APPENDIX 3

CUBIC SPLINE ESTIMATION

Consider the following set of equations

\[ y(t) = y''''(0) \frac{t^3}{6} + y'''(0) \frac{t^2}{2} + y''(0)t + y'(0) \]
\[ y'(t) = y'''(0) \frac{t^2}{2} + y''(0)t + y'(0) \]
\[ y''(t) = y'''(0)t + y''(0) \]
\[ y'''(t) = y''''(0) \]  \hspace{1cm} (A 3.1)

In matrix notation:

\[
\begin{bmatrix}
y(t) \\
y'(t) \\
y''(t) \\
y'''(t)
\end{bmatrix}
= 
\begin{bmatrix}
1 & t & \frac{t^2}{2} & \frac{t^3}{6} \\
0 & 1 & t & \frac{t^2}{2} \\
0 & 0 & 1 & t \\
0 & 0 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
y(0) \\
y'(0) \\
y''(0) \\
y'''(0)
\end{bmatrix}
\]  \hspace{1cm} (A 3.2)

By choosing \( t \) equal to one sample interval, equation (A 3.2) becomes

\[
\begin{bmatrix}
y(N+1) \\
y'(N+1) \\
y''(N+1) \\
y'''(N+1)
\end{bmatrix}
= 
\begin{bmatrix}
1 & 1 & \frac{1}{2} & \frac{1}{6} \\
0 & 1 & 1 & \frac{1}{2} \\
0 & 0 & 1 & 1 \\
0 & 0 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
y(N) \\
y'(N) \\
y''(N) \\
y'''(N)
\end{bmatrix}
\]  \hspace{1cm} (A 3.3)
where \( N \) and \( N+1 \) are adjacent sample indices starting with \( N=0 \). This system of equations can be recursively applied until all values of \( y(t) \) have been computed on interval \((0,T_1)\).

Location of PR - interval knot

The Abscissa, or location in time of a PR-interval knot is arbitrarily placed 66 milli seconds before the R-wave’s maximum downslope. The downslope of the ECG at any datum time index, \( I \), is computed using an average negative slope estimate

\[
\text{downslope}(I) = \frac{\text{datum}(I-6) + \text{datum}(I-2) - \text{datum}(I+2) - \text{datum}(I+6)}{4}
\]

The time interval between adjacent data points is 2 msec. The search for maximum downslope occurs when the computed downslope value exceeds 60% of the previous maximum (this 60% threshold may be initialized by calculating the maximum within the first 2 sec of data). During the search, the first downslope value, which is less than its predecessor, defines its predecessor’s value as the new maximum.

Once the abscissa of the PR-knot is located via the previous procedure, the ordinal value is chosen to be the average ordinal value of the eleven data points whose abscissa are nearest to and include the abscissa of the PR-knot. Rationale, for using eleven points to estimate the PR-interval knot, centers on eliminating the effects of 50 Hz noise based on the data sampling frequency. An average over eleven points, originally acquired at a sampling rate of 500 Hz spans 20 msec, or nearly one cycle of 50 Hz noise. From elementary digital filtering theory, we know that averages consisting of symmetrically spaced points spreading exactly over one cycle of a sinusoidal signal are biased by that signal component. Thus, a baseline estimate which is constructed from eleven point averaged PR-knots where the original data sampling rate was 500 Hz is relatively insensitive to 50 Hz noise (Meyer, C.R. 1977).