Distribution Functions for Measures of Lateral Placental Growth

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Outline of presentation

- Random Growth Processes
- Simple random walk and connection to probability densities
- Quantifying placental shapes
- Distributions
- Links to clinical data

Random Growth Processes

What affects placental growth?

Uterine environment, genetics

Is placental growth random?

Blood vessel structure
Umbilical cord insertion location
Huge variation in morphology

Can we learn anything about the processes involved in placental growth?

Example - Why is height Normally distributed?

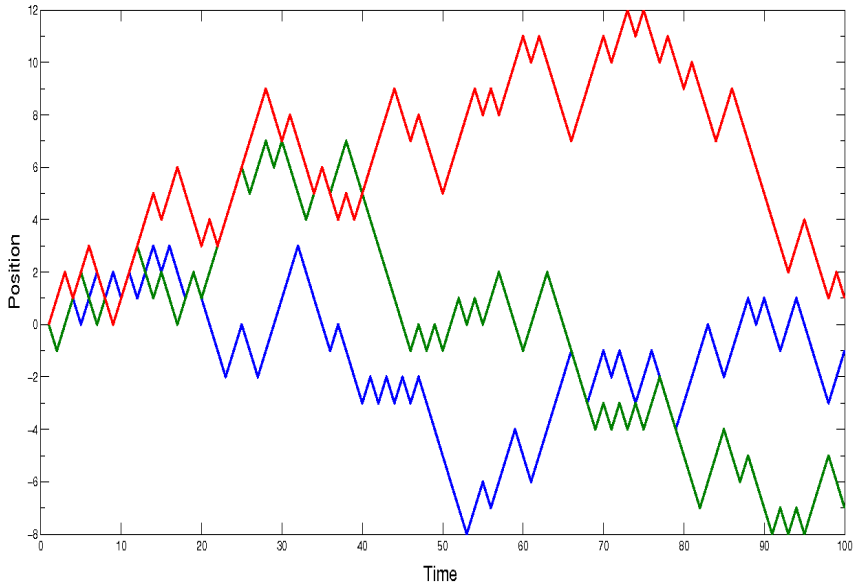
A normal distribution suggests a large number of independent random variables.
But height is strongly correlated to parents' height – a small number of variables?

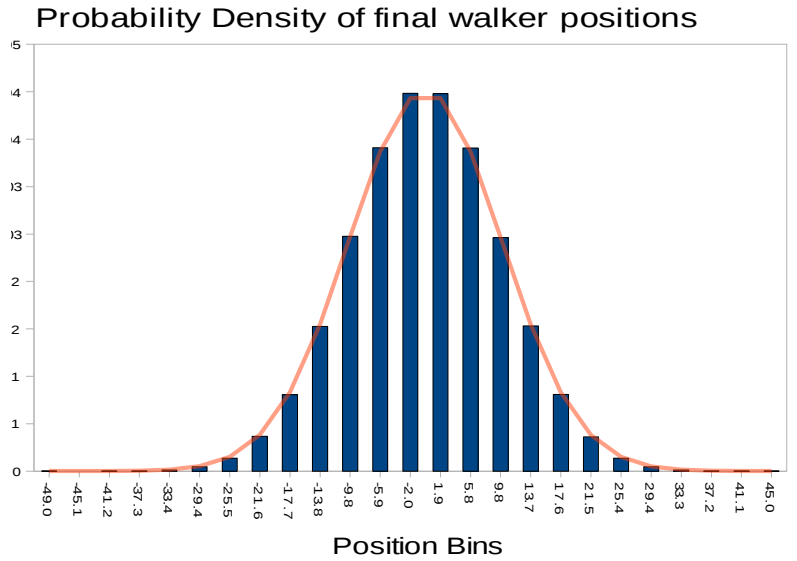
Analysis of the presence of a Normal distribution led to 'Multiple Gene Hypothesis' for height

Simple random growth processes

1-Dimensional Random walk:

In each time step, the walker can move up or down by one step. Both step directions are equally likely at all times:





Repeat the walk many times

The probability density of final positions is Normal

The final position of each journey is a sum of independent factors (the steps), hence the final distribution is Normal

- So distributions can imply things about the growth processes involved

Shape measures

Can we measure something on a placenta that is analogous to the final position of a random walk?

The perimeter shape (Chorionic plate perimeter) is the culmination of placental growth processes. However, to analyse any distributions the shape must be quantified.

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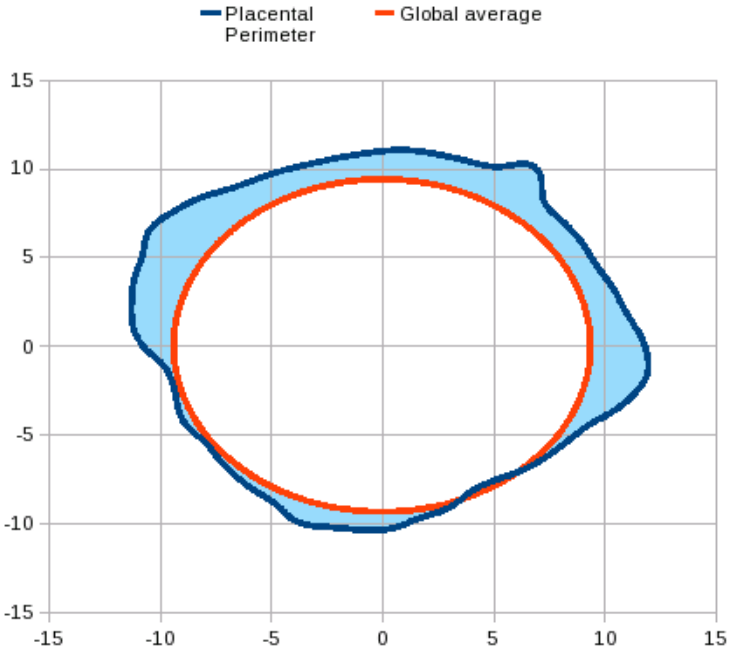
Roughness

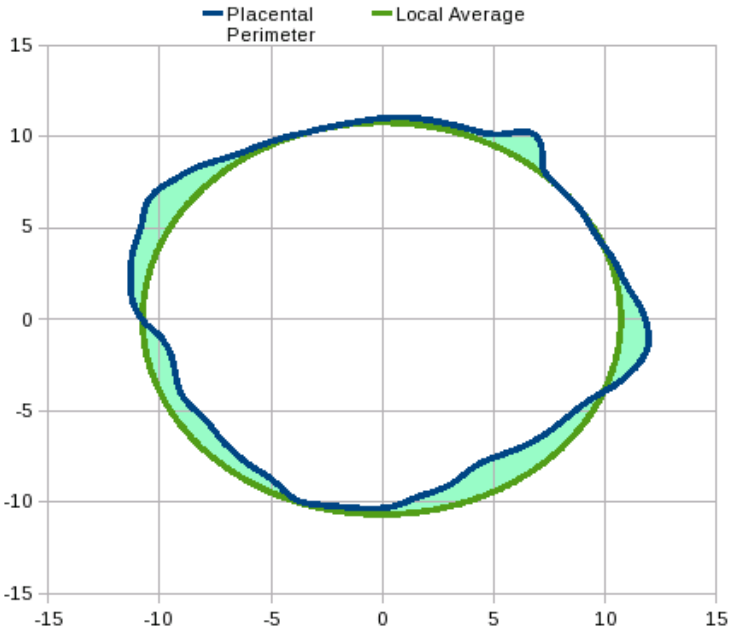
Normalised sum of root-mean-squared deviations of the perimeter from a constant value.

This constant value can be the average radius of all the placentas (giving Global Roughness)



Global roughness is a measure of shape and size compared to the 'average' placenta – which we found to be **circular**

or the average radius of an individual placenta (giving Local Roughness)



Local roughness is a measure of how a shape deviates from circularity

Shape measures

Another measure of shape is '**Correlation**'

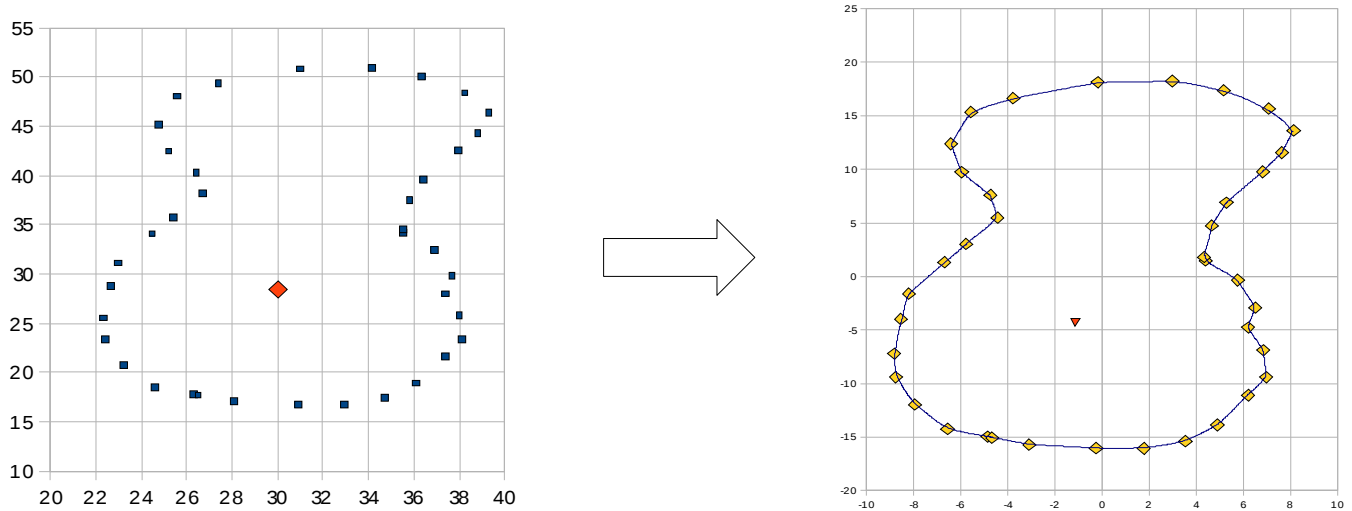
This quantifies how similar the radii of points along a Chorionic plate outline are.
I.e. A circle would have a correlation of zero

We can also calculate total **areas**, **perimeter lengths** and **distances from the centroid to the cord insertion** location – any of these characteristics could encode information about placental growth

Fourier Representation

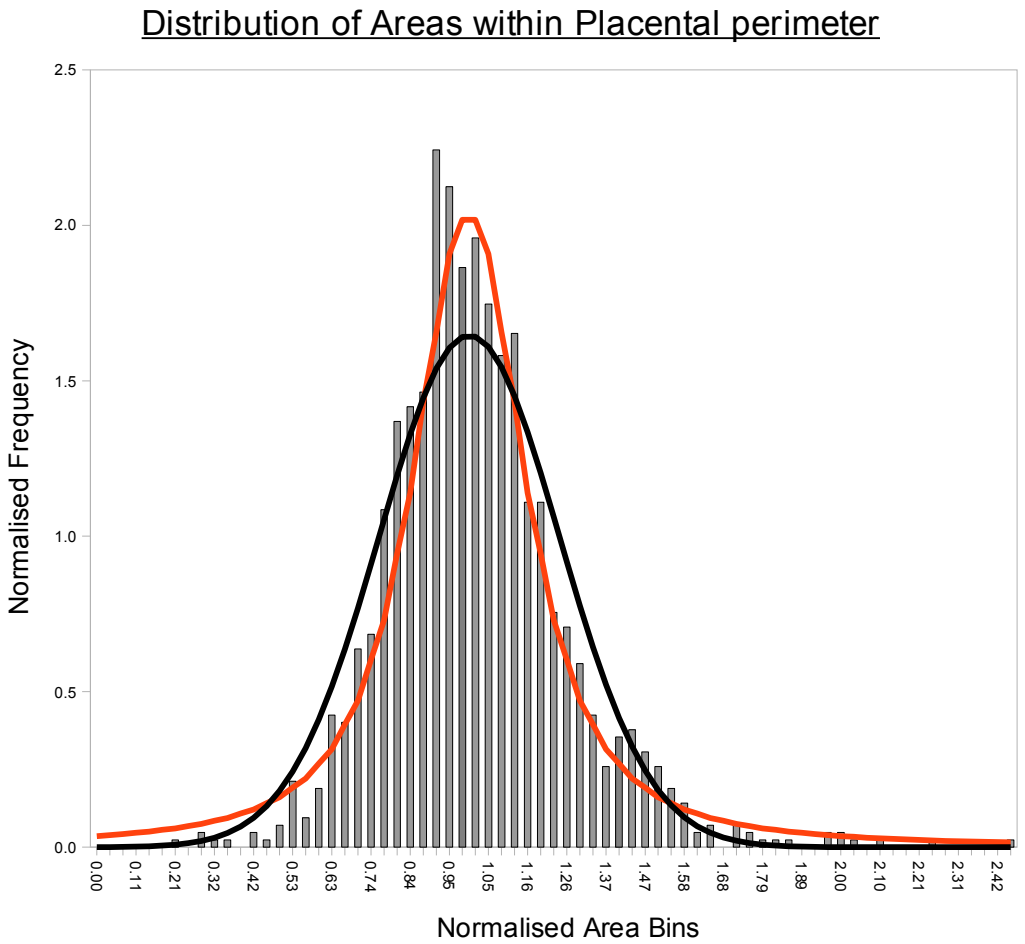
Data is provided in the form of discrete points measured along the Chorionic plate perimeter.

Using a mathematical function called a Fourier Series, we can create a continuous curve that fits the data.
Hence arbitrarily accurate perimeter points can be obtained for analysis



Distributions

Even a simple measure like Chorionic plate area seems to be more complex than anticipated



The black line shows a *Normal* distribution, which would imply the area is a result of a sum of independent factors (as we saw before)

However, the red line accounts better for some of the features of that data (like the tail at high areas, or the peak around the mean) The red curve is a *Levy* distribution.

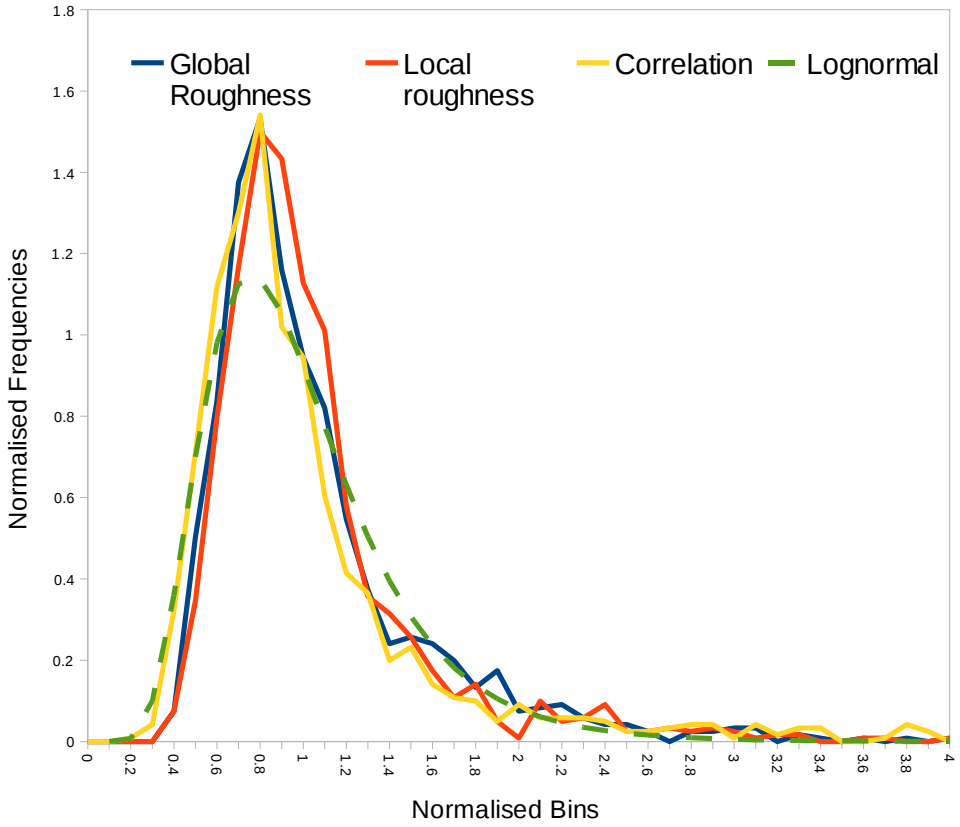
Levy distributions are associated with self-reinforcing processes - so the factors that account for the area (and hence the growth) are perhaps **not completely independent.**

Distributions

Other quantitative characteristics have even more unusual distribution shapes.

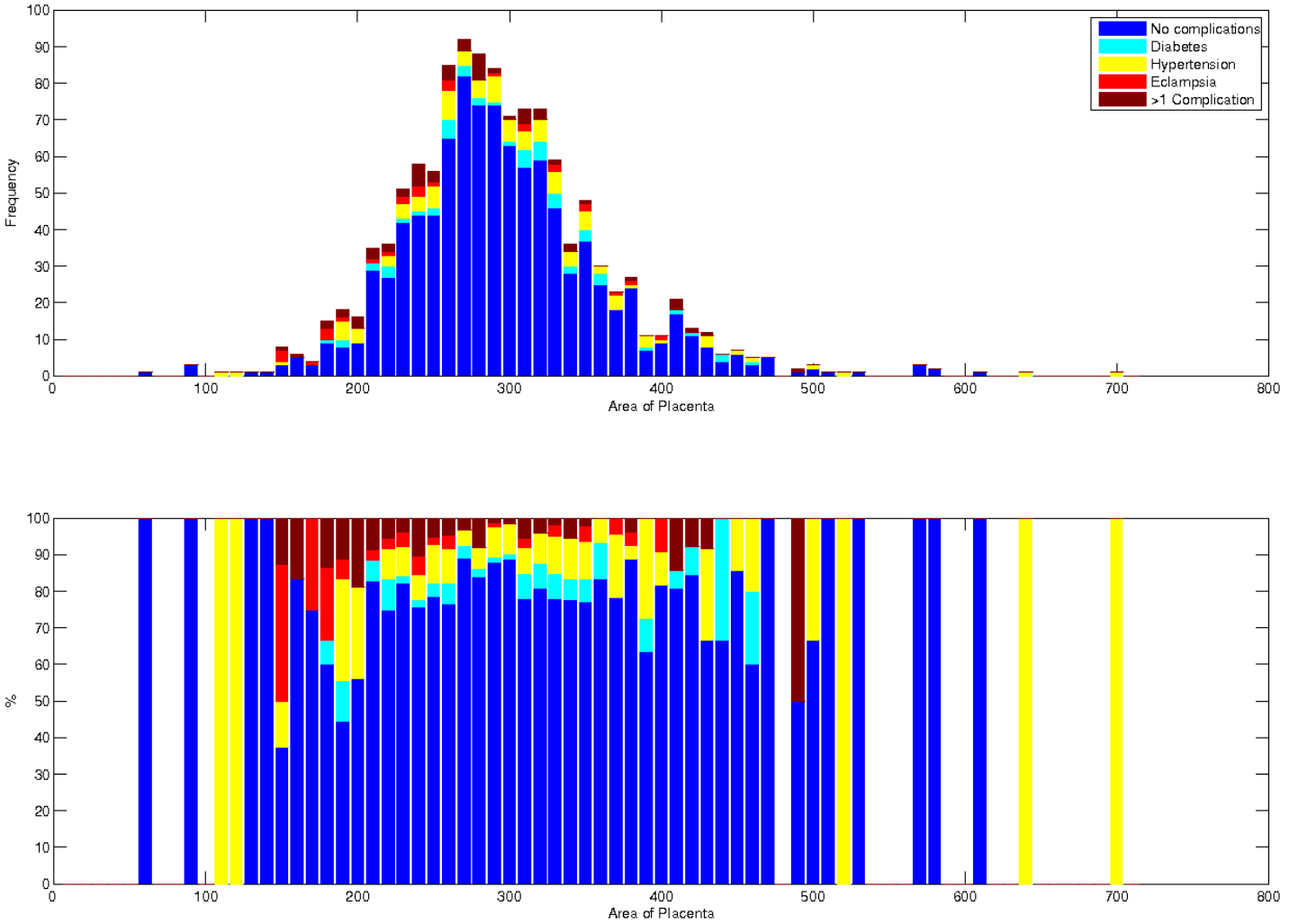
The parameters governing shape (roughness etc.) seem to fit a lognormal curve fairly well, except around the mean, where the peak height is unaccounted for.

A lognormal distribution arises when the logarithm of a variable is normally distributed.



Lognormal distributions arise from multiplicative **product** of many random variables, as opposed to a **sum** of random variables (as in the Normal distribution)

Plotting quantitative data about all of the placentas in the study allows for novel visualisation of clinical complications



Conclusions

Once characteristic parameters have been calculated and analysed, identifying the distribution can provide clues to the processes involved.

E.g. random vs. reinforcing processes

No assumptions need to be made to use the data, unlike regression methods.

Clinical data can be correlated to and compared with morphological characteristics.