量測不確定度基礎篇
基本概念與重要性

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2019.03.31

課程內容

一. 量測定義
二. 量測不確定度的來源
三. 量測不確定度的評估方法

何謂量測？

影片中的主角是否進行量測？(1)

影片中的主角是否進行量測？(2)

何謂量測？

- 量測描述了”某物”的”量之性質”，必須包含以下要件：
  - 量測目標
  - 量測工具 (尺、量筒、溫度計...等)
  - 數字
  - 單位 (公制單位、英制單位、其他公定單位)

International System of Units (SI)

SI Base Units

Base Quantity	Name	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

SI Derived Units

Derived Quantity	Name	Symbol	Equivalent SI units
Frequency	hertz	Hz	s^{-1}
Force	newton	N	$m \cdot kg \cdot s^{-2}$
Pressure	pascal	Pa	N/m^2
Energy	joule	J	N·m
Power	watt	W	J/s
Electric charge	coulomb	C	s·A
Electric potential	volt	V	W/A
Electric resistance	ohm	Ω	V/A
Celsius temperature	degree Celsius	°C	K*

*Unit degree Celcius is equal in magnitude to unit kelvin.

SI Prefixes

Factor	Name	Symbol	Numerical Value
10^{12}	tera	T	1 000 000 000 000
10^{9}	giga	G	1 000 000 000
10^{6}	mega	M	1 000 000
10^{3}	kilo	k	1 000
10^{2}	hecto	h	100
10^{1}	deka	da	10
10^{-1}	deci	d	0.1
10^{-2}	centi	c	0.01
10^{-3}	milli	m	0.001
10^{-6}	micro	μ	0.000 001
10^{-9}	nano	n	0.000 000 001
10^{-12}	pico	p	0.000 000 000 001

• Adapted from NIST Special Publication 811
• SI rules and style conventions recommend using spaces rather than commas to separate groups of three digits.

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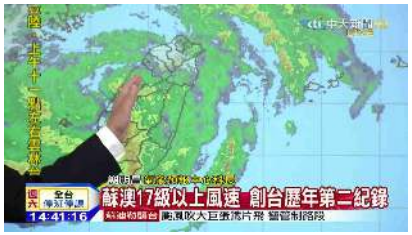
練習：以下敘述/例子為量測結果？

- 小琪對萱萱說：我比妳高一個頭。

- 賀伯颱風風速最高達17級。



- 農夫：這隻狗有40斤重。

- 我看到了3隻貓。

- 農夫：這隻狗有40斤重。

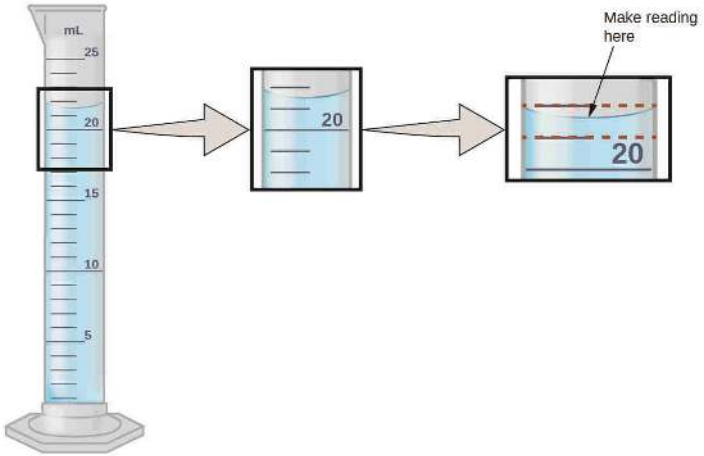
- 我看到了3隻貓。

- 埃及法老王拉美西斯金字塔的寬度為法老王前臂的5000倍長。

什麼不是量測？

- 相互比較
  - 描述為A比B來得(高/重/大/厚....)
  - 比較級
- 目視計數
- 定性結果
  - 是/否、陽/陰、成功/失敗

量測時的不確定性？



https://opentextbc.ca/chemistry/chapter/measurement-uncertainty-accuracy-and-precision/

小威某一天突然頭痛...

Dr. A: 住院

Dr. B: 心理作用

Dr. C

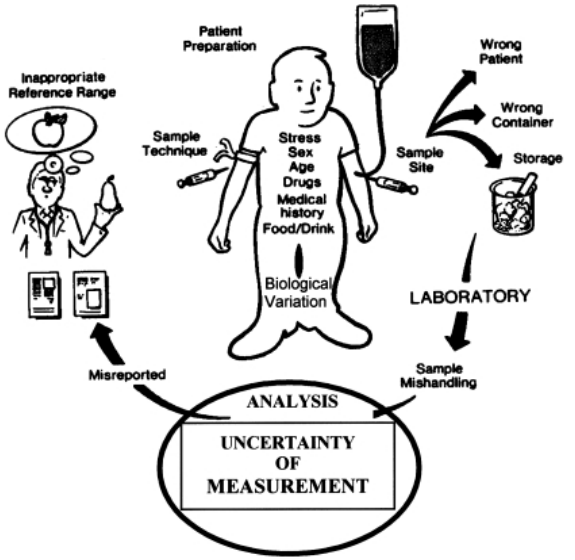
為了降低量測錯誤風險，只好...

'Measure thrice, cut once'. You can reduce the risk of making a mistake by checking the measurement a second or third time.

產生量測不確定性的來源

- ISO 15189, 5.6.2: Sources that contribute to uncertainty may include:
  - Sampling
  - Sample preparation
  - Sample portion selection
  - Calibrators
  - Reference materials
  - Input quantities
  - Equipment used
  - Environmental conditions
  - Condition of the sample
  - Changes of operator

檢驗結果的不確定性源自於...



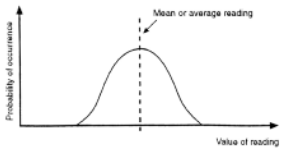
什麼是量測不確定度?

- ISO 15189, 3.17:
  - The uncertainty of measurement is a parameter associated with the result of a measurement, that characterizes the dispersion of the values that could be reasonably attributed to the measurand.

SD　　CV(%)

量測不確定度評估方法

- Type A:
  - 藉由統計資料(重複的測試)
- Type B:
  - 藉由非統計資料
    - 量測經驗
    - 校正資訊
    - 廠商說明書
    - 文獻資訊
    - 一般常識



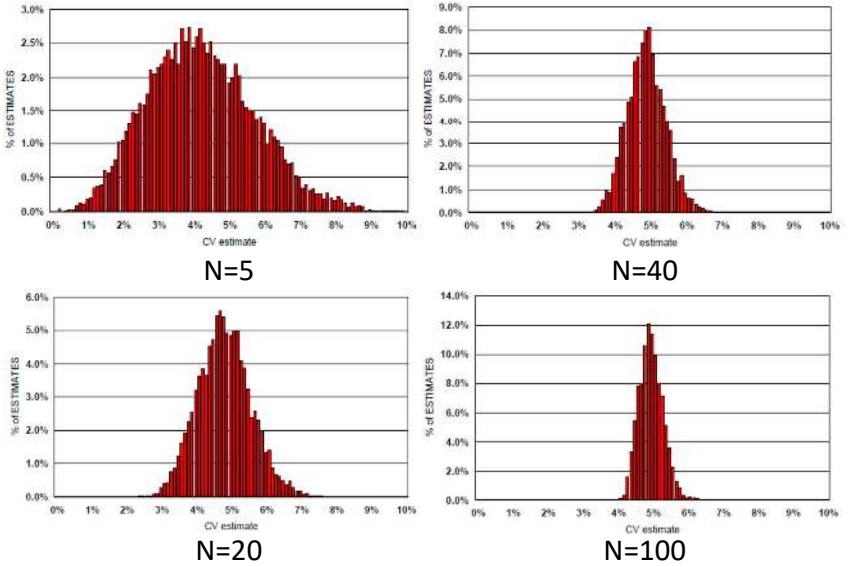
Type A估計法

平均值 $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$

標準差 $s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$ ➡ 標準不確定度(u)

變異係數 $CV = \frac{s}{\bar{x}} * 100\%$ ➡ 相對不確定度(u_{rel})

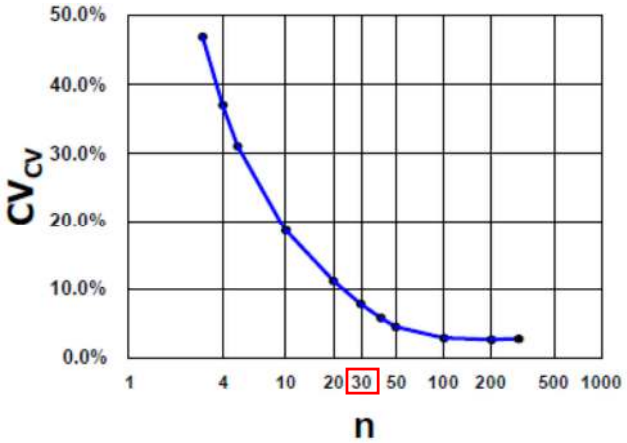
CV=5%的群體於不同N的估計值



N=5　N=40

N=20　N=100

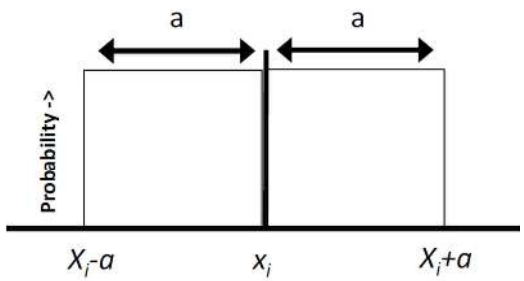
估計CV值建議採用N大於30筆資料



Type B估計法 (其他分布類型)

- Rectangular distribution (長方分布)
  - 無多餘分布資訊時適用
- Triangular distribution (三角分布)
- U distribution (U型分布)

長方分布估計法



X_i, the expected value, lies in the middle of an interval of range 2a.

$$u_R = \frac{a}{\sqrt{3}}$$

三角分布估計法

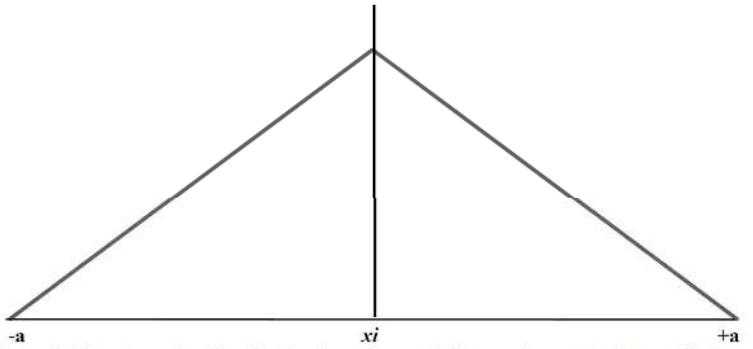


Figure 3. The triangular distribution is used to model cases where containment limits are known and values are more likely to be near the mean than at the extremes.

$$u_T = \frac{a}{\sqrt{6}}$$

U型分布估計法

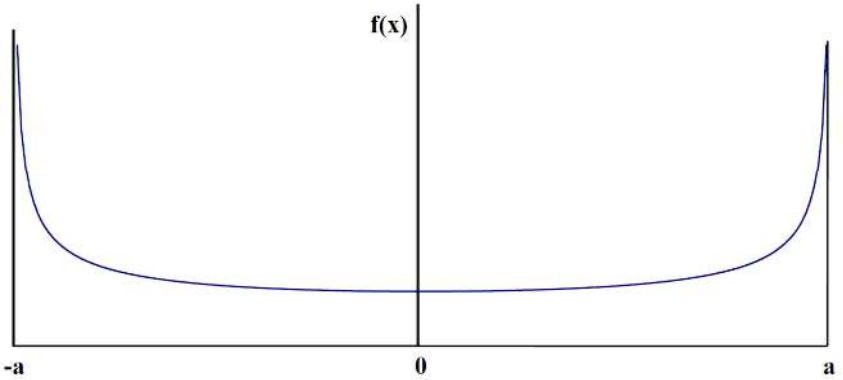


Figure 4. The U distribution models cases where the value of a measurand is likely to be near the containment limits.

$$u_U = \frac{a}{\sqrt{2}}$$

量測不確定度的計算

- Standard uncertainty標準不確定度: (u)
  - Standard deviation (s) 標準差
  - Coefficient of variance (CV) 變異係數
- Combined (standard) uncertainty: (u_c)
- Expanded uncertainty: (U)

量測不確定度的計算

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  - Coefficient of variance (CV) 變異係數
- Combined (standard) uncertainty: (u_c)
  - 組合(標準)不確定度
  - The “sum” of the known standard deviations/CV
- Expanded uncertainty: (U)

組合不確定度計算方式(1)

- 應用類型：(加/減)
  - R = X + Y
  - R = X – Y
- 計算方式：
  - $(SD_R)^2 = (SD_X)^2 + (SD_Y)^2$
- u_c以SD表示

組合不確定度計算計算實例(1)-anion gap

Calculation of anion gap	$(Na + K) - (Cl + HCO_3)$
Patient X	Na: 137; K: 4.0; Cl: 106; HCO_3: 10 (mmol/L) AG = 25 mmol/L
MU of AG calculated as square root of sum of squares of MUs of contributing results.	$u_{AG} = (u_{Na}^2 + u_K^2 + u_{Cl}^2 + u_{HCO3}^2)^{1/2}$
Calculation of AG uses addition and subtraction; hence, calculate u_{AG} using SDs.	$SD_{Na} = 1.48$ mmol/L; $SD_K = 0.04$ mmol/L; $SD_{Cl} = 0.72$ mmol/L; $SD_{HCO3} = 0.84$ mmol/L
Combining u_{Na}, u_K, u_{Cl}, u_{HCO3}	$u_{AG} = (1.48^2 + 0.04^2 + 0.72^2 + 0.84^2)^{1/2} = 1.85$ mmol/L
Coverage factor $k = 2$.	$U_{AG} = 3.7$ mmol/L (95% coverage probability)
Result rounded for clinical use.	$u_{AG} = 4$ mmol/L
Patient result.	AG = 25 ± 4 mmol/L (95% coverage probability)

組合不確定度計算方式(2)

- 應用類型：
  - R = X × Y
  - R = X / Y
- 計算方式：
  - $(SD_R/R)^2 = (SD_X/X)^2 + (SD_Y/Y)^2$
  - $CV_R^2 = CV_X^2 + CV_Y^2$
- u_c (u_{rel})先以CV表示，最後要與結果值相乘轉變為SD。

組合不確定度計算計算實例(2)-creatinine廓清速率

Calculation of creatinine clearance (Cl_{cr})	$\frac{\text{Urine creatinine (µmol/L) x Urine volume (mL)}}{\text{Plasma creatinine (µmol/L) x Collection time (min)}}$
Results for 68-year-old woman.	Plasma creatinine: 92 µmol/L, SD: 2.26 (QC), CV: 0.0246 Urine creatinine: 2560 µmol/L, SD: 340 (QC), CV: 0.1328 Urine volume 2683 mL, SD: 25 (estimate), CV: 0.0093 Collection time: 24 h (1440 min), SD: 30 (estimate), CV: 0.0208
Creatinine clearance.	$\frac{2560 \times 2683}{92 \times 1440} = 51.8$ mL/min
MU of Cl_{cr} calculated as square root of sum of squares of MUs of contributing results.	$u_{CrCl} = (u^2_{UCreat} + u^2_{UVol} + u^2_{PCreat} + u^2_{Time})^{1/2}$
Creatinine clearance calculated using division and multiplication; therefore must calculate u_{CrCl} using CVs.	$CV_{CrCl} = (CV^2_{UCreat} + CV^2_{UVol} + CV^2_{PCreat} + CV^2_{Time})^{1/2}$ $= (0.0246^2 + 0.1328^2 + 0.0093^2 + 0.0208^2)^{1/2} = 0.137$
SD = measurement result x CV.	SD = 51.8 mL/min x 0.137 = 7.096 mL/min = u_{CrCl}
Coverage factor $k = 2$.	$U_{CrCl} = 14.192$ mL/min
Result rounded for clinical use.	$U_{CrCl} = 14.2$ mL/min
Patient result.	51.8 ± 14.2 mL/min (95% coverage probability)

量測不確定度的計算

- Standard uncertainty: (u)
  - Standard deviation
- Combined (standard) uncertainty: (u_c)
  - The "sum" of the known standard deviations
- Expanded uncertainty: (U)
  - 擴充不確定度
  - The confidence limits around a result

擴充不確定度(*U*)計算

- Coverage factor (k): 擴充係數
  - The number of SD's for the confidence limit
- 計算方式
  - $U = u_c \times k$
- k值最常使用2 (或是1.96)
  - $k = 1$ 68.27% confidence
  - $k = 1.96$ 95% confidence
  - $k = 2$ 95.44% confidence
  - $k = 2.58$ 99% confidence

報告格式

- ISO 15189, 5.8.3:
  - Uncertainty of measurement should be provided upon request.
- 檢驗結果(y)、擴充不確定度(*U*)
  - 報告呈現: $y \pm U = y \pm k \times u_c$
  - TAF文件有關量測不確定度之政策(TAF-CNLA-R06)直接要求$k = 2$

數值處理原則

- 使用輔助工具(計算機、EXCEL等)幫助計算
- 位數多的時候，使用科學記號
- 計算開始前，先將各數值的單位轉換成可以進行計算的單位
  - 單位一致化
- 以四捨五入處理數值時，計算至最後一步驟再四捨五入，避免在中間過程就先行四捨五入。
  - 2.345→2.35→2.4
- 通常，不確定度僅需保留一位有效位數即可
- 不確定度與結果值小數點位數必須相同

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已經知道怎麼估計、表示量測不確定度了，接下來呢？

趨勢面-關於量測不確定論文數

Review

Measurement uncertainty: Friend or foe?

Ilenia Infusino*, Mauro Panteghini

Research Centre for Metrological Traceability in Laboratory Medicine (CIRME), University of Milan, Milano, Italy

Clinical Biochemistry 57 (2018) 3–6

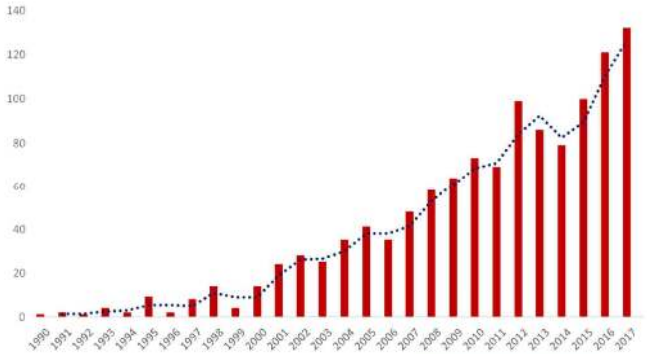


Fig. 1. Number of hits retrieved from PubMed using the key word 'Measurement Uncertainty' [www.ncbi.nlm.nih.gov/pubmed (Accessed December 2017)].

法規面-ISO的實驗室要求

- ISO 15189, 5.6.2 (2003)
  - The laboratory shall determine the uncertainty of results, where relevant and possible.
- ISO 17025, 5.4.6.2 (1999)
  - Testing laboratories shall have and shall apply procedures for estimating uncertainty of measurement.

需求面-符合實驗室與臨床的要求

Review

What information on measurement uncertainty should be communicated to clinicians, and how?

Mario Plebani*, Laura Sciacovelli, Daniela Bernardi, Ada Aita, Giorgia Antonelli, Andrea Padoan

Department of Laboratory Medicine, University Hospital of Padova, Via Giustiniani 2, 35128 Padova, Italy

Clinical Biochemistry 57 (2018) 18–22

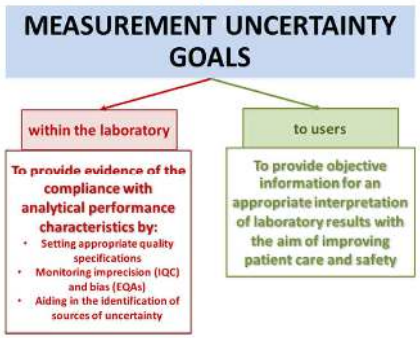
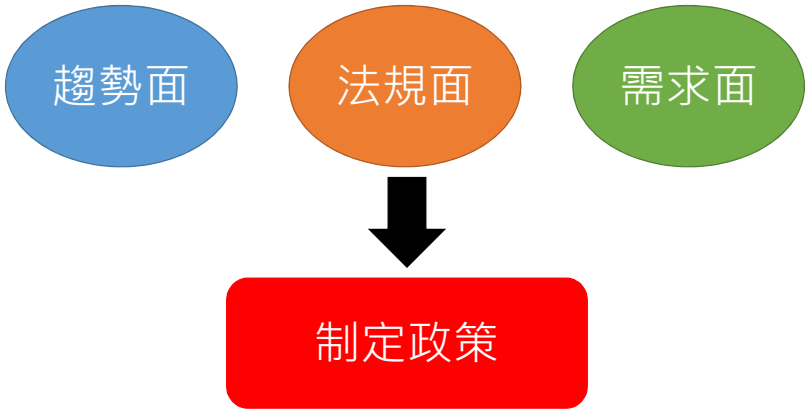


Fig. 1. Summary of the main goals of measurement uncertainty.

已經知道怎麼估計、表示量測不確定度了，接下來呢？



第一階段
課程結束