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TCAD and Cognitive Visualization in Electronic Engineering Education

Vladimir Terekhov
BMSTU

Authors:
Vadim Shakhnov
Lyudmila Zinchenko
Andrey Glushko
Elena Rezchikova
Vladimir Terekhov
Vladimir Makarchuk

Bauman Moscow State Technical University

TCAD and Cognitive Visualization in Electronic Engineering Education

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- Russian Higher Educational System
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- Cognitive Visualization in TCAD
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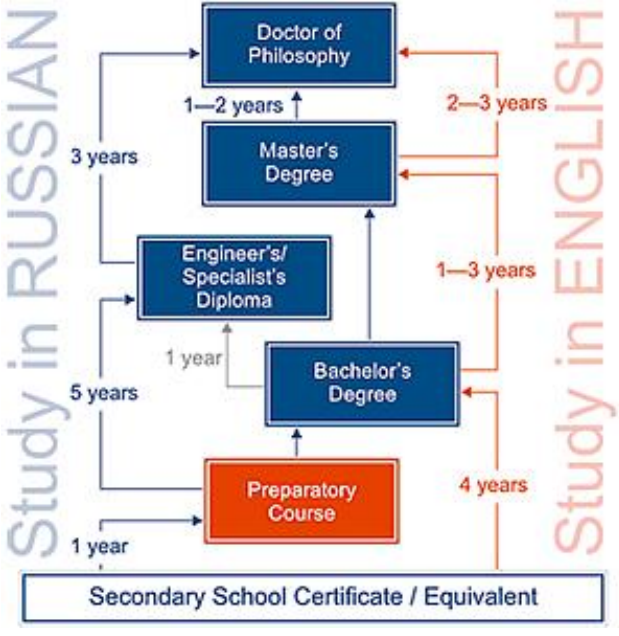
TCAD and Cognitive Visualization in Electronic Engineering Education

Russian Higher Educational System



The comparison between classical Russian education and Bologna process

Characteristics	Russian Federation
Square, km2	17 125 191
Population, million	146.78
Human population density, person/km2	8.56
Average wage, $/year	6912
State language	Russian
Quantity of higher education in the TOP 300 list	5

The case study country characteristics

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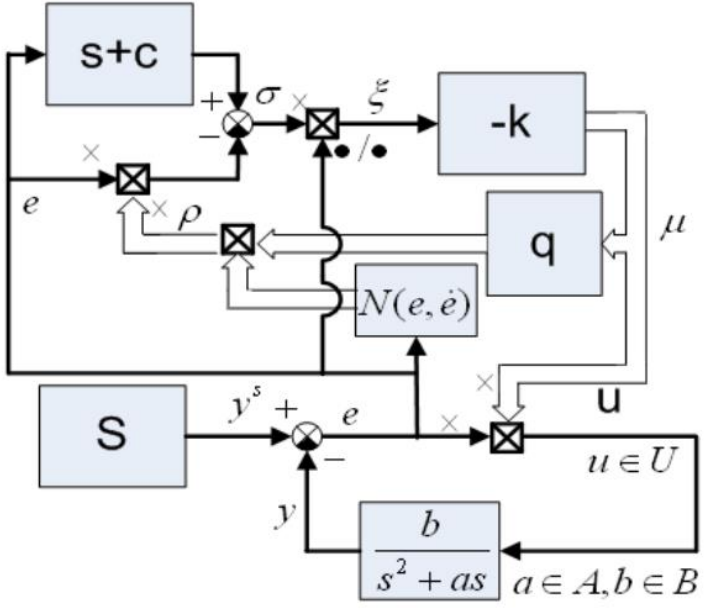
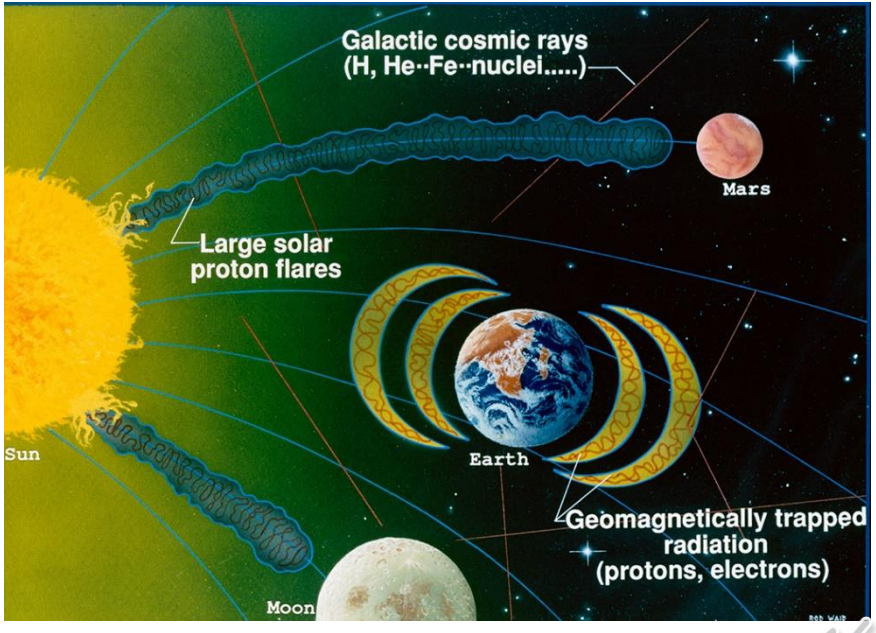
Devices in Space Missions

Coordinate-operator feedback circuits are widely used in air- and spacecrafts' control systems, but they need to be radiation-tolerant due to space environment. It can be simulated in Sentaurus TCAD.



Structure of coordinate-operator feedback circuit

Source: Emelianov et al., «Stabilization of the pitch angle of a helicopter in various flight modes using coordinate-operator and operator feedback»



Types of radiation in space

Source: www.nasa.gov

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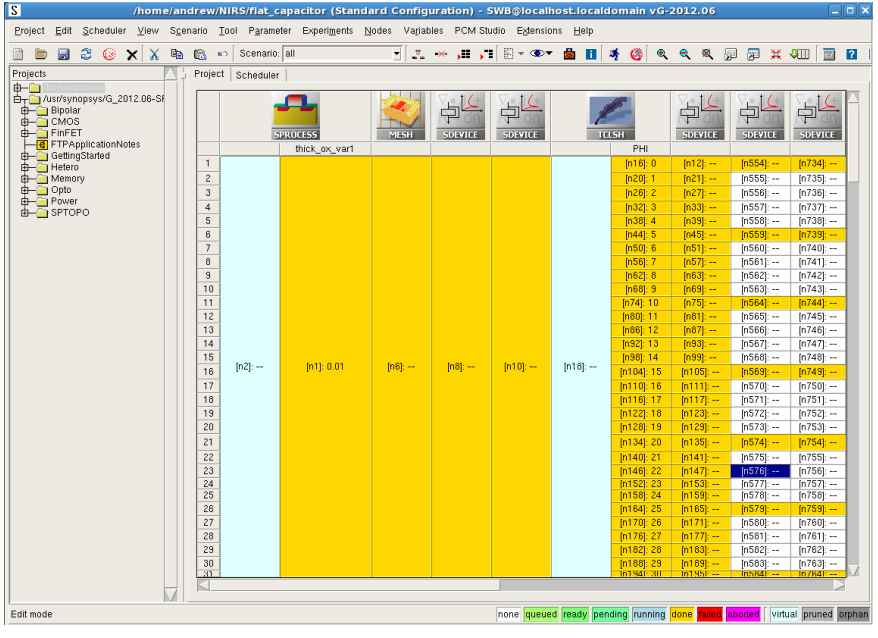
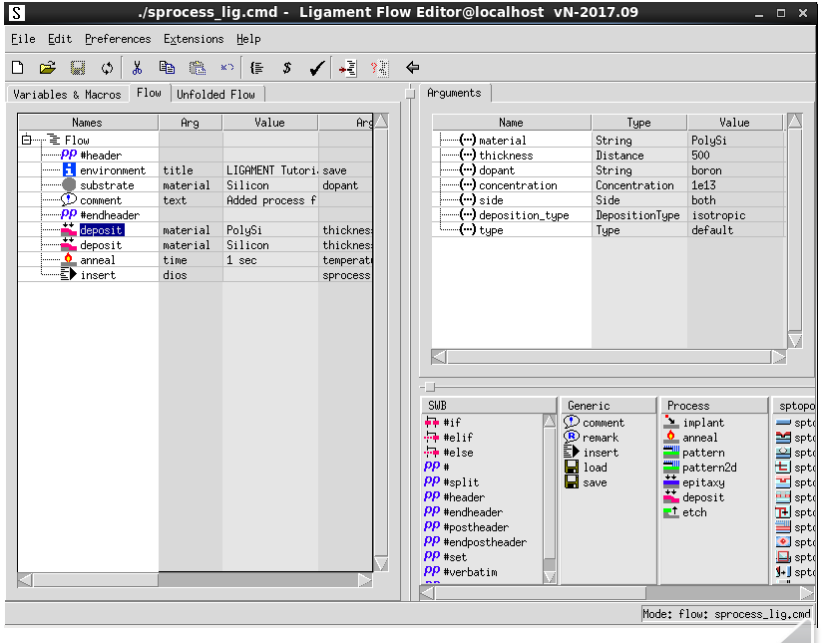
Sentaurus TCAD

Sentaurus TCAD is the leading tool in EDA (Electronic Design Automation), a professional new-generation multidimensional device simulator, which features simulation of electrical and thermal characteristics of silicon-based and compound semiconductor devices.



Main window of Sentaurus TCAD



MEMS formation process in Sentaurus TCAD

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Cognitive Visualization in Sentaurus TCAD

Distribution of generation of free charge carriers. Next step — Augmented Reality?

```
Info {
  version = 1.0
  type    = dataset
datasets   = [ "ElectrostaticPotential" "ElectrostaticPotential" "ElectrostaticPotential" "eDensity"
"eDensity" "eDensity" "hDensity" "hDensity" "hDensity" "LatticeTemperature" "LatticeTemperature"
"LatticeTemperature" "eMobility" "eMobility" "eMobility" "hMobility" "hMobility" "hMobility"
"DopingConcentration" "DopingConcentration" "DopingConcentration" "eCurrentDensity-Vector"
"eCurrentDensity-Vector" "eCurrentDensity-Vector" "hCurrentDensity-Vector" "hCurrentDensity-
Vector" "hCurrentDensity-Vector" "eGradQuasiFermi-Vector" "eGradQuasiFermi-Vector"
"eGradQuasiFermi-Vector" "hGradQuasiFermi-Vector" "hGradQuasiFermi-Vector"
"hGradQuasiFermi-Vector" "eQuasiFermiPotential" "eQuasiFermiPotential" "eQuasiFermiPotential"
"hQuasiFermiPotential" "hQuasiFermiPotential" "hQuasiFermiPotential" "ElectricField"
"ElectricField" "ElectricField" "SpaceCharge" "SpaceCharge" "SpaceCharge" "srhRecombination"
"srhRecombination" "srhRecombination" "DonorConcentration" "DonorConcentration"
"DonorConcentration" "AcceptorConcentration" "AcceptorConcentration" "AcceptorConcentration"
"HeavyIonGeneration" ]
}
Data {
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    function  = ElectrostaticPotential
    Values (1543) {
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7.7011141343215170e-02 1.2818196709051241e-01 1.2848727770307664e-01
1.4075113200802342e-01 9.6406616613721005e-02 9.6887571926924168e-02
1.0920888186318663e-01
```
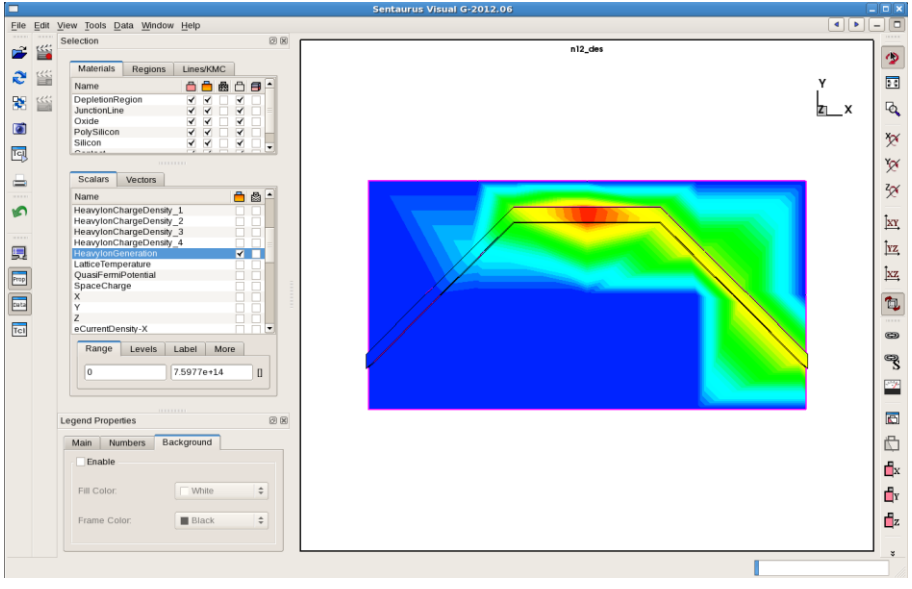

Raw data



Visualized data

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Cognitive Visualization in Sentaurus TCAD

Current peak in microcapacitor, induced by heavy charged particle

```
Info {
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  type      = xyplot
  datasets  = [
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    "minus OuterVoltage" "minus InnerVoltage" "minus QuasiFermiPotential" "minus
DisplacementCurrent" "minus eCurrent"
    "minus hCurrent" "minus TotalCurrent" "minus Charge" "plus OuterVoltage" "plus
InnerVoltage"
    "plus QuasiFermiPotential" "plus DisplacementCurrent" "plus eCurrent" "plus hCurrent" "plus
TotalCurrent"
    "plus Charge" ]
}

Data {
     0.00000000000000E+00
     0.00000000000000E+00  0.00000000000000E+00  0.00000000000000E+00
0.00000000000000E+00 -4.74234804854622E-11
    -4.59783521935876E-10 -5.07207002421338E-10 -2.00237797431117E-16
1.50000000000000E+00  1.49999999999697E+00
     0.00000000000000E+00  0.00000000000000E+00  4.74234804854628E-11
4.59783521935876E-10  5.07207002421338E-10
     2.00237797431111E-16
     4.00000000000000E-1
```
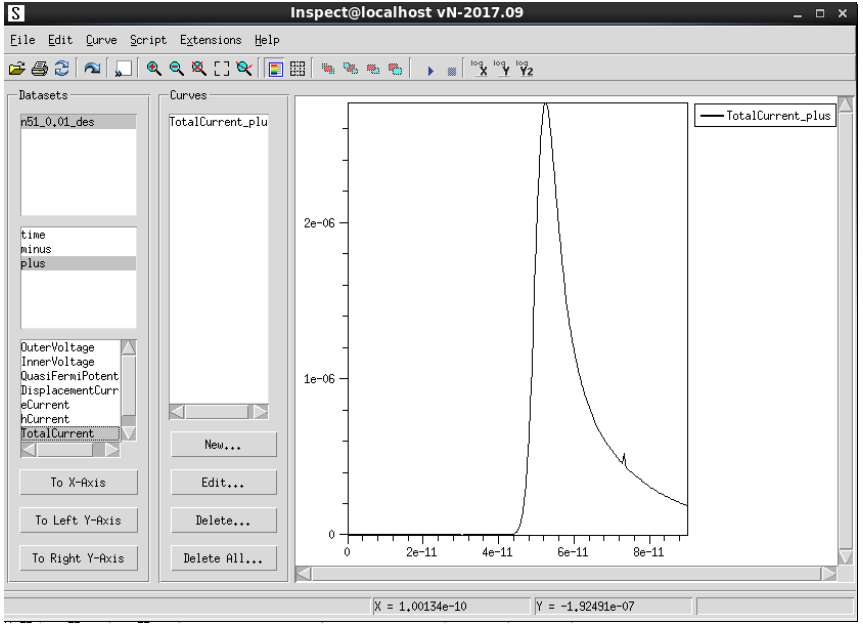

Raw data



Visualized data

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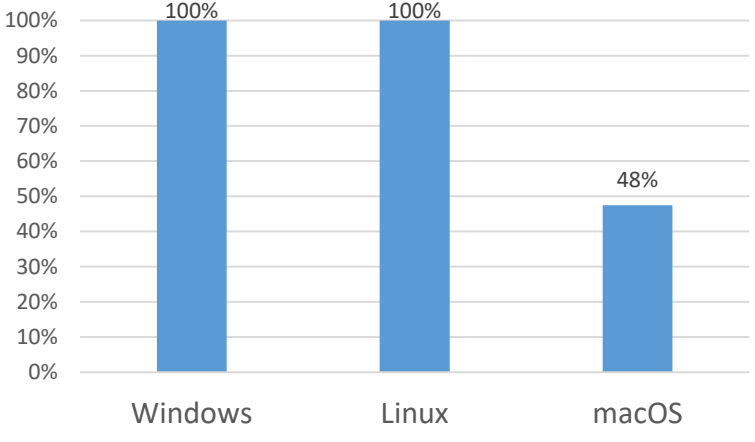
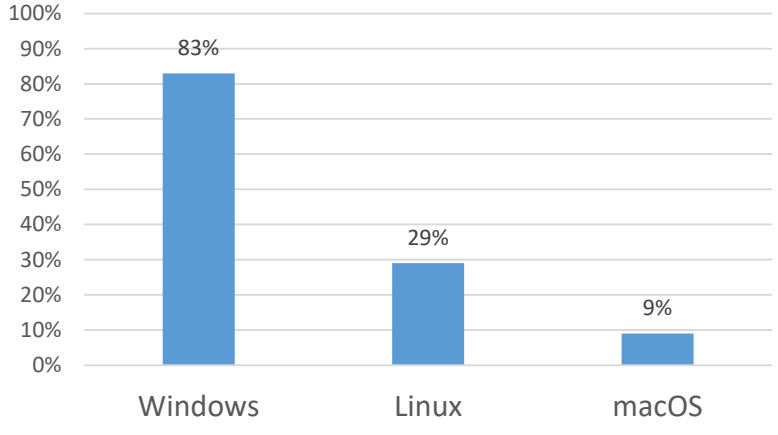
Our Experience

Respondents: >40 undergraduate engineering students.



Statistics about operating systems familiar to students



Operating systems used by students on the daily basis

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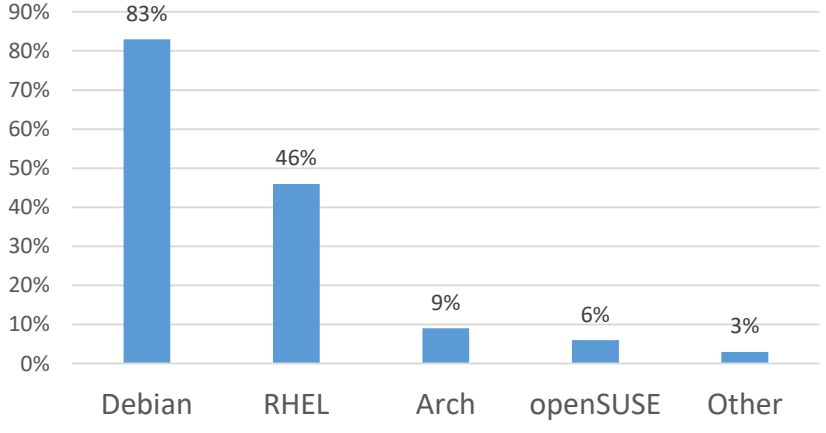
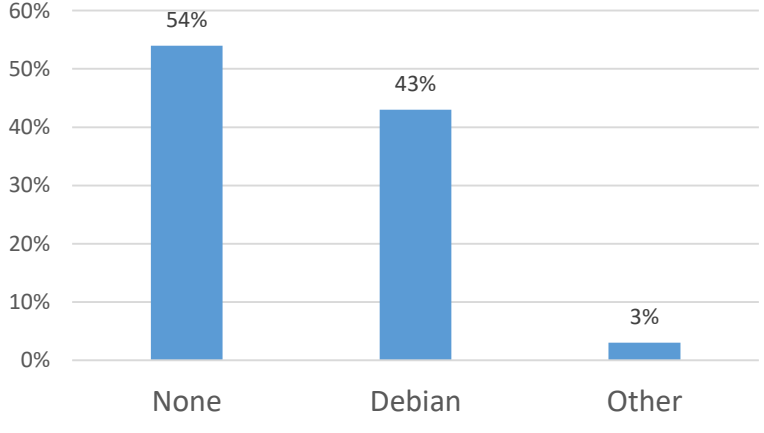
Our Experience

94% of students are ready to study new operation systems (including Linux distributions), if this is necessary for their future education and work



Linux distributions opertaing systems statistics



Linux distributions used by students regularly

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Conclusions

- Sentaurus TCAD can be used to calculate SPICE models of SOI MOSFET, to generate models of electrostatic MEMS and estimate their tolerance of heavy charged particles, etc. Graduates must be able to exploit such industrial tools, but Sentaurus TCAD requires Red Hat Enterprise Linux to work.
- Sentaurus TCAD has a lot of built-in visualization instruments, which can graphically show different processes in semiconductor devices. We can use built-in visualization tools as a basis for cognitive visualization and develop the visual thinking of students. Also we see a possibility for future use of AR technologies in electronic engineering education.
- All students are familiar with Linux-based operation systems (92% growth in comparison with 2015).
- Almost 30% of respondents use Linux-base operation systems regularly.
- Almost all students (94%) are ready to study new operation systems if they need them for future education, for example, in Sentaurus TCAD courses.

TCAD and Cognitive Visualization in Electronic Engineering Education

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Thank you for attention!

Speacker's contacts:

Vladimir Terekhov

BMSTU

vvterekhov.bmstu@gmail.com

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