Probabilistic forecasting: 
The example of weather forecasts

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23 September 2013
INTERNATIONAL YEAR OF STATISTICS
RECOGNIZING THE CONTRIBUTIONS OF STATISTICS TO SOCIETIES WORLDWIDE
http://statistics2013.org
300 years ago...
Ars Conjectandi

🔹 Jacob Bernoulli, 1655–1705.
🔹 Work on Ars Conjectandi from 1684–1689, published 1713.
🔹 Transferred the mathematics of games of chance to probabilities of real world events.

*Probability is a degree of certainty, and differs from certainty as a part from the whole.*

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- Kaplan-Meier Estimator improves drug trials, saving countless lives.
- Multicenter AIDS trials improve patient outcomes.
- Spatial statistics and epidemiology improve response to foot-and-mouth disease.
- Statisticians are involved in complex studies that advance understanding of migration patterns.
- Statistical thinking and methods play a pivotal role in quality improvement and resurgence of the economy.
- Transport infrastructure is improved based on statistical models of people flow.
- Transportation and methodologies advance scientific understanding.
- Improved tracking of disease rates through better statistical models.
- Statistics help reduce antibiotic over-consumption.
- Census data are collected and analyzed, allowing effective national and local policy decisions.
- Statistics help feed the world by identifying new crop varieties in breeding experiments.
- Tailored statistics are helping people in the ongoing recovery after the 2011 Christchurch earthquake.
- Statistics help catch drug cheats at the 27th Olympic Games.
- Statistics help with planning for new criminal justice system.
- Statistics help in the search for effective treatments for multiple sclerosis.
- Statistics help in the planning of efficient recycling systems.
- Statistics help in systematic synthesis of evidence that improves treatments for heart conditions.
- Statistics help identify and save endangered species.
- Statistics help in the planning of efficient recycling systems.
- Quick counting by panel of statisticians changes electoral culture in Mexico.
- Scientists use state-space models to understand marine animal movements.
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Without Statistics we wouldn't know how to dress for the weather.
Probabilistic weather forecasts

- The weather forecast of Tagesanzeiger for Bern today at 15:00 stated this morning at 6:52 that
  the temperature will be 20°C,
  and there is a 0% chance of rain.

- There is a conceptual difference between these two forecasts:
  - The temperature forecast is a point forecast.
  - The “chance of rain” forecast is a probabilistic forecast.
Probabilistic forecasts

J. Bernoulli, Ars Conjectandi:

We define the art of conjecture, or stochastic art, as the art of evaluating as exactly as possible the probabilities of things, so that in our judgments and actions we can always base ourselves on what has been found to be the best, the most appropriate, the most certain, the best advised; this is the only object of the wisdom of the philosopher and the prudence of the statesman.

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Saying that forecasts should incorporate uncertainty is like saying that governments should reduce waistful spending.
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A probabilistic forecast for temperature could be: We predict that the temperature today at 15:00 will be distributed according to \( \mathcal{N}(20, \sigma^2) \).
Forecasts for real-valued quantities
80 years ago...
Prediction spaces

- Let $\Omega$ denote the set of states of nature.
- Encode today’s information for prediction by a $\sigma$-Algebra $\mathcal{A}$.
- Consider, both, the probabilistic forecasts $F$ and the future event $Y$ as random variables on $\Omega$, where $F$ only depends on $\mathcal{A}$.

Now, we can do statistics!
Calibration

It the observation $Y$ has (continuous) distribution function $F$ then

$$F(Y) \sim UNIF(0, 1).$$

This can be checked empirically with PIT histograms.

Quality rankings of probabilistic forecasts can be done using proper scoring rules.
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Ensemble methods
Wind vector predictions

- Probabilistic forecasts of surface wind vectors over the North American Pacific Northwest based on the University of Washington Mesoscale Ensemble.
- Test data of year 2008 with 19,282 forecast-observations pairs at a prediction horizon of 48 hours.
- Forecasts to compare:
  - Raw ensemble forecast (8 ensemble members).
  - Statistically postprocessed regional bivariate EMOS forecast (Schuhen et al., 2012).
  - Independent EMOS forecast.
Results for wind vectors

Applications and challenges

- Statistical postprocessing of ensemble forecasts
- Interpretation of ensemble forecasts
- Combination of forecasts
- Multivariate forecasts
- Climate predictions
- Probabilistic forecasts for inflation, GDP growth, ...
- Uncertainty in risk assessment
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Current activities

- Interpretation of predictive probabilities
  Workshop on Probabilistic Modeling in Science and Philosophy
  11-12 October 2013, Bern

- Uncertainty in risk assessment
  Symposium on Uncertainty: from Insight to Action
  20–22 November 2013, EPF Lausanne

- Precipitation models
  group of Professor Hans Rudolf Künsch at ETH Zürich
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Communication of probabilistic forecasts

- Is it possible to communicate probabilistic forecasts to decision makers or the general public?
- Example concerning the general public:
  
  There is a 30% chance of rain tomorrow.
Communication of probabilistic forecasts

![Bar chart showing percentage of first choices for city forecasts](chart.png)

**Fig. 1.** First choice. People in New York \((n = 103)\), Amsterdam \((n = 117)\), Berlin \((n = 219)\), Milan \((n = 203)\), and Athens \((n = 108)\) were asked what the statement “There is a 30% chance of rain tomorrow” refers to. The three alternatives were “It will rain tomorrow for 30% of the time,” “in 30% of the region,” and “on 30% of the days like tomorrow.”

See Gigerenzer et al. (2005), Risk Analysis 25, 623–629.
We [statisticians] all have experienced the fascination and joy that the analysis of chance, data and uncertainty brings. We are aware of the astonishing achievements that have been made in our field and of the impact and importance it has on our society. We are also convinced that our field can contribute much to solve the challenges that we currently face. However, not all of this is recognized in other scientific areas and among the general public. In particular, statistics is still too often viewed as a dull, marginal or dubious activity with a potential for manipulation and distortion. Hence the International Year of Statistics gives us a platform to reach out and present a more accurate view of our field.

IMS President, Hans Rudolf Künsch
Thank you for your attention!