Feasibility analysis of the cascade regressors based on Deep neural network subjected to the classification problem of the particles' tracks in the STS detector of the CBM experiment

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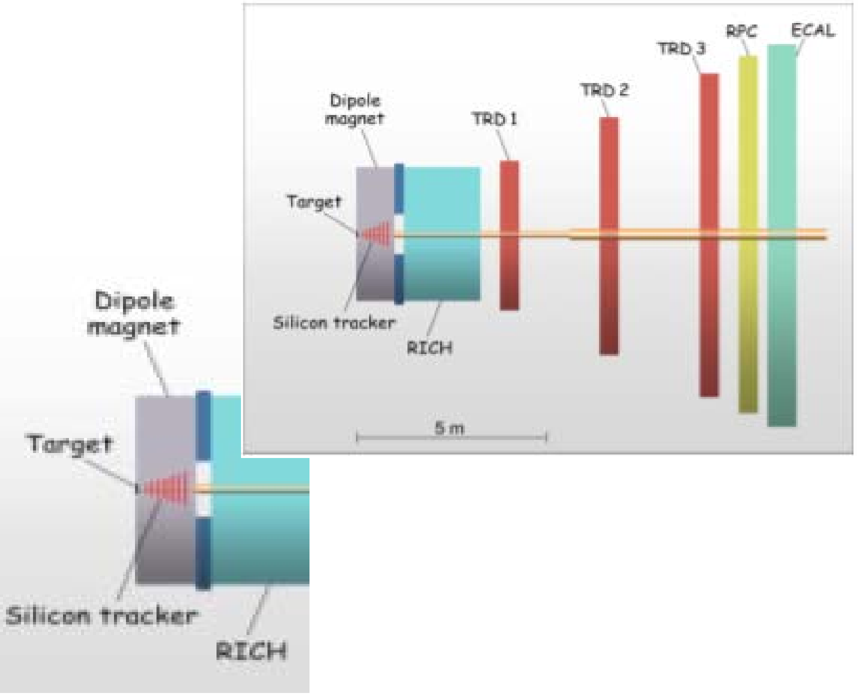
CBM Experiment at FAIR

GOAL
The heavy-ion experiment (CBM) is to investigate the properties of highly compressed baryon matter produced in nucleus-nucleus collisions at the FAIR in Darmstadt, Germany.

EXPERIMENTAL OBJECTIVES
The measurement and collection of extremely rare signals of hadrons, electrons and photons emitted in an environment typical for heavy-ion collisions.

REQUIREMENTS
The necessity of the high reaction rates & long data taking periods requires for:
- identification of electrons (pion sup. factor 1e+5);
- identification of hadrons with large acceptance;
- determination of the primary and secondary vertexes (accuracy of 30 μm);
- high-speed trigger and data acquisition;
- tolerance towards delta-electrons.

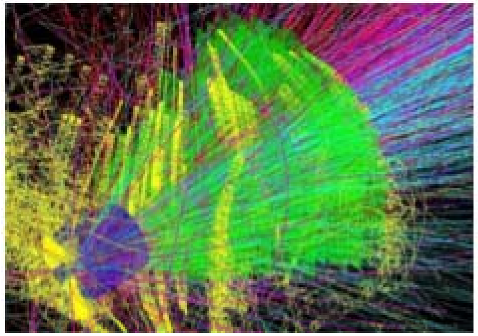
ENVIRONEMENTS
Target Au+Au (25Gev) reaction rate 10 MHz
Beam intensity of 1e+10 particle/sec.



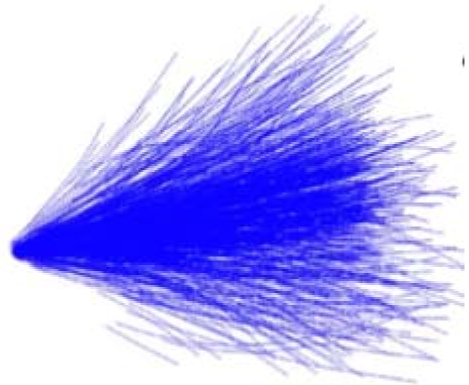
OUR FOCUS
Inside the dipole magnet gap are the target and a 7 plane Silicon Tracking System (STS) consisting of pixel and strip detectors. It is intended for the reconstruction tracks of particles.

Event Reconstruction

EVENT RECONSTRUCTION
Reconstruction of all events (central Au+Au collision) based on:
- **track finding** of charged particles from the hits registered by the STS detectors;
- **vertex & track fitting** procedure intended to definition of the decay vertexes of the particle assigned to each track.



PROBLEM
The large track densities (500-700 tracks) together with the non- homogeneous magnetic field influence makes the reconstruction of events complicated.



TRACK FINDING & FITTING APPROACH
The track finding algorithm based on the cellular automatons method that reconstructs tracks in the inner tracker of the CBM experiment.
Track and vertex fitting procedures are based on the Kalman filter approach.

Track r $(x, y, tg_x, tg_y, q/p)$

⇩

Vertex r $(x, y, z, p_x, p_y, p_z, E, s)$

FEAIBILITY TEST
The algorithms have shown **high reconstruction efficiency** and low ghost rate. Moreover they demonstrate **acceptable time consumption and robustness** with respect to large track densities.

Event Classification

NECESSITY

The recovering of the mother- daughter dependences is necessary after the definition of the production & decay vertexes. Particularly that task is solved via vertex fitting algorithm via Kalman filtering.

Track r $(x, y, tg_x, tg_y, q/p)$

Vertex r $(x, y, z, p_x, p_y, p_z, E, s)$

Event r $(x, y, z, p_x, p_y, p_z, E, s, t)$

TASK

The vertex fitting algorithm doesn't take into account that fact that **the accelerated ion beam won't have a bunched structure**. It means that we cannot assign the reconstructed graph of the mother-daughters relations between particles to the certain event.

APPROACH

Thus within current work **the neural network** based solution is suggested to resolving **a distribution of events in time and classification** of them, where:

- the input layer of neurons is the 9D production vertex state vector;
- the output layer is a prediction on vertex which corresponds to the certain event.

SOLUTION

Here is suggested the solution for regression of the vertex position of the daughter particles according to the trainable model of decays of the certain event.

Deep Learning

Deep learning technique is a powerful approach for training networks that allows to effective & robust solution for a wide range of tasks and fields.

BENEFITS

- the universality of neuron nets;
- a machine learning in the depth: multi layered-nets;
- a parallel computation: fast forward propagation;
- a huge number of the training parameters: generalization ability;
- an integration ability: combining the different kinds of neural nets;
- the one updating rule for the all layers & nets;

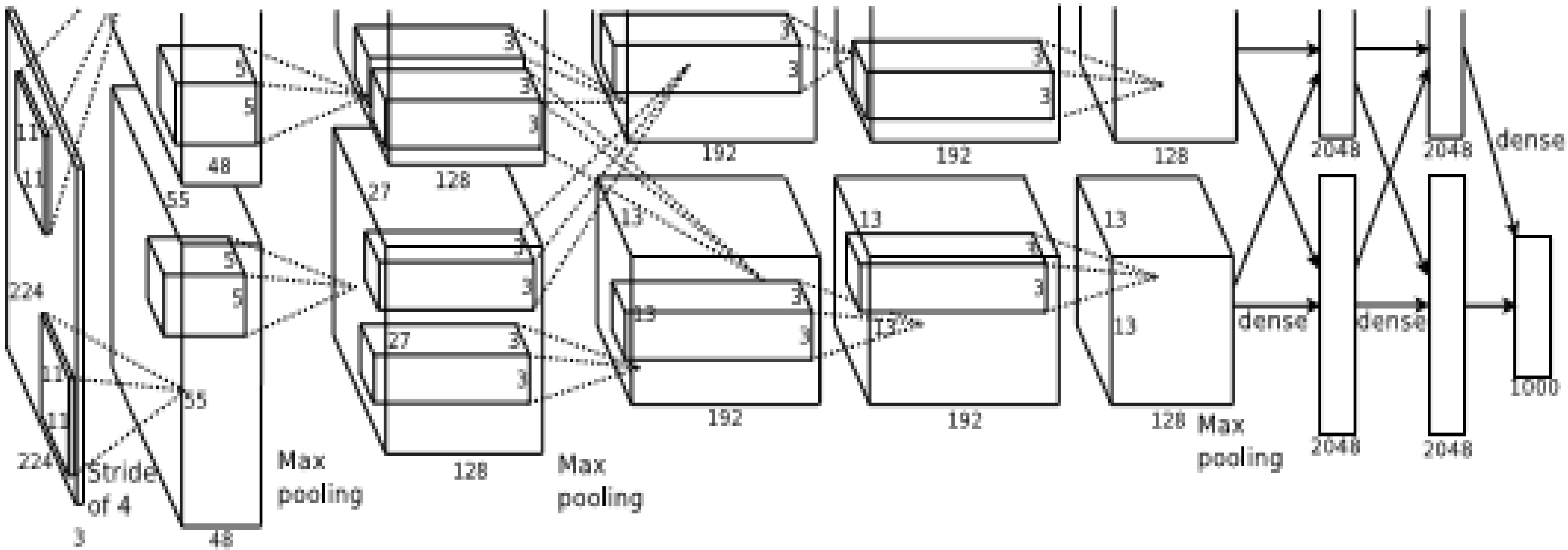
The last 5-6 years the state of the art results for the classification, prediction & regression task belong to the deep learning based solutions.

$$\delta^L = \nabla_a C \odot \sigma'(z^L)$$

$$\delta^l = ((w^{l+1})^T \delta^{l+1}) \odot \sigma'(z^l)$$

$$\frac{\partial C}{\partial b^l_j} = \delta^l_j$$

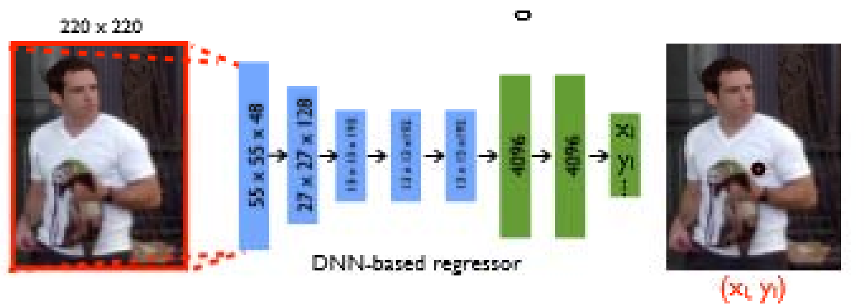
$$\frac{\partial C}{\partial w^l_{jk}} = a^{l-1}_k \delta^l_j$$



Feasibility Test

BACKROUND

Current solution based on the existing state of the art works aimed to computer vision field, where the Deep Neuron Net (DNN) based regressors were used to predict the position of each human body part in the natural image.



TEST

To perform the feasibility check a same regression of parts were developed and compared with the prototype. That choice was caused by the following reasons:

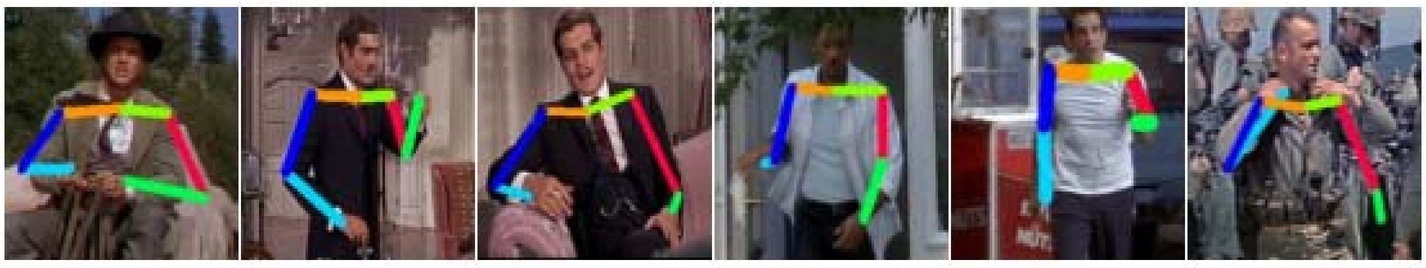
- perception human body graph of parts is a similar for this work task;
- the input and output layer takes the 3D data **r(x, y, E)** and generates the decision on 2D positions of parts. The dimension of the data is easy to visualization, thus it will be simple to check & tunning of the net.

DNN REGRESSOR

The developed neural net consists of the combination of the several kinds of the nets:

- the 5 Convolution NN layers;
- the 2 Fully Connected NN layers;
- the last is an output layer with loss function.

$$\theta_s = \arg\min_{\theta} \sum_{(x,\mathbf{y}_i)\in D_A^s} \|\mathbf{y}_i - \psi_i(x;\theta)\|_2^2$$



Thank You