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HearRestore RTD 2013

FNSNF

Temperature prediction model for bone drilling based on density distribution and *in vivo* validation experiments

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Motivation

Hearling Loss or Impairment →  → **Minimally Invasive Robotic Cochlea Access Drilling** →

+ reduces Hospitalization time
+ saves Costs
- possible Facial Nerve Damage...
  - due to Mechanical Interaction
  - due to **Heat**
- ➢ **Risk Assessment**

Modelling

Hypothesis:
Temperature Elevation dependent on Bone Density
(average Housfield value on Drill Bit-Ø for each drilling depth)

$$1.)\ Drilling\ Force \sim Density(drill\ bit\ position)^b$$

$$2.)\ Heat\ Rate = Feed\ velocity * A * Density(t)^b \quad [Watt]$$

with a constant feed velocity and calibration coefficents „A" and „b"

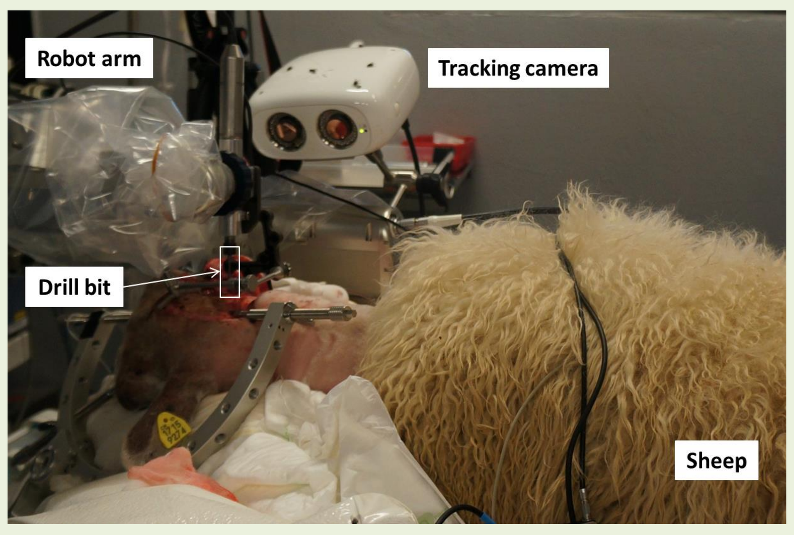
$$3.)\ Drill\ Bit\ modeled\ as\ moving\ point\ heat\ source$$

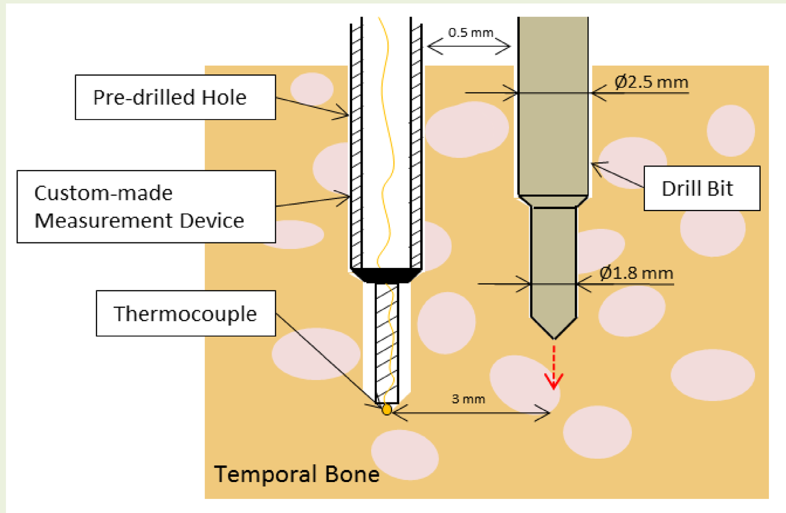
the heat equation can then be solved over time using a moving point source Green's function.

$$\Rightarrow Temperature(t, x, y, z)$$

Experimentation

Setup:
In Vivo Drilling Temperature Measurement on Sheep

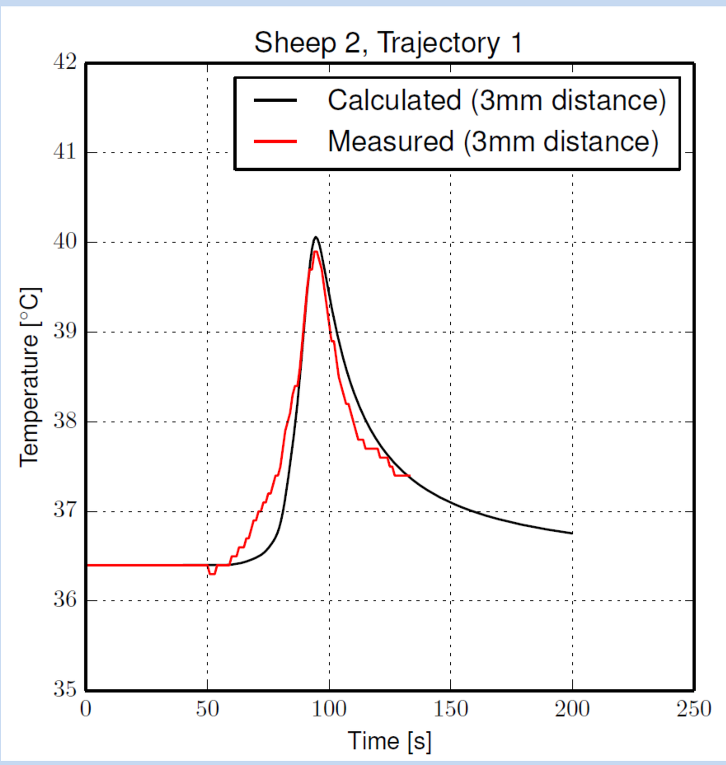




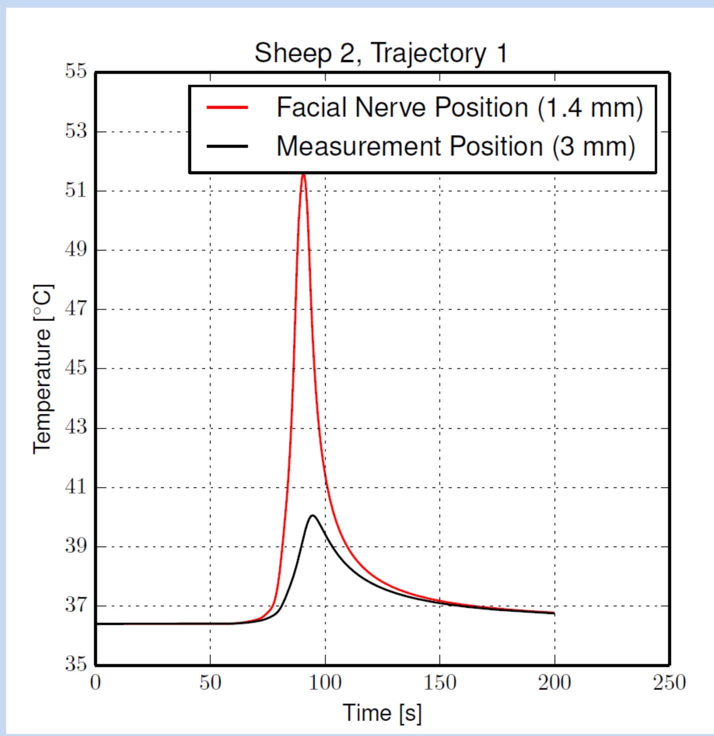
- Surgical drilling robot with tracking device
- Measurement with thermocouple in neighbouring hole
- 12 Holes drilled in 4 different sheep

Results

- ❑ Measured **temperature data** used for **calibration** (constants: „A", „b") and **validation** of model
- ➢ Overall good temperature prediction
  - ➢ Average Root Mean Square Error = 0.5°C
  - ➢ Average error at max. Temperature = 0.7°C



- ❑ Temperature prediction at facial nerve position
- ➢ **Thermal damage risk evaluation**
  - ➢ Cumulative Equivalent Minutes (CEM43°C)



Conclusion

- ❑ Possible facial nerve damage due to heat in patients with high density mastoids
- ❑ Exact threshold for thermal nerve damage unknown
- ➢ A „safe" drilling process has to be found by optimizing cooling and other drilling paramters
- ➢ Temperature model allows patient spetific temperature prediction based on bone density information

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