



Aerodynamic drag is not the major determinant of performance during giant slalom skiing at the elite level

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Norwegian University of
Science and Technology



IJS



Uvod: biomehanika alpskega smučanja

Pospešujoče in zavirajoče sile pri smučanju

$$\vec{F}_{din} + \vec{F}_{trenje} + \vec{F}_{upor} = m\vec{a}_=$$

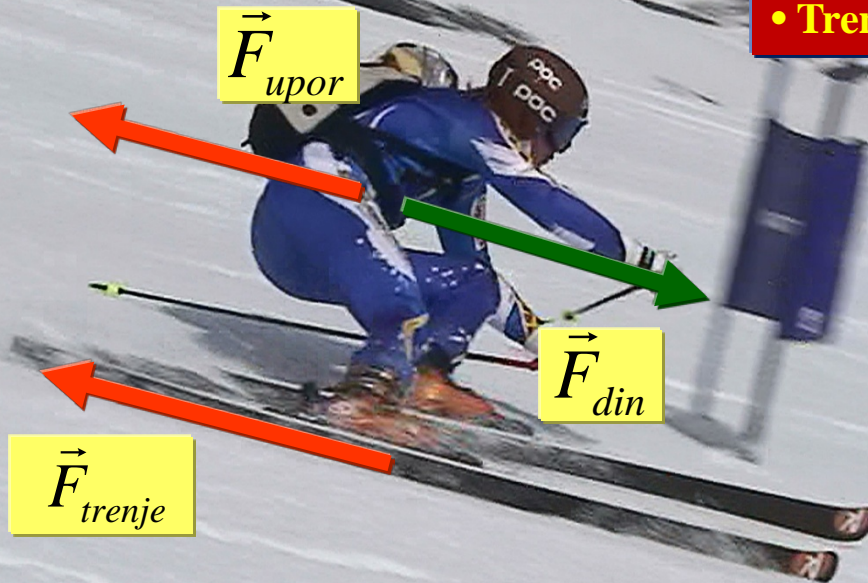
Pospešujoča sila

- Dinamična komponenta sile teže

Zavirajoče sile (energijske izgube)

- Zračni upor
- Trenje

$$A_i = \int (\vec{F}_{trenje} + \vec{F}_{upor}) d\vec{s}$$



Uvod: biomehanika alpskega smučanja

Pospešujoče in zavirajoče sile pri smučanju

Pospešujoča sila

Cilji študije: Energijske izgube zaradi upora in trenja

• Trenje

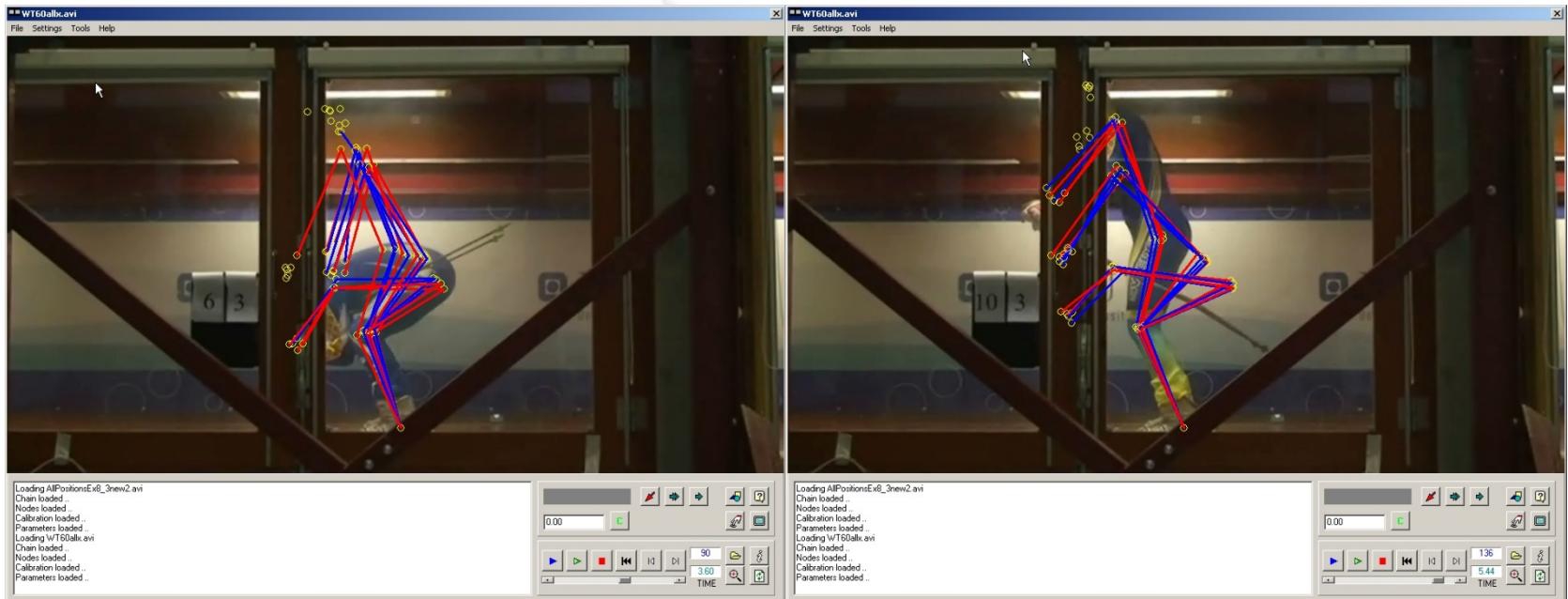


Kako “določiti” upor zraka med smučanjem?

● **Vetrovnik**

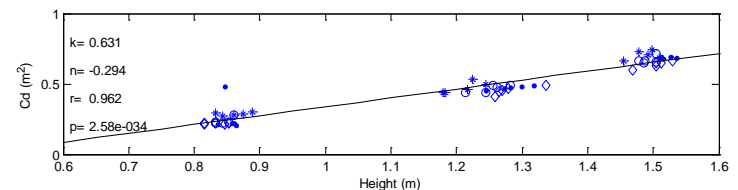
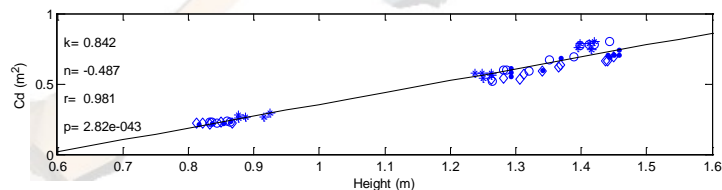
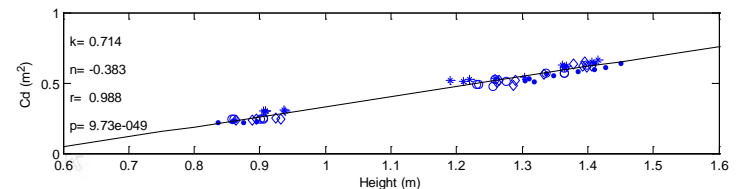
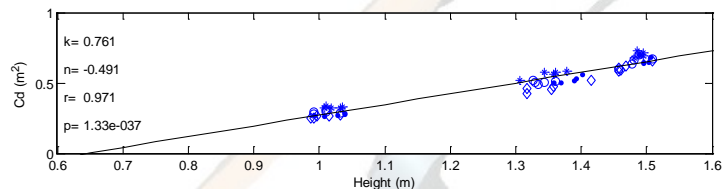
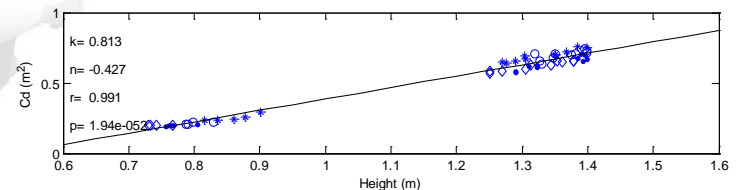
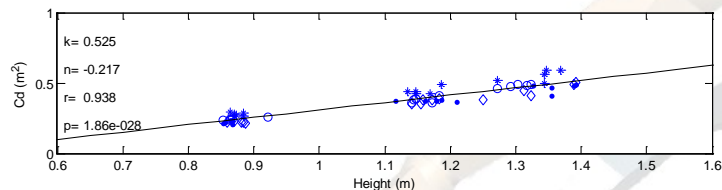
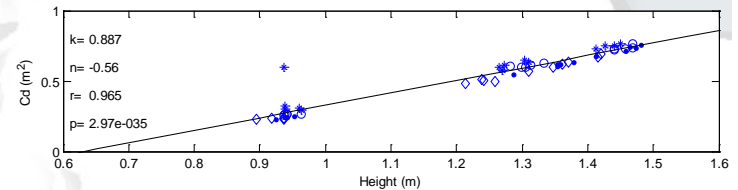
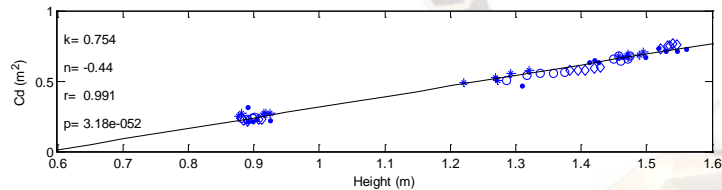
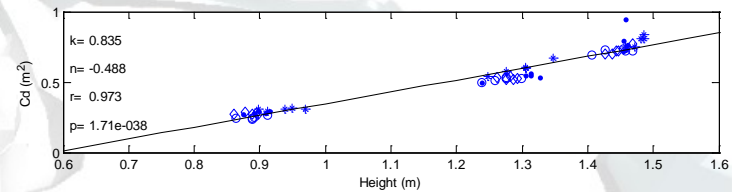
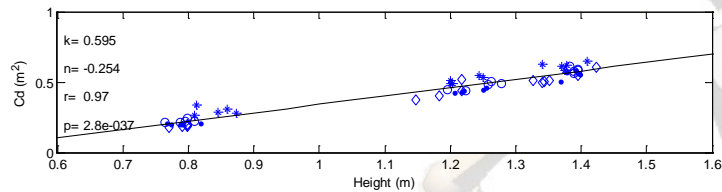
- **Neposredna meritev sile v vzdolžni smeri**
- **Kvadratni zakon upora zraka**

$$F_{upor}(položaj) = \frac{1}{2} C_u(položaj) S(položaj) \rho v^2; Re \gg 10^3$$



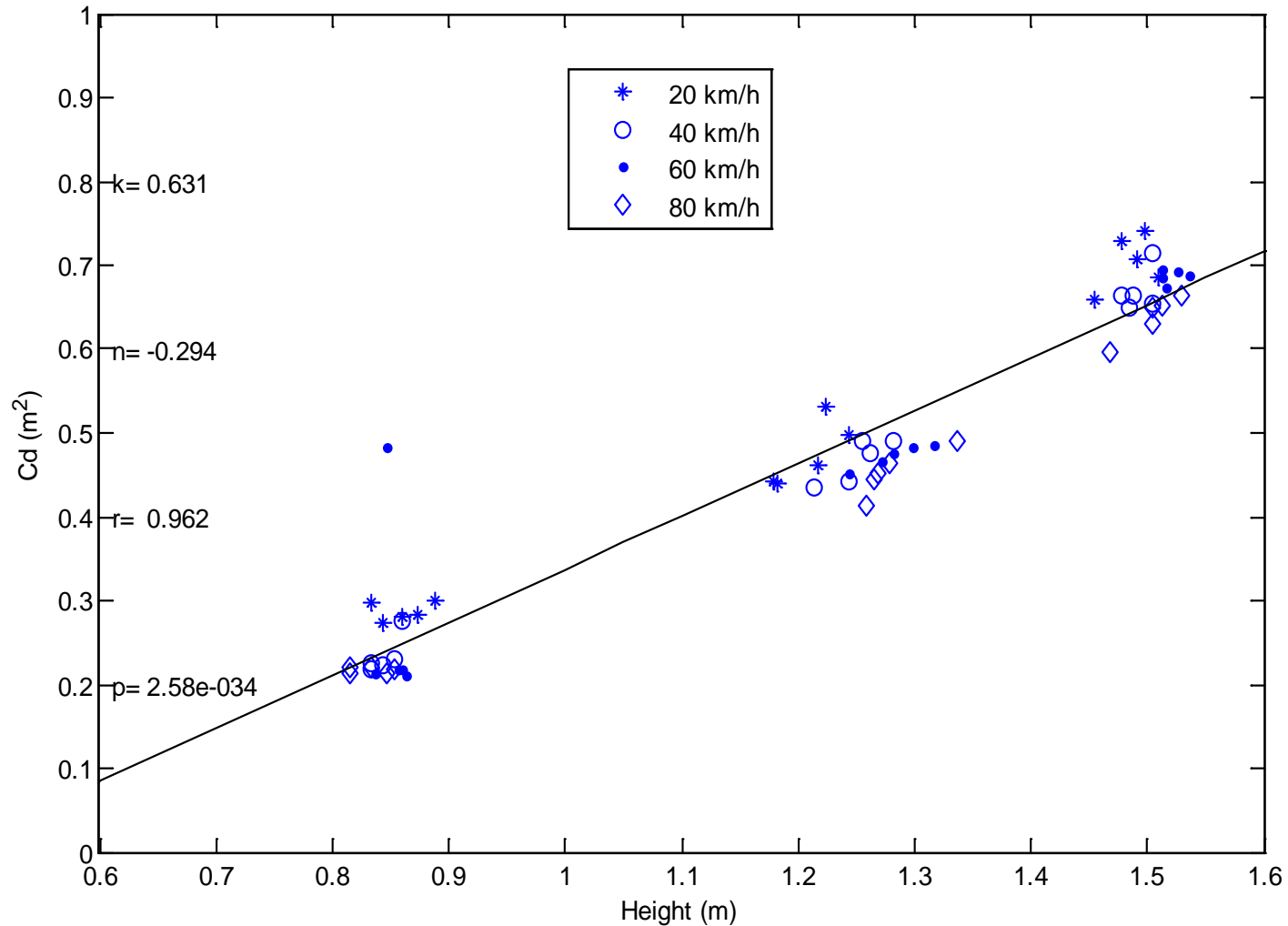
Model iz vetrovnika

Različne hitrosti (20, 40, 60 in 80 km/h) in položaji



Model iz vetrovnika

- Različne hitrosti (20, 40, 60 in 80 km/h) in položaji



GNSS meritve in modeliranje smučarja

Pod-determiniran sistem



Potrebni približki, poenostavitve

Sila reakcije podlage

$$\vec{f}_{gr} = \vec{F}_{gr} / m = \vec{a} - \vec{g}$$

Antena

Težišče telesa

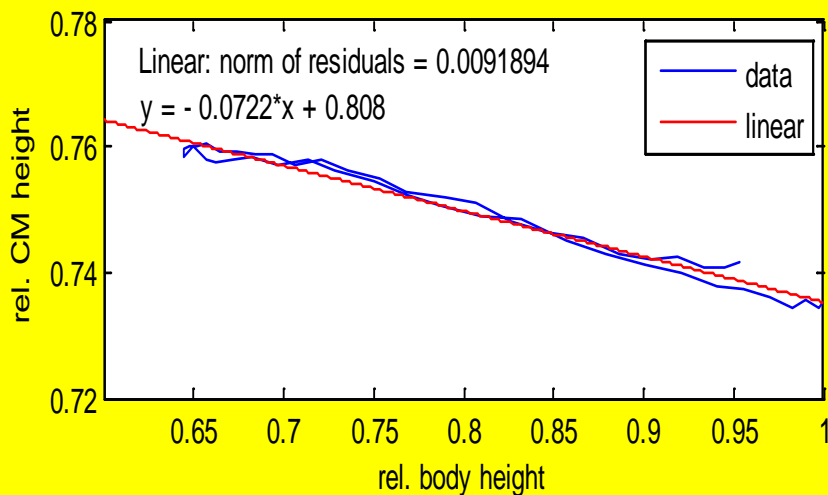
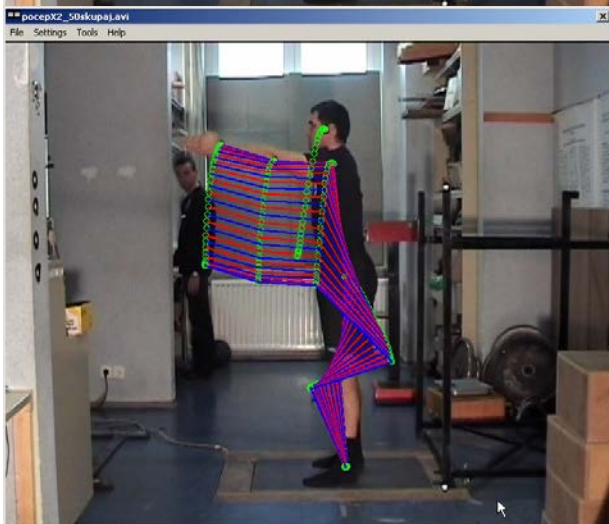
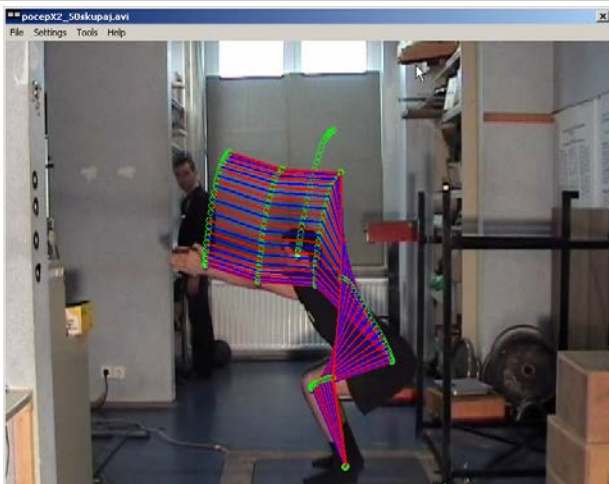
Smučī

3D površina (RTK GNSS)

Ron LeMaster, 2002

Model težišča telesa

višina težišče telesa
višina ramenske osi



Model GNSS antene in ramenske osi

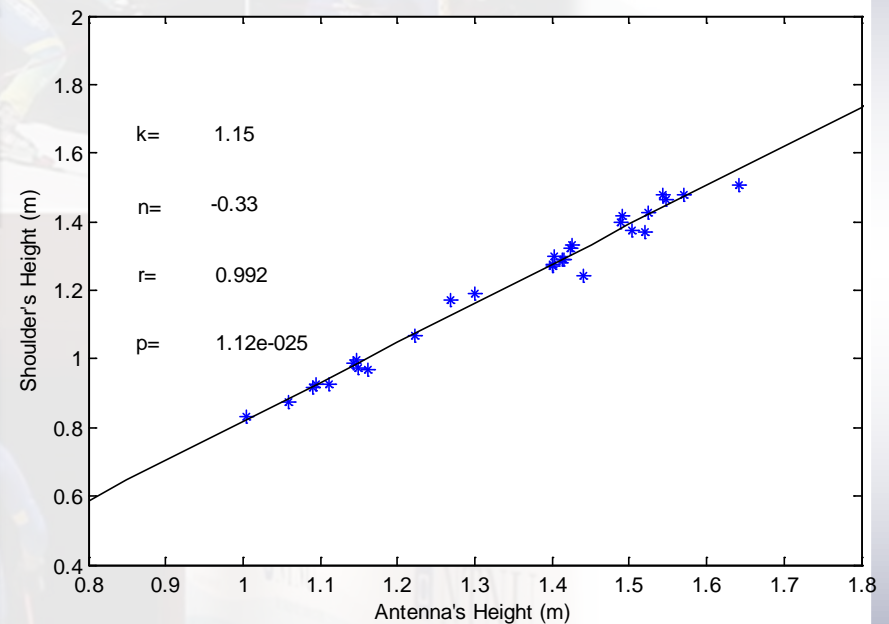
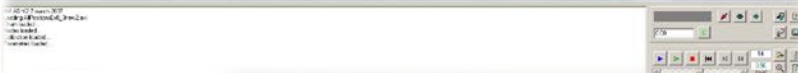


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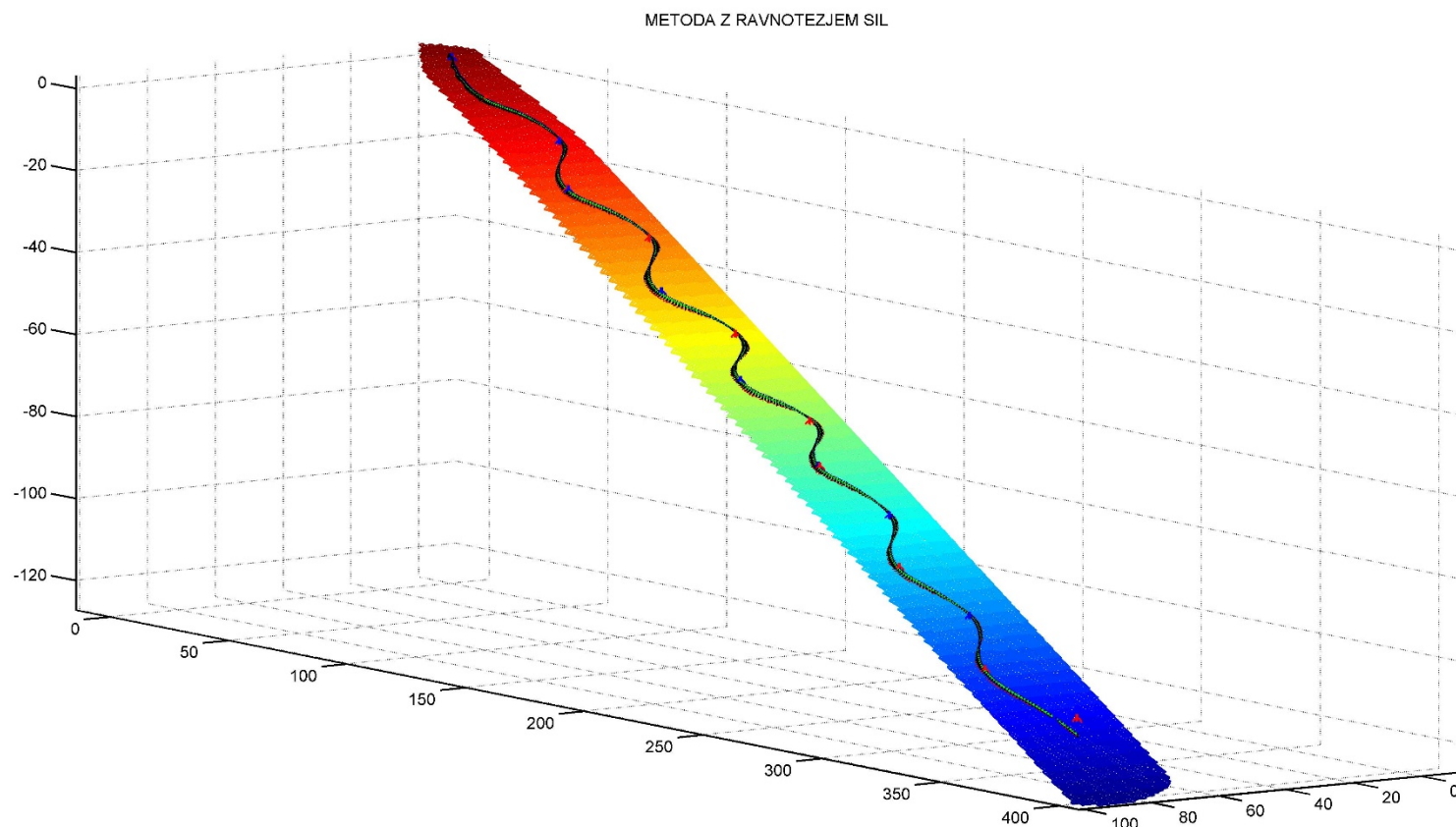
Kontakt: izr. prof. dr. Matej Supej
e-mail: Matej.Supej@fsp.uni-lj.si

Model GNSS antene in ramenske osi

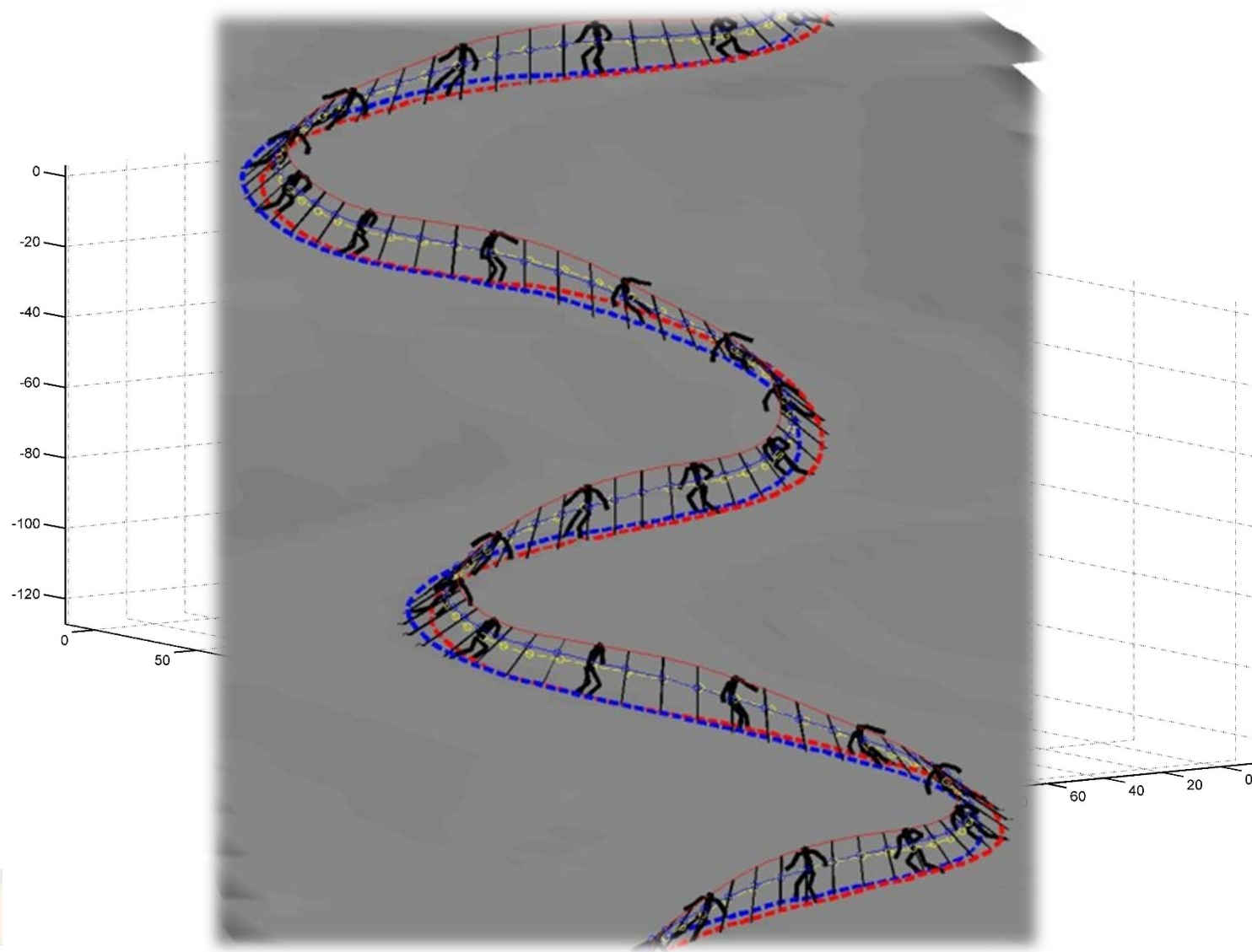
Model višina ramen v odvisnosti od višine antene



Rezultati: grafični prikaz modela



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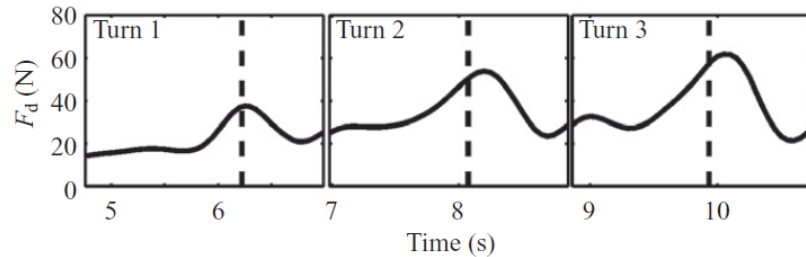


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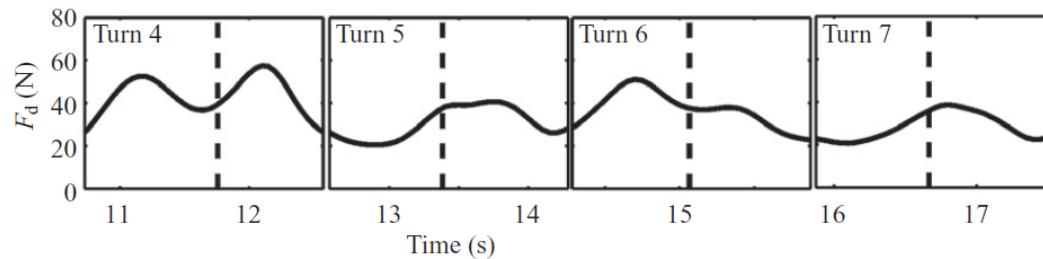
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Rezultati: upor in trenje

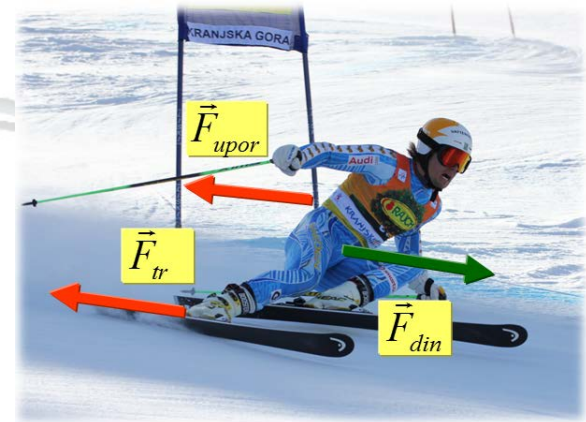
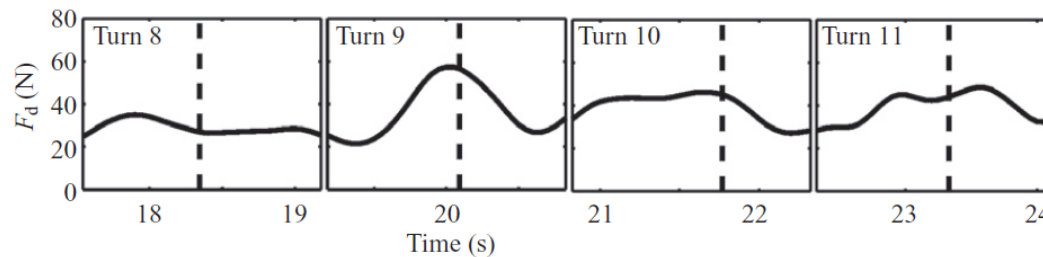
Section 1



Section 2

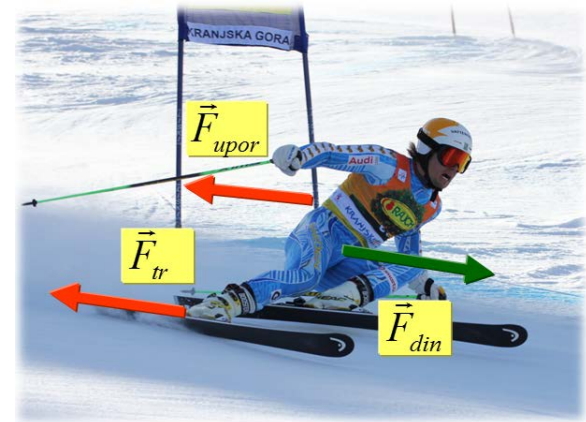
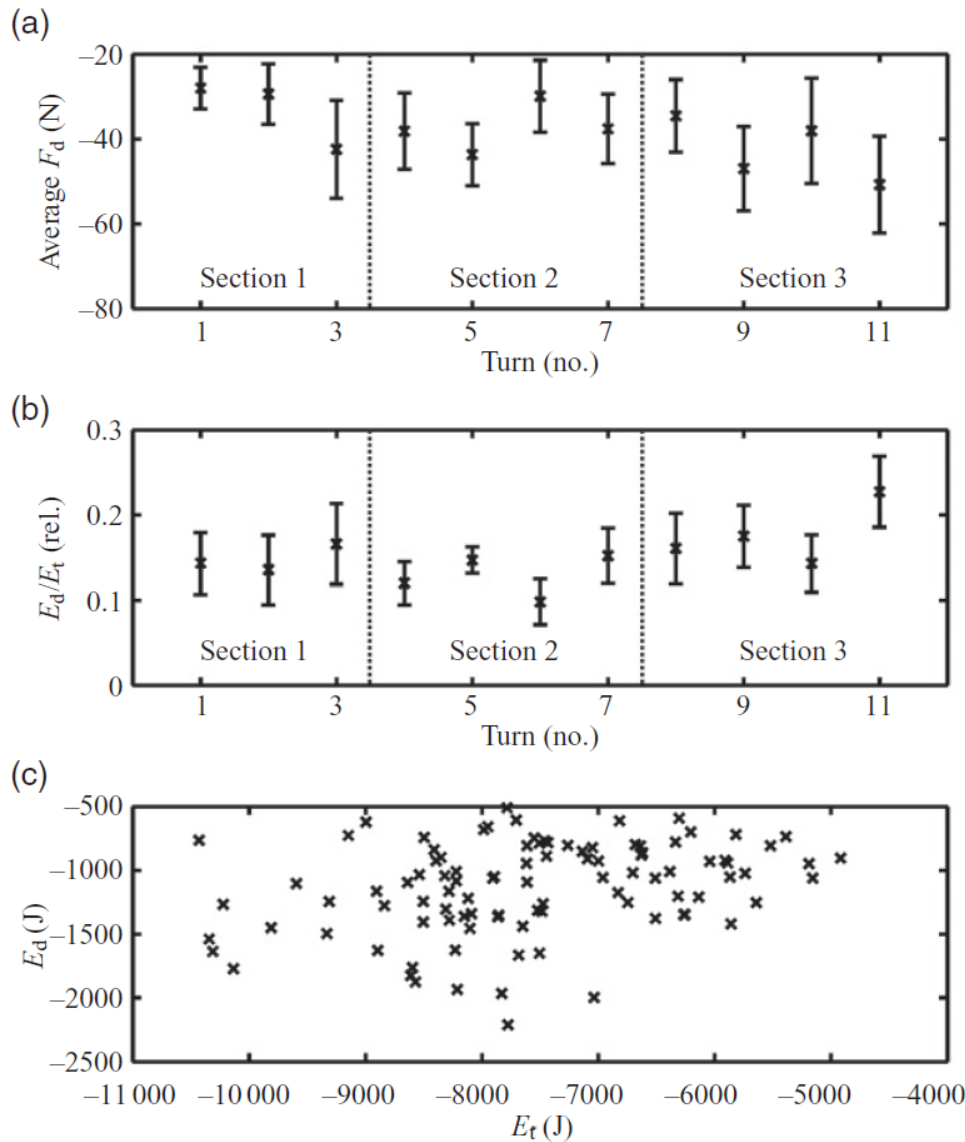


Section 3



$$\vec{F}_{upor} = \langle 20N \mid 60N \rangle$$

Rezultati: upor in trenje



$$\vec{F}_{upor} = \langle 20N | 60N \rangle$$

$$\frac{E_{upor}}{E_{skupaj}} \approx 15\% \langle 5\% | 28\% \rangle$$

Zaključek

Znanstveni doprinos

Zahtevno analitično/numerično modeliranje

Merjenje upora in trenja med smučanjem

Aplikativni doprinos

Trenje pomembnejše od upora

Možnost uporabe modela za testiranje športnikov

Zaključek

Znanstveni doprinos

Zahtevno analitično/numerično modeliranje

**HVALA ZA
POZORNOST**

Trenje pomembnejše od upora

Možnost uporabe modela za testiranje športnikov

