

- Continuity check: $\lim_{t \rightarrow t_0} \bar{r}(t) = \bar{r}(t_0)$ continuous in each component
- Differentiate: $\bar{r}(t) = (f(t), g(t), h(t))$
 $r'(t) = (f'(t), g'(t), h'(t))$
- Dot product: $d(\bar{u}, \bar{v}) = \bar{u}' \bar{v} + \bar{v}' \bar{u}$
- Cross product: $d(\bar{u} \times \bar{v}) = (\bar{u}' \times \bar{v}) + (\bar{u} \times \bar{v}')$ scalar
- Chain rule: $\frac{d}{dt} [u(f(t))] = \frac{df}{dt} \frac{d\bar{u}}{dt}$ vector
- Parametric tangent = $\frac{d\bar{r}}{dt} + r(t)$ at $t = t_0$
(for every component)
- Arc length = $\int_A^{t_B} \text{speed } dt$
 $= \int_A^{t_B} \sqrt{x'^2 + y'^2 + z'^2} dt$ (given)
- Tangent to arc = $\frac{\bar{r}'}{|r'|} = \frac{d\bar{r}/dt}{ds} = \frac{d\bar{r}'}{ds}$
- Curvature $K_n = \left| \frac{d\bar{T}}{ds} \right| = \frac{1}{|s|} \left| \frac{d\bar{T}}{dt} \right| = \frac{1}{s^2} \left| \frac{d\bar{T}}{dt} \right|$
- Unit Normal $\bar{N} = \frac{1}{K_n} \frac{d\bar{T}}{ds} = \frac{d\bar{T}/dt}{|d\bar{T}/dt|}$
- Binormal vector $\bar{B} = \bar{T} \times \bar{N}$

$$\bullet \frac{d\bar{B}}{ds} = \bar{v} \times \bar{T} \bar{N} = \begin{vmatrix} x' & y' & z' \\ x'' & y'' & z'' \\ x''' & y''' & z''' \end{vmatrix} / (\bar{v} \times \bar{a})$$

$$\bullet \bar{a} = \frac{d^2 \bar{r}_t}{dt^2} = K \bar{N} a_c + a_T \bar{T}$$

$$\bullet \text{Centrifugal force} = \frac{d}{dt} \left(\bar{T} \frac{ds}{dt} \right)$$

$$\bullet \bar{v} + \bar{v} \times \bar{a} = \frac{(ds)}{dt} \bar{K} \bar{B}$$

$$\bullet \bar{B} = \bar{v} \times \bar{a}$$

$$\bullet K = |\bar{v} \times \bar{a}|$$

To express a_T or a_T in an

$$\frac{d|\bar{v}|}{dt} = \bar{a}_T = \frac{ds}{dt} \times \frac{ds}{dt}$$

$$\bullet K = \frac{\bar{a}_T}{|\bar{v}|^2}$$

• $\bar{a}_T = \bar{v} \times \bar{a}_T$ - sum of tangential

$$\bullet \bar{a}_T = \bar{v} \times \bar{a}_T = \bar{v} \times \bar{a}_T$$

$$\bullet a_T = v \cdot \omega = v \cdot \omega$$

$\omega = \theta / t = \theta / T$