Probability and Forensic Science
Overview

• In this presentation we are going to introduce some basic probability concepts
• We will focus only on those ideas you will need to appreciate the fingerprint probability software
What is Probability?

- In any forensic science investigation we need to deal with uncertainty
- How likely is it that the recovered trace came from the suggested source?
  - Fibres from a coat
  - Paint on a jacket
  - Hair from an individual
What is Probability?

- We need a way of assessing the likelihood of a specific event
- Given the use to which our assessment is being put, it is desirable that our assessment is not wholly based on intuition
- Is there a way in which we can do this?
What is Probability?

- Science of statistics refers to two distinct but linked areas of knowledge
  - Counts, analysis of events, etc.
  - Examination of uncertainty
- We are interested in the second of these
What is Probability?

• We can define two types of probability
  • Aleatory: deduce from observation of a system
    • Ideal
  • Epistemic: induce from observation of a system
    • Real
What is Probability?

- **Deduction**
  - Conclusion from stated premises: from the general to the specific

- **Induction**
  - Deriving general principles from facts or instances: specific to the general
What is Probability?

- Probability is a branch of mathematics and therefore mathematical language is used.
- Here we are going to simplify the ideas.
  - We will keep the use of mathematical nomenclature and formulae to the minimum.
What is Probability?

- “First Law of Probability”
  - Probability \((Pr)\) can take any value between 0 and 1
    - Where 1 = certainty
    - Where 0 = impossible
What is Probability?

• We can think of probabilities as odds
  – 1/10
  – 1/1000
  – 2/3
• Which is the same as
  – 0.1
  – 0.001
  – 0.67
What is Probability?

- “Second law of probability”
  - The sum of the probabilities of mutually exclusive events equals 1
What is Probability?

- **Real** probabilities are induced by observation
- **Realist** interpretation is concerned with frequencies and numbers of outcomes
What is Probability?

- Let’s think about the rolling of a die
- What is the probability of rolling a 6 with one die?
  - 1/6
- How did we calculate this?
What is Probability?

Number of events being considered

Number of possible events
**What is Probability?**

- To calculate this probability we have made an **assumption**
- We have accepted the die to be **fair**
- This is unlikely to be the case in the real world
- We have created a simple **model**
What is Probability?

- Of course any assumptions we make will affect our assessment of the probability
- If our assumptions are wrong then our outcome will be wrong
What is Probability?

- What about rolling a 6 on each on two fair dice?
  - 1/36
- How did we arrive at this?
- Did we make any assumptions?
What is Probability?

- Multiplied the odds for each event
- Assumed that one die does not influence the other; the events are independent
What is Probability?

• How about tossing a coin?
• How likely is it to toss a head with one coin?
  – \( \frac{1}{2} \)
• Again we assume the coin is fair
• We have created a model
What is Probability?

• How accurate are models?
• If the coin model is accurate, we would expect to see the distribution of outcomes predicted in the long run
• Comte de Buffon, Karl Pearson and John Kerrich
  – Close to ½ with approximately 4000, 24,000 and 10,000 throws, respectively
What is Probability?

- In forensic science we are generally concerned with the likelihood of one specific event.
- Is it possible to speak of the probability of a single event?
What is Probability?

- Consider our answer to rolling a 6 with a single die
- There is no physical state of affairs which corresponds to a probability of 1/6 for a single event
  - It either happens or it doesn’t!
What is Probability?

• To quantify a probability for a single event it needs to be conceived of as a product of the mind
• This has been called subjective probability\(^1\)

\(^1\) O’Hagan 2004
What is Probability?

- Subjective Probability is informed by
  - Empirical observations
  - Beliefs
- We need to be careful of the word subjective because we are not implying that the probability is unfounded
What is Probability?

- What is the probability it will rain tomorrow?
- How might we arrive at that decision?
  - Weather today, yesterday, this week, etc.
  - Month
  - Season
  - Last year
  - Etc.
What is Probability?

• For each of these factors we can make a statement:
  – If rained yesterday, it always rains in April
  – Etc.
What is Probability?

• Given the use of forensic science, this has some limitations
  – How do we get consistency?
  – How do we get reproducibility?
• What if we assign numerical probability to each of these pieces of information?
What is Probability?

- A way of doing this is to consider two competing propositions for a particular event and then assess the probability of the observations in each case
- We can then calculate a Likelihood Ratio (LR)
What is Probability?

- In forensic science we can frame propositions like these to consider trace evidence:
  - What is the probability of the observations we have made (E) if the prosecution hypothesis \((H_p)\) is correct and the suspect did leave the trace?
  - What is the probability of the observations we have made (E) if the defense hypothesis \((H_d)\) is correct and the trace was left by a random other person?
What is Probability?

- In mathematical language the Likelihood Ratio (LR) is:

\[ LR = \frac{Pr(E|H_p)}{Pr(E|H_d)} \]
What is Probability?

- Let’s assume that the probability of making one particular observation if the prosecution hypothesis ($H_p$) is correct is 0.9
- Therefore, the probability of making the same observation if $H_d$ is true is 0.1
- What is the LR?
What is Probability?

- LR = 9
- A LR which is greater than 1 indicates that the observations are more likely if $H_p$ is true than $H_d$
What is Probability?

- Now let’s assume that the probability of making one particular observation if the prosecution hypothesis $H_p$ is correct is 0.5
- Therefore, the probability of making the same observation if $H_d$ is true is 0.5
- What is the LR?
What is Probability?

- LR = 1
  - This means the evidence is of no assistance
  - It is equally likely to make the observations in each case
What is Probability?

- Finally, if the probability of the observations in the case of $H_p$ is 0.2
- And $H_d$ is 0.8
- What is the LR?
**What is Probability?**

- LR = 0.25
- A LR which is less than 1 indicates that the observations are more likely if $H_d$ is true than $H_p$
What is Probability?

- The greater the LR, the greater the support for the prosecution proposition
- If the LR is 1 then the examination is of no assistance
- If the LR is less than 1 then it supports the defense proposition
What is Probability?

- We can articulate LR as numbers, through graphs or diagrams, or by relating to a verbal scale.
- Each of these approaches has benefits and issues.
- In this workshop we will use a verbal scale such as this:
### What is Probability?

<table>
<thead>
<tr>
<th>LR</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;10^6</td>
<td>Extremely strong</td>
</tr>
<tr>
<td>10^5 - 10^6</td>
<td>Very Strong</td>
</tr>
<tr>
<td>10^3 - 10^5</td>
<td>Strong</td>
</tr>
<tr>
<td>10^2 - 10^3</td>
<td>Moderate</td>
</tr>
<tr>
<td>&gt;1 - 10^2</td>
<td>Limited</td>
</tr>
</tbody>
</table>
What is Probability?

- Let’s consider a very simple example to explain these numbers
What is Probability?

- Let’s evaluate the probability of observing a correspondence if $H_p$ is true as 0.99999999
- Therefore, the probability for $H_d$ is 0.00000001
What is Probability?

\[
LR \text{ for this scenario} = \frac{0.99999999}{0.00000001} = 9.9 \times 10^7
\]
What is Probability?

- Referring to our verbal scale, we would call this extremely strong evidence
What is Probability?

• Why use a LR?
  – It provides a versatile and simple measure
  – It allows evidence to be combined and evaluated

• Bayes Theorem
What is Probability?

- Posterior odds of C = likelihood ratio of the evidence (E) x prior odds of C
- What you want to know = what you calculate x what you already know
What is Probability?

- In the next sessions we will take these ideas and see how we can apply them to fingerprint examination
Questions?
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