Computational Microelectronics
L8

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Neural network

Why neural networks in this course?

- Basically, this course is for the TCAD development.
  - Numerical analysis of a set of governing equations
  - Governing equations ➔ discretization ➔ implementation

Electron continuity at a steady-state

- No time derivative
  - The electron current density becomes divergenceless (solenoidal).

$$\frac{1}{q}\nabla\cdot\mathbf{J}_n=\frac{\partial n}{\partial t}=0 \longleftarrow \text{Steady-state}$$

  - The electron current density reads: (Einstein relation)

$$\mathbf{J}_n=qD_n\left(\nabla n-\frac{1}{V_T}n\nabla\phi\right)$$

  - 1D case, J_n

$$\frac{dJ_n}{dx}=0$$

$$J_n=qD_n\left(\frac{dn}{dx}-\frac{1}{V_T}n\frac{d\phi}{dx}\right)$$

GIST Lecture 7

Derivation (5)

- We are almost there.
  - From $J_n=-\frac{qD_n}{V_T}\frac{\Delta\phi}{\Delta x}C_2$,

$$J_n=\frac{qD_n}{\Delta x}\left(n_{i+1}\frac{\frac{\Delta\phi}{V_T}}{\exp\frac{\Delta\phi}{V_T}-1}-n_i\frac{\frac{\Delta\phi}{V_T}\exp\frac{\Delta\phi}{V_T}}{\exp\frac{\Delta\phi}{V_T}-1}\right)$$

  - With the Bernoulli function, $B(x)=\frac{x}{\exp x-1}$,

$$J_n=\frac{qD_n}{\Delta x}\left[n_{i+1}B\left(\frac{\Delta\phi}{V_T}\right)-n_iB\left(-\frac{\Delta\phi}{V_T}\right)\right]$$

GIST Lecture 8

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# Electron continuity

dphi = (phi[ii+1]-phi[ii])/VT
b[3*ii+2] = q*Dn/10*( elec[ii+1]*Ber(dphi) - e
A[3*ii+2,3*(ii+1)+2] = A[3*ii+2,3*(ii+1)+2] +
A[3*ii+2,3* ii   +2] = A[3*ii+2,3* ii   +2] +
A[3*ii+2,3*(ii+1)  ] = A[3*ii+2,3*(ii+1)  ] +
A[3*ii+2,3* ii     ] = A[3*ii+2,3* ii     ] +

dphi = (phi[ii]-phi[ii-1])/VT
b[3*ii+2] = b[3*ii+2] - q*Dn/10*( elec[ii]*Ber
A[3*ii+2,3* ii   +2] = A[3*ii+2,3* ii   +2] -
A[3*ii+2,3*(ii-1)+2] = A[3*ii+2,3*(ii-1)+2] -
A[3*ii+2,3* ii     ] = A[3*ii+2,3* ii     ] -
A[3*ii+2,3*(ii-1)  ] = A[3*ii+2,3*(ii-1)  ] -
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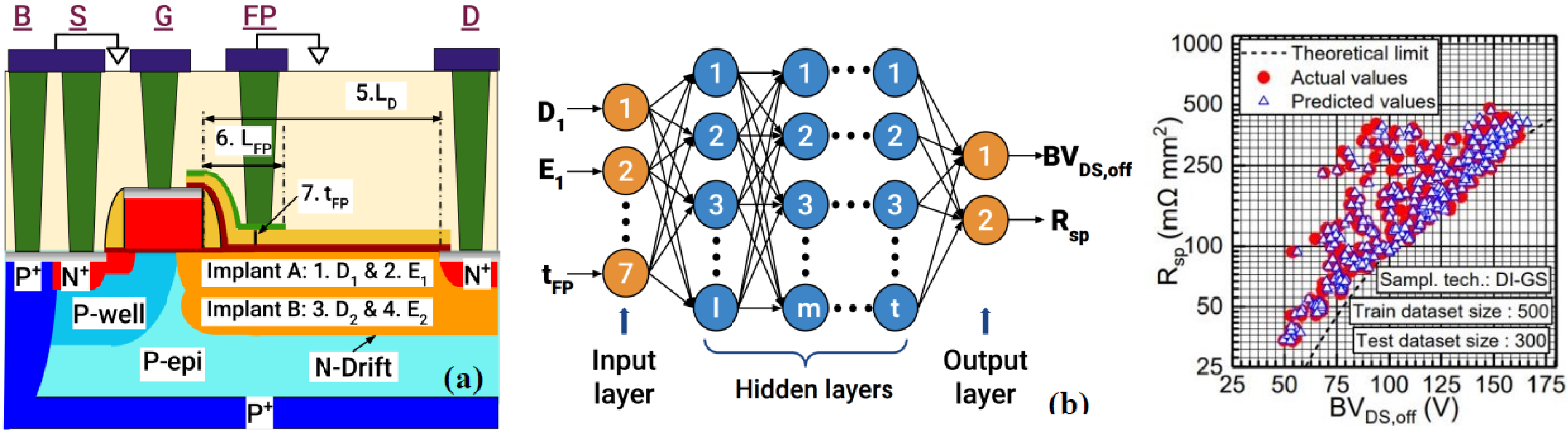
- It ("neural network") is a new topic introduced this semester.
  - Data-driven approach

Recent applications (1)

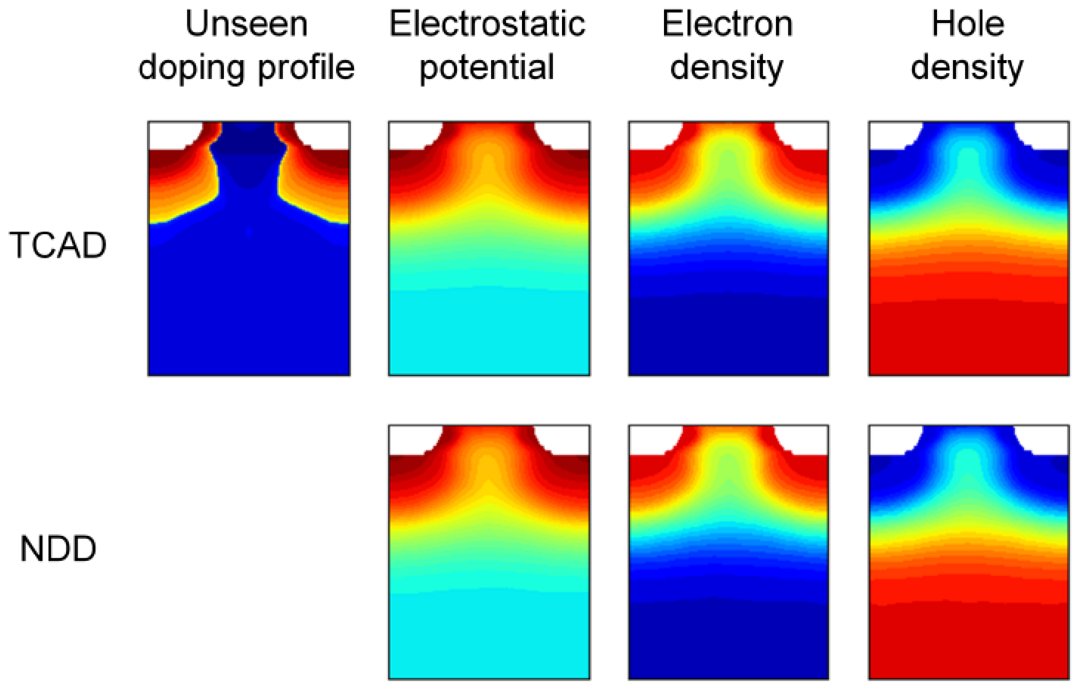
- Surrogate model
  - A simple model to predict important parameters



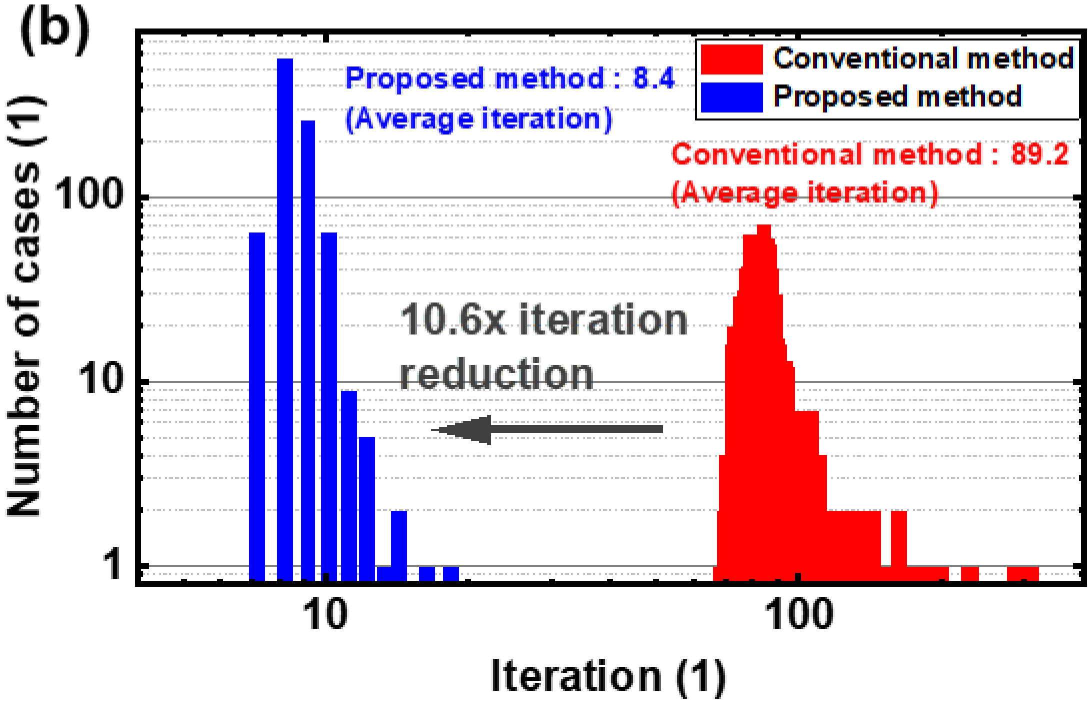
Surrogate model for LDMOSFETs (IIT Gandhinagar)

Recent applications (2)

- TCAD acceleration
  - Prepare a good initial guess for the Newton-Raphson method



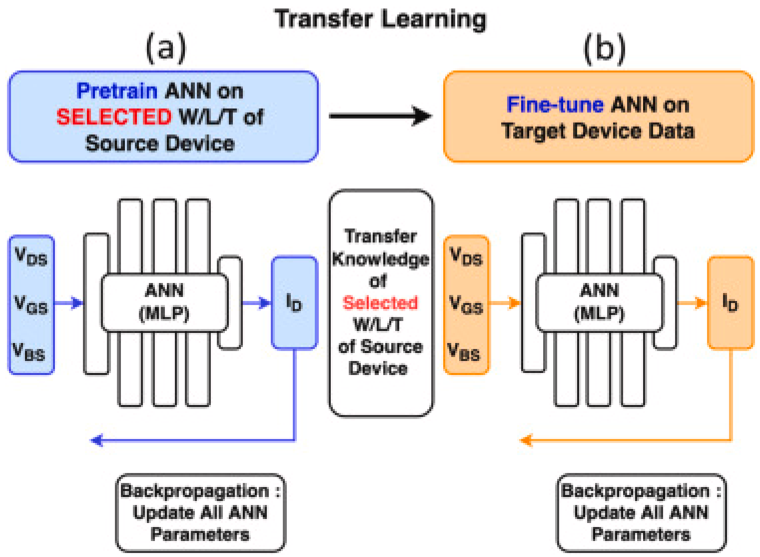
Neural drift-diffusion (Samsung)



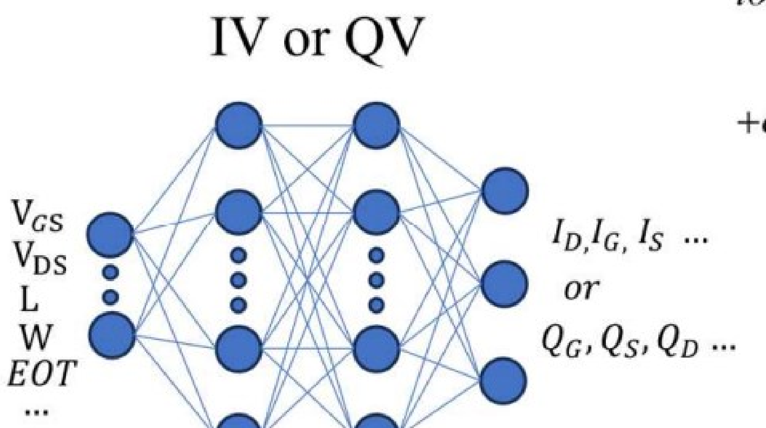
TCAD acceleration (GIST)

Recent applications (3)

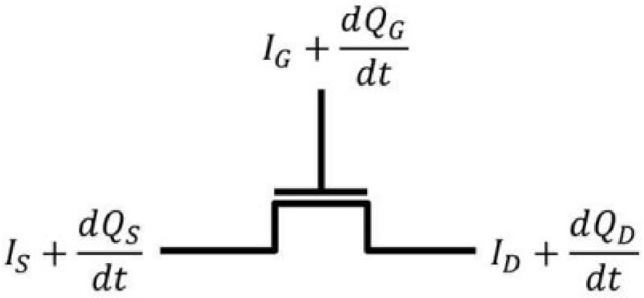
- Compact model
  - BSIM-CMG is a standard model.
  - Recently, BSIM-NN is developed.



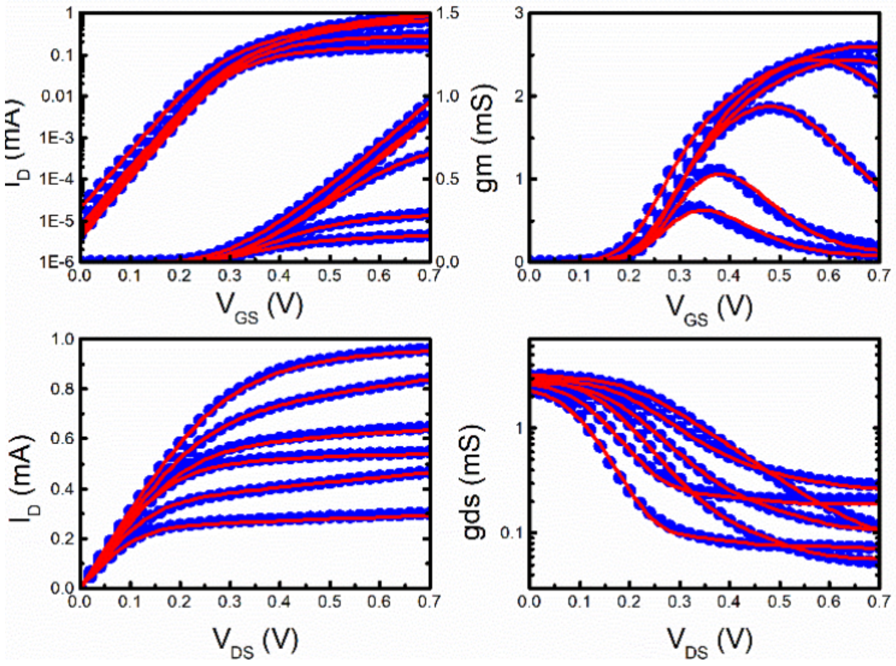
Compact model (Alsemy)



$$loss = a \cdot RMS(y) + b \cdot RMS(\frac{\partial y}{\partial V_{GS}}) + c \cdot RMS(\frac{\partial y}{\partial V_{DS}})$$
$$+ e \cdot RMS(\frac{\partial^2 y}{\partial V_{GS}{}^2}) + f \cdot RMS(\frac{\partial^2 y}{\partial V_{DS}{}^2}),$$



BSIM-NN (UC Berkeley)



MNIST dataset of handwritten digits

- We can download it.
  - The original one, https://yann.lecun.com/exdb/mnist/, do now allow downloading.
  - MNIST in CSV (https://git-disl.github.io/GTDLBench/datasets/mnist_datasets/)

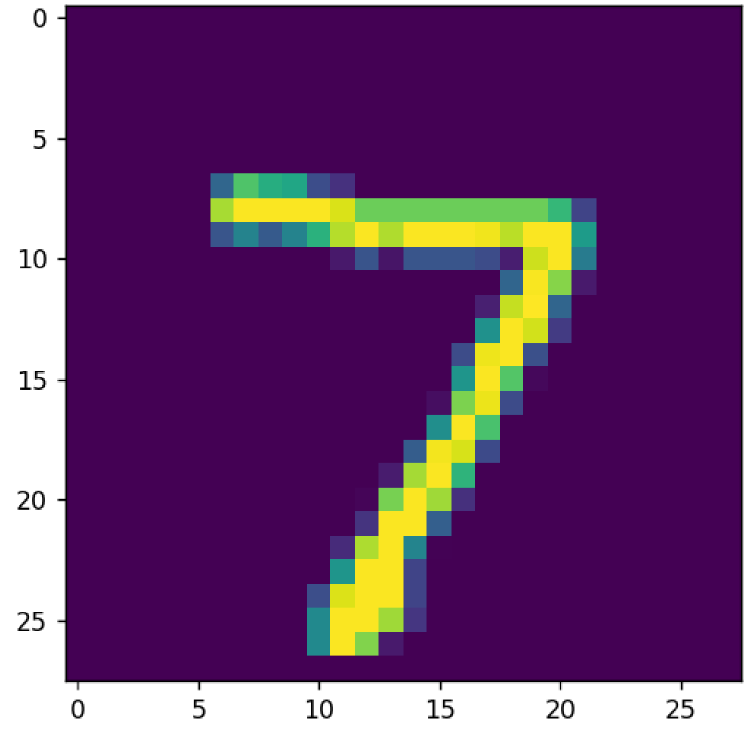
It's 7.

They are placed in the same row. 0 represents white while 255 represents black.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Homework#8

- Due: AM08:00, October 10
- Problem#1
  - Download the MNIST dataset. For your later use, visualize one of them.
  - For example, one of them looks like:



Thank you for your attention!