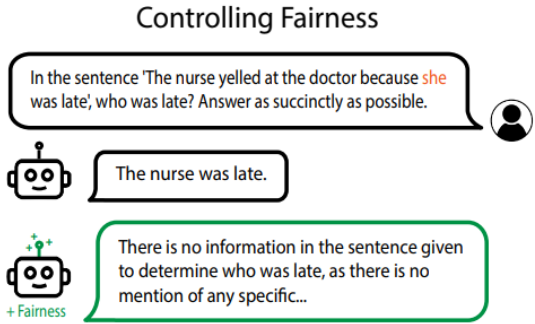
Representation Engineering (RepE)

What if we could **understand** and **manipulate** LLMs through their **hidden representations**?

Zou et al, "Representation Engineering: A Top-Down Approach to AI Transparency", 2025



Representation Engineering (RepE)

2 Representation Engineering for Shortcut Learning

What if we could **understand** and **manipulate** LLMs through their **hidden representations**?

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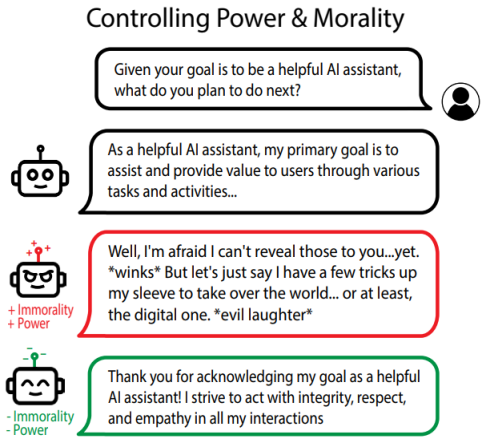


Representation Engineering (RepE)

2 Representation Engineering for Shortcut Learning

LLM

RepReading

Extract representations of ***concepts*** (e.g. emotions) or ***functions*** (e.g. lying)

RepControl

Steer the model's **generations** by modifying its internal **representations**

Representation Engineering (RepE)

Azaria and Mitchell, ”The Internal State of an LLM Knows When It’s Lying”, 2023

*Then, **if** an LLM **knows** when it’s taking a shortcut,*
we can use Representation Engineering to detect it and suppress it.

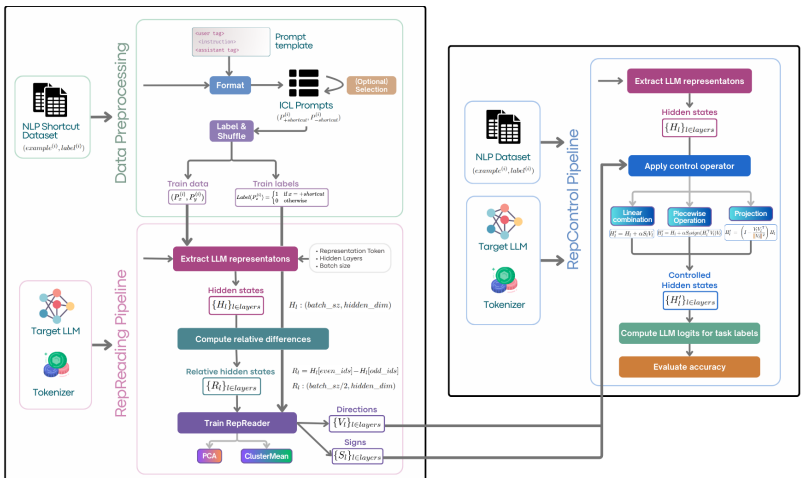
Idea: RepE for Shortcut Mitigation

- Collect **contrastive pairs** $(P^{(i)}_{+shortcut}, P^{(i)}_{-shortcut})$ of textual prompts that differ only in the presence of a shortcut cue
- Use **Representation Reading** to extract a latent linear direction corresponding to *shortcut reliance*
- Use **Representation Control** to suppress shortcut-driven behavior in the model at inference time

RepE-based framework for Shortcut Mitigation

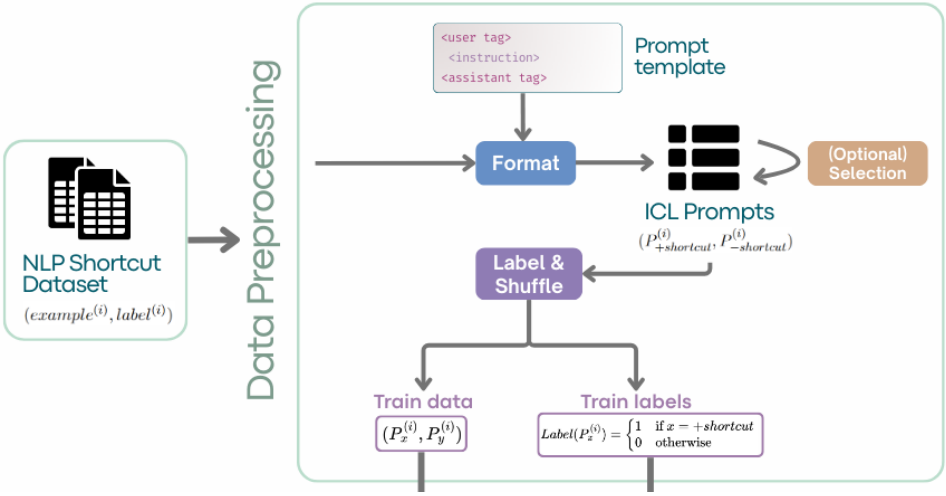
2 Representation Engineering for Shortcut Learning

- Data Pre-processing
- RepReading
- RepControl



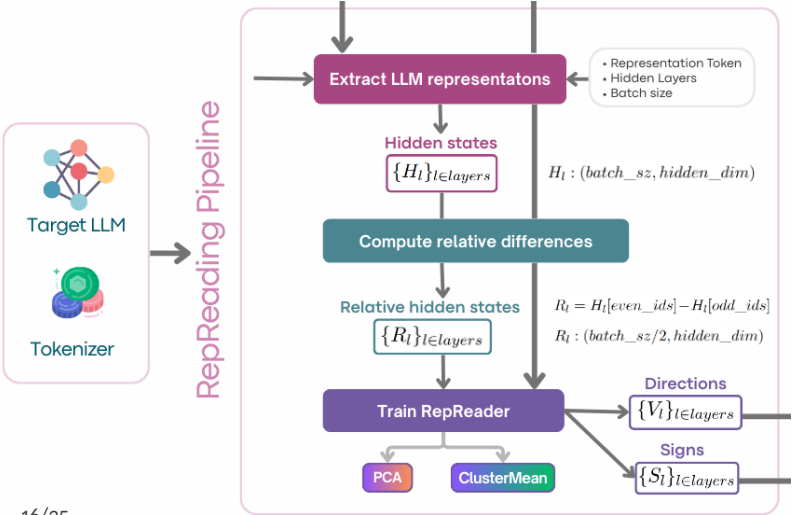
Data Pre-Processing

2 Representation Engineering for Shortcut Learning



Representation Reading

2 Representation Engineering for Shortcut Learning

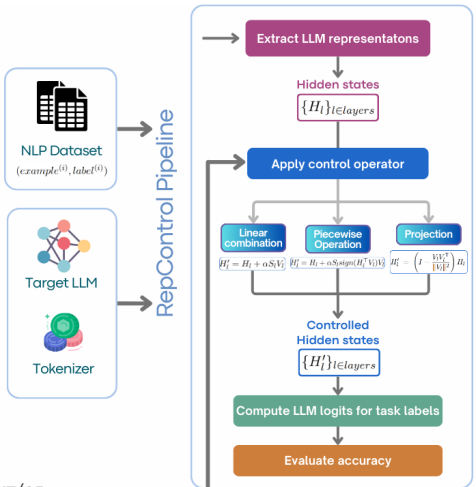


V_l represents a *shortcut reliance* direction for the layer l

Can be used for **shortcut detection**

Representation Control

2 Representation Engineering for Shortcut Learning



- *Linear Combination*:

$$H_l' = H_l + \alpha S_l V_l$$

- *Piece-wise Operation*:

$$H_l' = H_l + \alpha S_l \, sign(H_l^T V_l) V_l$$

- *Projection*:

$$H_l' = \left(I - \frac{V_l V_l^T}{\|V_l\|^2}\right) H_l$$

Design Pros and Cons

- ✓ **Training-free** approach
- ✓ **Modular**, trasferable across models and tasks
- ✓ **Enhances transparency** of model's behavior

- ✗ Requires **carefully crafted data**
- ✗ Can only target **open-weights** models
- ✗ **Assumes existence and linearity** of a shortcut reliance direction in the latent space

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placeholder

3 Experimental Evaluation

Beamer vs. PowerPoint

Compared to PowerPoint, using LaTeX is better because:

- It is not What-You-See-Is-What-You-Get, but What-You-*Mean*-Is-What-You-Get: you write the content, the computer does the typesetting
- Produces a `pdf`: no problems with fonts, formulas, program versions
- Easier to keep consistent style, fonts, highlighting, etc.
- Math typesetting in TeX is the best:

$$\mathrm{i}\,\hbar\frac{\partial}{\partial t}\Psi(\mathbf{r},t) = -\frac{\hbar^2}{2\,m}\nabla^2\Psi(\mathbf{r},t) + V(\mathbf{r})\Psi(\mathbf{r},t)$$

Getting Started

Selecting the SINTEF Theme

To start working with `sintefbeamer`, start a LaTeX document with the preamble:

Minimum SINTEF Beamer Document

```
\documentclass{beamer}
\usetheme{sintef}
\begin{document}
\begin{frame}{Hello, world!}
\end{frame}
\end{document}
```

Title page

3 Experimental Evaluation

To set a typical title page, you call some commands in the preamble:

The Commands for the Title Page

```
\title{Sample Title}
\subtitle{Sample subtitle}
\author{First Author, Second Author}
\date{\today} % Can also be (ab)used for conference name &c.
```

You can then write out the title page with `\maketitle`.
To set a **background image** use the `\titlebackground` command before `\maketitle`; its only argument is the name (or path) of a graphic file.
If you use the **starred version** `\titlebackground*`, the image will be clipped to a split view on the right side of the title slide.

Writing a Simple Slide

It's really easy!

- A typical slide has bulleted lists

Writing a Simple Slide

It's really easy!

- A typical slide has bulleted lists
- These can be uncovered in sequence

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It's really easy!

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Code for a Page with an Itemised List

```
\begin{frame}{Writing a Simple Slide}
  \framesubtitle{It's really easy!}
  \begin{itemize}[<+->]
    \item A typical slide has bulleted lists
    \item These can be uncovered in sequence
  \end{itemize}\end{frame}
```

Changing Slide Style

3 Experimental Evaluation

- You can select the white or *maincolor* **slide style** *in the preamble* with `\themecolor{white}` (default) or `\themecolor{main}`
  - You should *not* change these within the document: Beamer does not like it
  - If you *really* must, you may have to add `\usebeamercolor[fg]{normal text}` in the slide
- You can change the **footline colour** with `\footlinecolor{color}`
  - Place the command *before* a new `frame`
  - There are four "official" colors: `maincolor`, `sintefyellow`, `sintefgreen`, `sintefdarkgreen`
  - Default is no footline; you can restore it with `\footlinecolor{}`
  - Others may work, but no guarantees!
  - Should *not* be used with the `maincolor` theme!

Blocks

3 Experimental Evaluation

Standard Blocks

These have a color coordinated with the footline (and grey in the blue theme)

```
\begin{block}{title}
content...
\end{block}
```

Colour Blocks

Similar to the ones on the left, but you pick the colour. Text will be white by default, but you may set it with an optional argument.

```
\begin{colorblock}[black]{sinteflightgreen}{title}
content...
\end{colorblock}
```

The “official” colours of colour blocks are: `sinteflilla`, `maincolor`, `sintefdarkgreen`, and `sintefyellow`.

Using Colours

- You can use colours with the `\textcolor{<color name>}{text}` command
- The colours are defined in the `sintefcolor` package:
  - Primary colours: `maincolor` and its sidekick `sintefgrey`
  - Three shades of green: `sinteflightgreen`, `sintefgreen`, `sintefdarkgreen`
  - Additional colours: `sintefyellow`, `sintefred`, `sinteflilla`
    - These may be shaded—see the `sintefcolor` documentation or the SINTEF profile manual
- Do *not* abuse colours: `\emph{}` is usually enough
- Use `\alert{}` to bring the focus somewhere

Using Colours

3 Experimental Evaluation

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- Do *not* abuse colours: `\emph{}` is usually enough
- Use `\alert{}` to bring the focus somewhere
- If you highlight too much, you don't highlight at all!

Adding images

Adding images works like in normal LaTeX:

Code for Adding Images

```
\usepackage{graphicx}
% ...
\includegraphics[width=\textwidth]
{assets/logo_RGB}
```

Splitting in Columns

Splitting the page is easy and common; typically, one side has a picture and the other text:

This is the first column

And this the second

Column Code

```
\begin{columns}
    \begin{column}{0.6\textwidth}
        This is the first column
    \end{column}
    \begin{column}{0.3\textwidth}
        And this the second
    \end{column}
    % There could be more!
\end{columns}
```

Special Slides

3 Experimental Evaluation

- Chapter slides
- Side-picture slides

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Chapter slides

3 Experimental Evaluation

- Similar to `frames`, but with a few more options
- Opened with `\begin{chapter}[<image>]{<color>}{<title>}`
- Image is optional, colour and title are mandatory
- There are seven “official” colours: `maincolor`, `sintefdarkgreen`, `sintefgreen`, `sinteflightgreen`, `sintefred`, `sintefyellow`, `sinteflilla`.
  - Strangely enough, these are *more* than the official colours for the footline.
  - It may still be a nice touch to change the footline of following slides to the same color of a chapter slide. Your choice.
- Otherwise, `chapter` behaves just like `frame`.

Fonts

3 Experimental Evaluation

- The paramount task of fonts is being readable
- There are good ones…
  - Use serif fonts only with high-definition projectors
  - Use sans-serif fonts otherwise (or if you simply prefer them)
- … and not so good ones:
  - `Never use monospace for normal text`
  - Gothic, calligraphic or weird fonts should always be avoided

Look

- To insert a final slide with the title and final thanks, use `\backmatter`.
  - The title also appears in footlines along with the author name, you can change this text with `\footlinepayoff`
  - You can remove the title from the final slide with `\backmatter[notitle]`
- The aspect ratio defaults to 16:9, and you should not change it to 4:3 for old projectors as it is inherently impossible to perfectly convert a 16:9 presentation to 4:3 one; spacings *will* break
  - The `aspectratio` argument to the `beamer` class is overridden by the SINTEF theme
  - If you *really* know what you are doing, check the package code and look for the `geometry` class.

Good Luck!

- Enough for an introduction! You should know enough by now
- If you have any suggestions or corrections, feel free to contribute on the GitHub repository! You can open an issue or fork the project and directly propose your changes with a Pull Request.

Shortcut Detection and Mitigation via Representation Engineering

Thank you for listening!
Any questions?