Schedule

Day1

- **Lecture 1: 1 hr (PS)**
  Short introduction to matrix inversion and generalized matrix inversion. Particularly the introduction of the Moore-Penrose, weighted Moore-Penrose, Drazin, and Group inverse, {i,j,k} inverses, inner inverses, and outer inverses with prescribed range and null space. Least squares solutions and best approximate solution.

- **Lecture 2: 1 hr (PS)**
  Definitions of gradient and Hessian, matrix and vector norms. Basic principles and methods in nonlinear unconstrained optimization, overview of line search methods. Overview of gradientdescent methods, Newton method and quasi-Newton methods, conjugate gradient nonlinear optimization methods.

- **Lecture 3: 1 hr (SSA)**
  Matrix decompositions, Singular Value Decomposition (SVD), Moore Penrose Inverse, computation of condition numbers of a matrix.

Day 2

- **Lecture 4: 1 hr (PS)**
  Recurrent Neural Networks (RNN), Continuous-time RNN, Gradient Neural Networks (GNN), GNN dynamics for solving linear matrix equations AXB=C, GNN for computing generalized inverses of constant matrices, GNN for solving systems of linear equations.

- **Tutorial 1: 2 hr (PS)**
  Simulink as an efficient tool for agile software development. Simulink implementation of GNN for solving the general linear matrix equations AXB=C. Simulink for GNN design for computing the matrix inverse, left and right inverse and the Moore-Penrose generalized inverse. Simulink implementation of GNN models for solving systems of linear equations.

- **Lecture 5: 1 hr (SSA)**
  Computation of SVD, computation of condition numbers, solving least square problems using SVD.

Day 3

- **Lecture 6: 1 hr (PS)**
  Design parameters in GNN evolutionary design. Properties of activation functions in RNN, overview of commonly used activation functions (AFs): linear, bipolar sigmoid,

power AF, power-sigmoid, hyperbolic sine, sign-bi-power, tunable AF. Influence of gain parameters and activations functions on the convergence speed.

- **Lecture 7: 1 hr (SSA)**
  LU and its Sensitivity analysis. Pivoting, matrix rank, matrix range and null space.

- **Tutorial 2: 2 hrs (SSA)**
  Computations of LU and solving systems of equations using forward and backward substitutions.

Day 4

- **Lecture 8: 1 hr (PS)**
  Basic principles of Zhang Neural Networks (ZNN), scalar-valued, vector-valued and matrix-valued error function for time-varying inversion.

- **Lecture 9: 1 hr (PS)**
  Development of ZNN models for solving time-varying scalar-valued reciprocal, vector-valued models for solving systems of linear equations, matrix-valued and matrix-valued time-varying inversion. ZNN for solving over-determined and under-determined systems of linear equations.

- **Tutorial 3: 2 hrs (PS)**
  Implementation of nonlinear GNN and ZNN models based on various activation functions. Numerical experiments and comparison of obtained results regarding influence of the gain parameter and AFs.

Day 5

- **Lecture 10: 1 hr (PS)**
  Solving time-varying inversion problems using scalar-valued, vector-valued and matrix-valued error functions. Computing time-varying generalized inverses.

- **Lecture 11: 1 hr (SSA)**
  QR matrix decomposition and its application to solve least square problems, minimum norm least square solution.

- **Tutorial 4: 2 hrs (SSA)**
  Computation of Reflectors, and rotators, to solve least squares problems using QR factorizations.

Day 6

- **Lecture 12: 1 hr (PS)**
  Application of ZNN in solving time-varying linear matrix equations AXB=C and systems of linear equations Ax=b.

- **Lecture 13: 1 hr (PS)**
  Application of ZNN in solving time-varying linear matrix equations AXB=C, Lyapunov equation AX+XAT+Q=0, Sylvester equation AX+XB=C and non-symmetric algebraic Riccati equation DX+XAXBX+Q=0.

- **Tutorial 5: 2 hrs (PS)**
  Implementation of ZNN models for solving various time-varying matrix equations. Applications in computing generalized inverses and solving linear systems.

Day 7

- **Lecture 14: 1 hr (PS)**
  Correlations between GNN and gradient descent methods of unconstrained nonlinear optimization. Newton iteration for matrix inversion as discretized ZNN continuous-time dynamics. Modifications of GNN and ZNN dynamics arising from gradient and Newton optimization methods.

- **Lecture 15: 1 hr (PS)**
  Survey about nonlinear activations. Overview of main activation functions which enable finite time and predefined time convergence. Finite-time and predefined-time convergence analysis of ZNN design.

- **Lecture 16: 1 hr (PS)**
  Development of ZNN models for solving scalar-valued and matrix-valued time-varying inversion and generalized inversion.

Day 8

- **Lecture 17: 1 hr (PS)**
  Implementation of finite-time ZNN models. Experiments on finite time convergent ZNN dynamical systems and comparison of various activations.

- **Lecture 18: 1 hr (PS)**
  Application of ZNN in approximating time-varying square root, inverse square root, constrained matrix equations and various matrix functions.

- **Lecture 19: 1 hr (PS)**
  Overview of activation functions in RNN, survey on nonlinear activations. Finite-time and predefinedtime convergent ZNN based on nonlinear AFs. Finite-time ZNN design.

Day 9

- **Lecture 20: 1 hr (PS)**
  Existence and representations of solutions to some constrained matrix equations and systems of matrix equations. Computation of various generalized inverses arising from corresponding systems of matrix equations.

- **Tutorial 6: 2 hrs (SSA)**
  Computation of Eigenvalues by using Raleigh Quotient shifts and Wilkinson Shifts.

- **Lecture 21: 1 hr (PS)**
  Modified ZNN dynamical systems, ZNN based on optimization method, ZNN models based on iterative methods, ZNN dynamical systems based on fuzzy and neutrosophic logic systems.

Day 10

- **Lecture 22: 1 hr (PS)**
  RNNs for solving linear inequalities and equations, RNNs for generating LU decomposition, QR decomposition and Cholesky factorization.

- **Lecture 23: 1 hr (SSA)**
  QR-Algorithm for computing Eigenvalues.

- **Lecture 24: 1 hr (PS)**
  Applications of ZNN neural design in mobile object localization, time-varying nonlinear equations solving. Discussion about possibilities for further research.