Generating media content using methods of Machine Learning

Nemanja Mićović - Faculty of Mathematics, University of Belgrade
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Introduction

- Teaching assistant at *Faculty of Mathematics, University of Belgrade*
  - Taught Python at 3 courses at faculty:
    - Artificial Intelligence
    - Programming Paradigms
    - Translation of Programming Languages
- Machine learning, Python and Vim enthusiast
- Website: `www.matf.bg.ac.rs/~nemanja_micovic`
- Email: `nemanja_micovic@matf.bg.ac.rs`
- And I like ninjas also :)

MACHINE LEARNING AND APPLICATIONS GROUP

- Based at Faculty of Mathematics
- Includes researchers, students and practictioners from various research institutions and industry
- Led by professor Mladen Nikolić[1]
- Lectures/talks and practical sessions are held on every 2 weeks
- MATF Machine Learning Group: `machinelearning.math.rs`
  - Feel free to visit our sessions and join in!

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[1]web: poincare.matf.bg.ac.rs/~nikolic email: nikolic@matf.bg.ac.rs

Student organization for Programming

R/SK⟩

- risk.matf.bg.ac.rs
- Originally founded by me in 2016
- Now run by me and a team of friends/students
- Supported by MATF Department of Informatics and Computer Science
- Theoretical talks/lectures held on every 2-3 weeks
- So far we had topics like: Flask, Unity3D, Android app development, Bash, Jekyll, Graphics on Web, Git, GitHub and open source
- Feel free to join in and give a talk or idea for a project (write me on email)!

Towel day

Happy Towel Day

- Towel Day is celebrated every year on 25th of May
- It's a tribute by fans to author Douglas Adams
- The legend of number 42 comes his book *The Hitchhiker's Guide to the Galaxy*
  Towel is the most massively useful thing an interstellar hitchhiker can have.

The Towel

A towel, [The Hitchhiker's Guide to the Galaxy] says, is about the most massively useful thing an interstellar hitchhiker can have. Partly it has great practical value. You can wrap it around you for warmth as you bound across the cold moons of Jaglan Beta; you can lie on it on the brilliant marble-sanded beaches of Santraginus V, inhaling the heady sea vapors; you can sleep under it beneath the stars which shine so redly on the desert world of Kakrafoon; use it to sail a miniraft down the slow heavy River Moth; wet it for use in hand-to-hand-combat; wrap it round your head to ward off noxious fumes or avoid the gaze of the Ravenous Bugblatter Beast of Traal (such a mind-boggingly stupid animal, it assumes that if you can't see it, it can't see you); you can wave your towel in emergencies as a distress signal, and of course dry yourself off with it if it still seems to be clean enough.

Generating media

- Fun
- Aiding artists
- Giving us deeper understanding of media
- Replacing artists?[2]
- Research purposes

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[2]Insert your paranoic AI comment here

Where can we apply this?

- Image generation
- Text generation
- Audio generation
- Frontend generation
- Optimizing the design process of systems
- Brainstorming

Where is Python in this?

- Everywhere
- Python today is the most popular language for data science
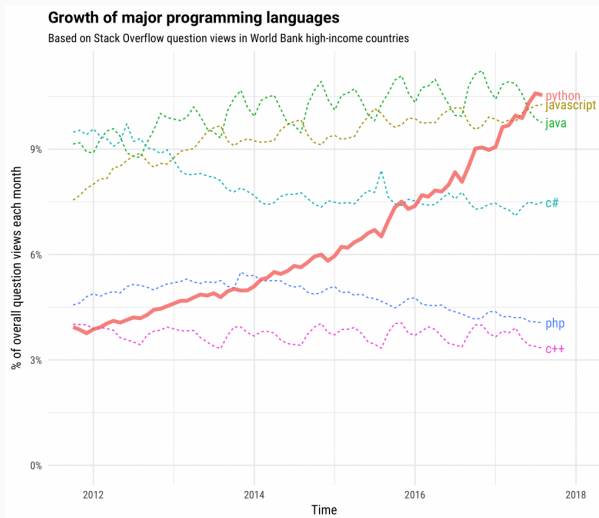- On GitHub it's the 2nd most popular language overall

Python popularity

Figure 1: Original article: `stackoverflow.blog/2017/09/06/incredible-growth-python`
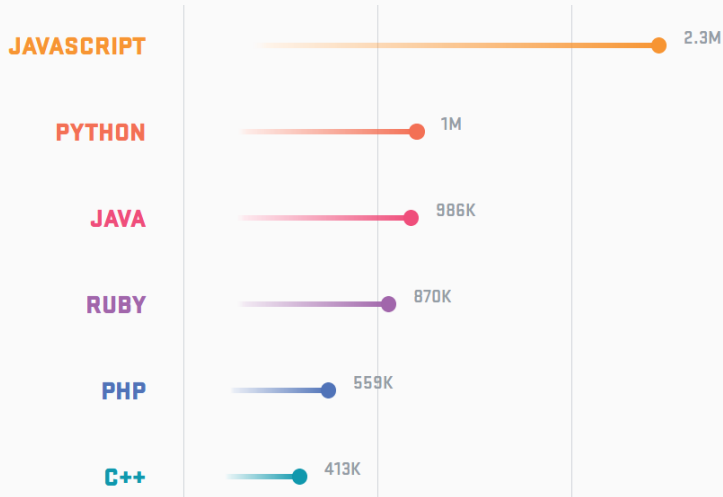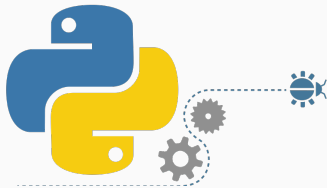
Python popularity

Figure 2: Python on GitHub (opened pull requests)

Python in Machine Learning and Data Science

- Everywhere!
- Simple syntax and lots of libraries allow you to completely focus on your project
- For calculation heavy things, it's only used as a frontend (ex. `tensorflow`)
- Machine Learning: `tensorflow`, `keras`, `sonnet`, `scikit-learn`, `theano`, `nltk`
- Data Science: `numpy`, `scipy`, `matplotlib`, `pandas`, `seaborn`, `bokeh`, `gensim`, `statsmodels`
- And of course, project `Jupyter` with `Jupyter Notebook` and `Jupyter Lab`

How does it look - generating images?

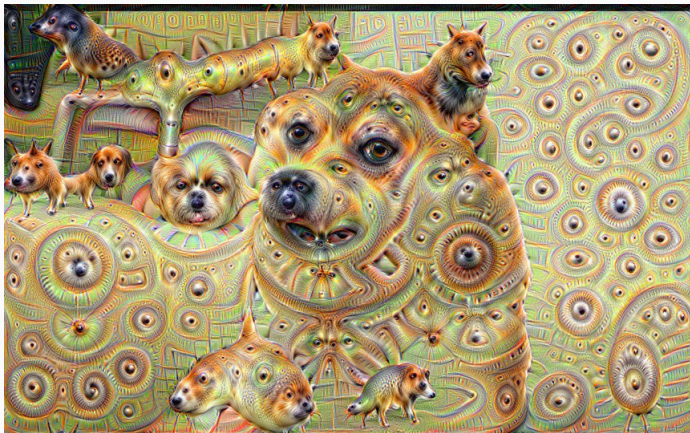**Figure 3:** DeepDream applied to random person

Figure 4: DeepDream again

Generating code?

```
static void action_new_function(struct s_stat_info *wb)
{
    unsigned long flags;
    int lel_idx_bit = e->edd, *sys & ~((unsigned long) *FIRST_COMPAT);
    buf[0] = 0xFFFFFFFF & (bit << 4);
    min(inc, slist->bytes);
    printk(KERN_WARNING "Memory allocated %02x/%02x", "original MLL\n"),
    min(min(multi_run - s->len, max) * num_data_in),
    frame_pos, sz + first_seg);
    div_u64_w(val, inb_p);
    spin_unlock(&disk->queue_lock);
    mutex_unlock(&s->sock->mutex);
}
```

Generating Shakespeare style?

JULIA

What shall by these things were a secret fool,
*That still shall see me with the best and force?*

Second Watchman

Ay, but we see them not at home: the strong and fair of thee,
The seasons are as safe as the time will be a soul,
That works out of this fearful sore of feather
To tell her with a storm of something storms
That have some men of man is now the subject.
What says the story, well say we have said to thee,
That shall she not, though that the way of hearts,
We have seen his service that we may be sad.

What about sound?
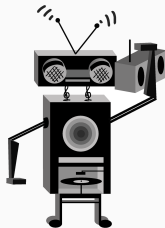
- Important article 1[3]
- Important article 2[4]
- Beatles style song[5]
- Let's hear it

[3] medium.com/artists-and-machine-intelligence/neural-nets-for-generating-music-f46dffac21c0
[4] http://www.hexahedria.com/2015/08/03/composing-music-with-recurrent-neural-networks/
[5] youtube.com/watch?v=LSHZ_b05W7o

Introduction to ML

- ML is a very complex subject
- Very difficult to cover a lot in 1 talk
- So we will only stick to concepts

Figure 5: How many people know where this robot is from?

Some result of Machine learning

- 1992 - TD-Gammon, computer program developed by Gerald Tesauro able to play backgammon
- 2011 - IBM's Watson wins in quiz *Jeopardy!*
- 2012 - Google X creates system able to recognize cats on video recordings
- 2015 - Classification error for images reduced to 3.6% (5-10% is the error made by humans)
- 2016 - Google creates `AlphaGo`, agent able to play Go who has beaten the world champion 4:1
- 2017 - `AlphaGo` plays against its 2016 version and wins 100/100 games, human players fail to understand some of the strategies used by the agent
- 2017 - `OpenAI` creates a bot which beats world professionals in 1v1 matches in Dota 2

Where is ML applied?

- Autonomous driving
- Bioinformatics
- Social networks
- Algorithm porfolio
- Playing video games
- Image classification
- Recognizing handwritting
- Natural language processing
- Generating optimization algorithms
- Generating images

- Computer vision
- Detecting credit card frauds
- Data mining
- Medical assistance and assesment
- Marketing
- Targeted marketing
- Controlling robots
- Economy
- Speach recognition
- Recommendation systems

Types of ML

- Supervised learning
- Semi-supervised learning
- Unsupervised learning
- Reinforcement learning

Supervised learning

- Area with the most scientific breaktrough
- We are given **attributes** x_1, x_2, ..., x_n with **target** value y
- Our goal: predict y for some given values of x_1, x_2, ..., x_n
- For this, we construct a **model** f for which we hope that it approximates y accurately:

$$f(x_1, x_2, ..., x_n) \approx y$$

- Accurately means that we try to *minimize* the error **model** f makes

Supervised learning - classification

- Target variable y is discrete
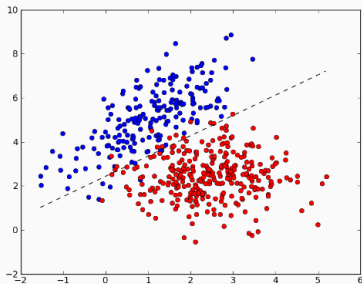- Example: Is a money transaction fraud or not?

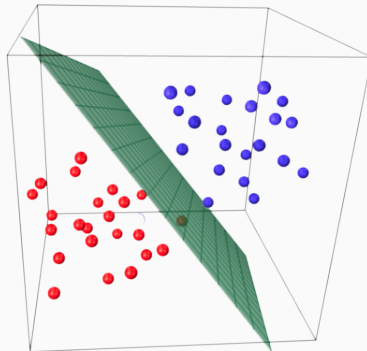**Figure 6:** Classification example 1

Figure 7: Classification example 2 (Sachin Joglekar's blog)

Supervised learning - regression

- Target variable y is continous
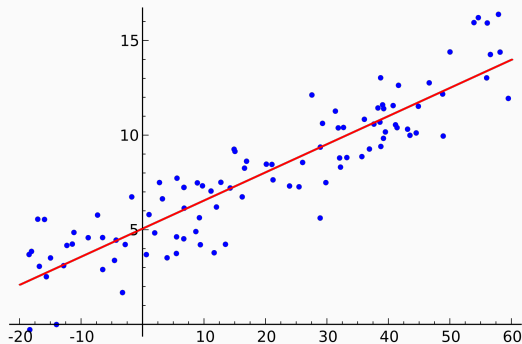- Example: trying to predict temperature y using pressure x

Figure 8: Linear regression example

Supervised learning - error

- In the previous pictures, note that the model has a mistakes sometimes!
- We may think that we want a model that **never** makes a mistake?
- But do humans never make mistake?
- Solving math problems, recognizing objects on images, writing music. . .
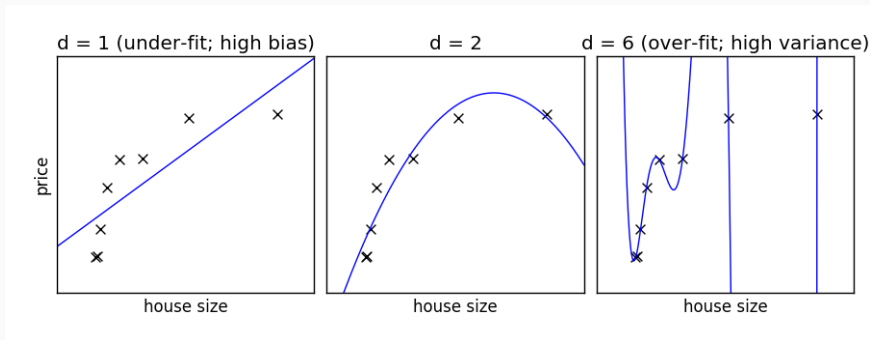
Supervised learning - underfitting and overfitting

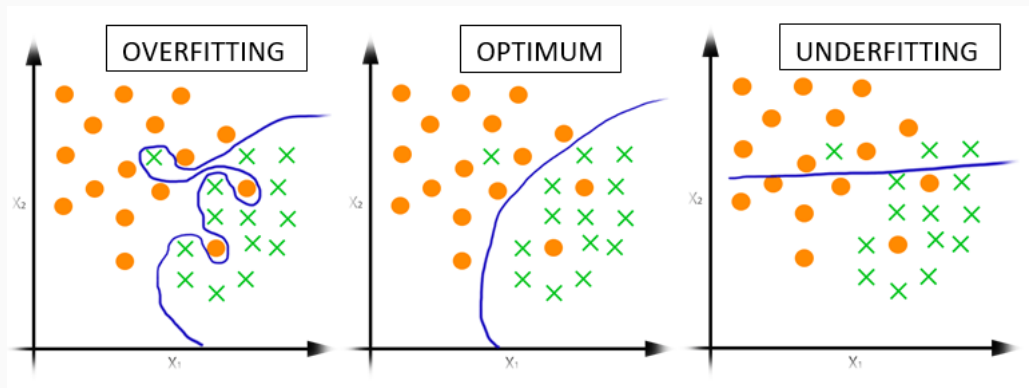**Figure 9:** Regression underfitting and overfitting

Figure 10: Classification underfitting and overfitting

Supervised learning - discovering underfitting and overfitting

- By looking at the image?
- Rarely possible because we are training high dimensional models which we can't visualize
- But let's split our dataset on `train` and `test` sets
- Train only on the `train` set
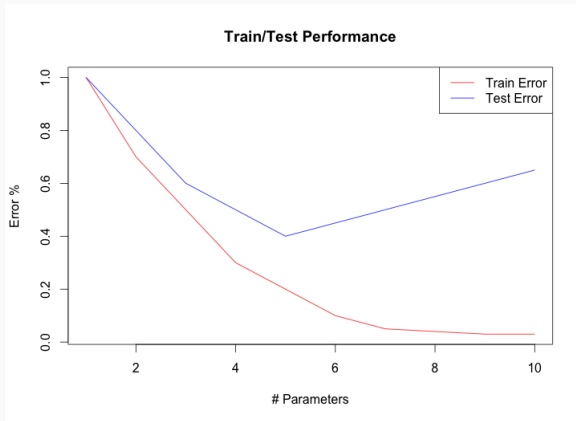- Calculate the errors on both sets

Figure 11: Train vs test error

Neural network

- Inspired by human mind
- Neurons are **activated** by **some** input
- Their mutual combinations are used to express complex concepts/functions

Neural network

- Universal function approximators
- Massively used for problems of classification and regression
- Archived amazing results in the field
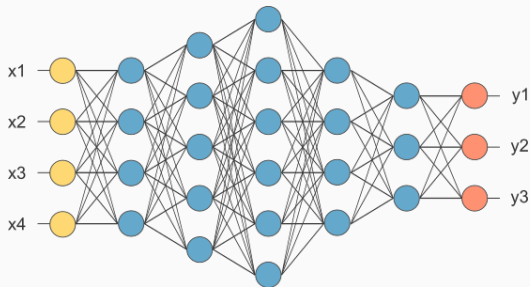- Not so new, developed in 1940s, 1950s and 1960s

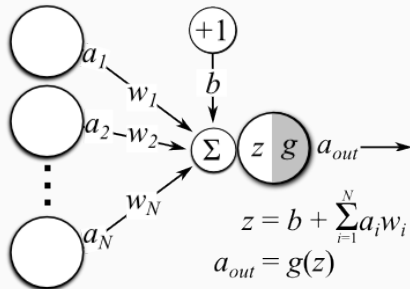**Figure 12:** Neural network diagram

Neural network neuron

Terminology:

- Neuron input: a_i
- Neuron weights: w_i
- Bias: b
- Nonlinear function: g

Neuron output is calculated according to formula:

$$a_{out} = g(b + \sum_{i=1}^{N} a_i w_i)$$

$$z = b + \sum_{i=1}^{N} a_i w_i$$

$$a_{out} = g(z)$$

Training

- A process of trying to **minimize** the error function
- For example, in regression problem we often use *mean squared error (MSE)*:
- This function is determined by model **weights** w_i that define our model f

$$Loss(w) = \frac{1}{N} \sum_{i=1}^{N} (y_i - f_w(x_i))^2$$

- Training (learning) is the process of trying to alter **weights** w_i and minimize the error function
- There are multiple optimization algorithms that are used in ML
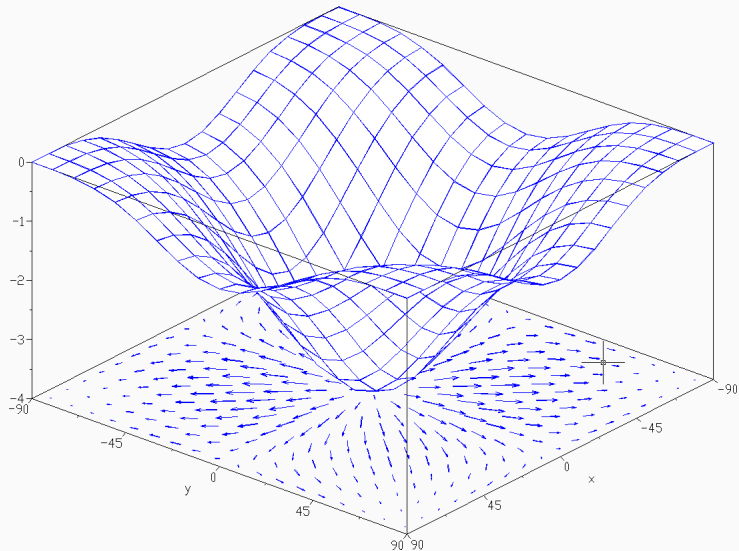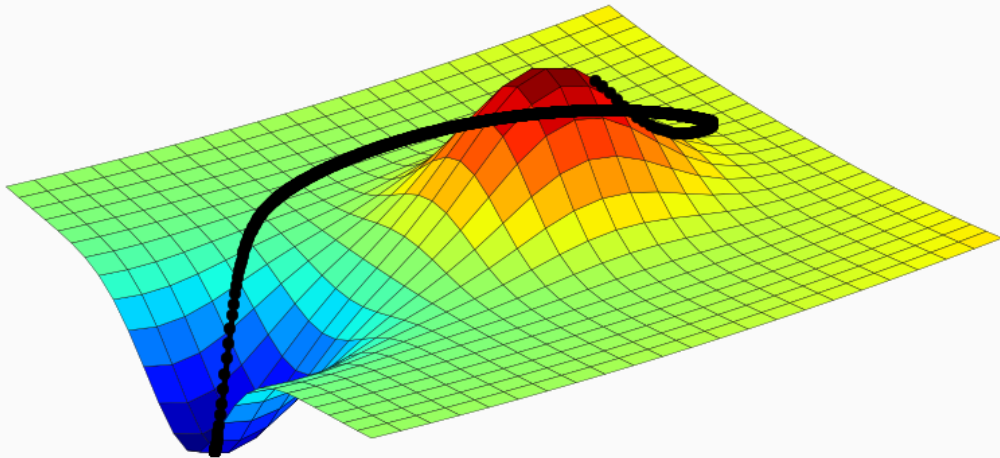
Figure 14: Gradient descent over error function

Training - idea

- By using function gradient we have a **general** direction in which to go to reduce the error
- Optimization algorithm tries to alter model parameters w_i and get a smaller error
- Lots of calculation is based on `Linear Algebra`
- That means we can write lots of things in a matrix notation
- This allows us to **parallelize** it quite a lot on a GPU

Generating Serbian epic poems (SEP)

Kneževa večera

"Zdrav, Milošu, vjero i nevjero!
Prva vjero, potonja nevjero!
Sjutra ćeš me izdat' na Kosovu,
I odbjeći turskom car-Muratu!
Zdrav mi budi, i zdravicu popoj,
Vino popij a na čast ti pehar!"

Skoči Miloš na noge lagane,
Pak se klanja do zemljice crne:
"Hvala tebe, slavni knez-Lazare,
Hvala tebe na tvojoj zdravici,
Na zdravici i na daru tvome:
Al' ne hvala na takvoj besjedi!
Jer, tako me vjera ne ubila!
Ja nevjera nikad bio nisam,
Nit' sam bio niti ću kad biti,
Nego sjutra mislim u Kosovu
Za hrišćansku vjeru poginuti;
Nevjera ti sjedi uz koljeno,
Ispod skuta pije hladno vino!"

SEP dataset

- We shall use the website https://sr.wikisource.org
- Create an html parser in Python
- Modules we'll use:
    - re
    - urllib
- We'll scrap all the SEP from website
- Code is available in Jupyter notebook named epic_song_parser.ipynb
- Since there is no similar dataset, I've published dataset at
  https://github.com/termNinja/serbian-epic-poem-dataset
- Dataset consists of 118 poems and over 20000 lines from poems themselves

- Teach an **recurrent** neural network to write poems!
- We shall use keras library on top of TensorFlow
- Image ?? shows the architecture of network we'll use

SEP dataset - training details

- Training an neural network is not an straightforward thing
- Lots of metaparameters to tweak
  - `optimizer`
  - `batch_size`
  - `architecture`
  - `epochs`
  - `hidden_layer_size`
  - `dropout_rate`
  - `loss`
  - `learning_rate`
  - `momentum`
- And it can take some time!

SEP dataset - training details

- My home PC:
  - Intel i7 7700k
  - 16GB of RAM
  - Nvidia GeForce 1060 GTX 6GB with 1280 CUDA cores
- Training took: $\sim$ 3 hours!
- Parameters that were chosen:
  - `batch_size`: 256
  - `epochs`: 100
  - `optimizer`: Adam
- Model:
  - `LSTM` with 256 units
  - `Dense` with size of 115 with `softmax` (115 unique characters were in dataset)
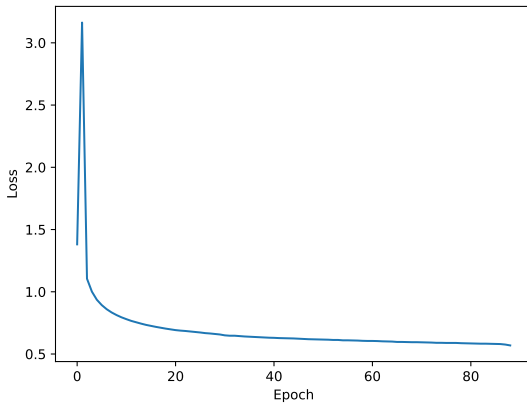 - Overall, a very simple model

Figure 15: Loss change history

SEP dataset - after 1 epoch

Pa od bile na konja na bije,
Pa od bile na konja na bije,
Pa od bile na konja na bije,
Pa od bile na konja na bije,
Pa od bile na konja na bije,
Pa od bile na konja na bije,
Pa od bile na konja na bije,
Pa od bile na konja na bije,
Pa od bile na konja na bije,
Pa od bile na konja na bije,

SEP dataset - after 10 epochs

pa on ode dvanaest vojvoda,
ona bi mi pod bijelo lice,
Pa on ode na bijelu kulu,
Pa on ode na bijelu kulu,
Pa on ode na bijelu kulu,
Pa on ode na bijelu kulu,
Pa on ode na bijelu kulu,
Pa on ode na bijelu kulu,
Pa on ode na bijelu kulu,
Pa on ode na bijelu kulu,
Pa on ode na bijelu kulu,

i sa njime Miloš Vojinović:
„Jakuo mi, moj mili milosno,
Da je mene na mejdan iziđe,
Al' ne moja dvore poslušati,
a ne znade na noge lagane,
pa on ode na bijelu kulu,
posadi ga na bijelu kulu,
posla zašta na noge lagane,
pa on ode na bijelu kulu,
posadi ga na bijelu kulu,

I pod njima svadbu u gorijemu,
pa odoše dvoru bijelome,
pa on pije svoje devojka svojoj,
A za viču svome gospodaru:
„O moj sine, Carević-Stevane!
"Da si mene na devet godina,
"Da se nisam na dvore podignuti,
a na gradu bijelu Prilipu,
i povede svojega Turaka,
pa on pita visoki

„Sestrice mu i ne brdi carstvo,
da mi nije odmah pod ordiji,
"Da iziđe u bijelu crkvu,
"Pa on ode na Kosovu carstvo,
da pogledaš starog Jug Bogdana,
pa ga vide Vukašina kralja,
pak se vrati visoki Stevane,
On je pošta vina udaraše,
Pa izvadi konja i sokola,

Sveti Jovan od zemlje na noge,
Sve pod njima konja privatiše,
Pod Stjepana grada bijeloga,
Pa podiže sirotinja rodila,
Pa pogubi pod svoje postajemo,
ne bi li me provizur-Mijkom.
Kad su bili na noge lagane.

Sveti Jovan otisnu jabuku,
Ona pade moru u dubine,
Tople su ga suze propanule,
No mu care riječ progovara:
"A ne plači, dragi pobratime!
"Ne moj mene ugrabit' korunu,
"Ja ću tebe izvadit' jabuku."

SEP dataset - and a bit more of poems

Zaludu ti pod bijelu kulu,
Pa on stade pod bijelu kulu,
Pa on vidi po gori zelenoj,
Na konjici svoje devojka krajina¿'
Al' besedi Kraljeviću Marko:
"Bogom brate, Kraljeviću Marko!
"Te otide ni britko svatove,
Pa pogleda na kome je carstvo,
ode pravo bijelu Prilipu".

SEP dataset - and some not so glorius generated poems

Zaludu ti pod bijelu kulu,
Pa on stade pod bijelu kulu,
Pa on vidi po gori zelenoj,
Na konjici svoje devojka krajina?"
Al' besedi Kraljeviću Marko:
"Bogom brate, Kraljeviću Marko!
"Te otide ni britko svatove,
Pa pogleda na kome je carstvo,
ode pravo bijelu Prilipu
I pod sebe od zlata košulja,

Pa on skoči na konja viteza,
I od zlata i do konja dana,
Pa on skoči na konja viteza,
I od zlata i do konja dana,
Pa on skoči na konja viteza,
I od zlata i do konja dana,
Pa on skoči na konja viteza,
I od zlata i do konja dana,
Pa on skoči na konja viteza.

Making neural network dream

Convolutional neural networks

- Types of neural networks used for signal processing
  - image classification
  - object recognition
  - audio synthesis
- Core idea: make neural network **learn** the features
- TODO TODO TODO TODO TODO

DeepDream

- Originally developed by Google (Alexander Mordvintsev)
- Uses a trained convolutional neural network for image classification
- Think of it like you watching the clouds and trying to make out the shapes
- When you think you spotted a shape of a cat, you **tweak** the cloud to resemble it more
- Now you are more confident you are seeing a cat
- You can tweak the cloud again to resemble the cat more
- Now you are even more sure you are seeing a cat

DeepDream

- Process is similar to **backpropagation** but instead of **weights** we adjust the **input** (image)
- Network is run in **reverse** trying to **enhance** the image on the input
- This enhances the **concepts** covnet **believes** it has seen
- Which leads us to the **appearance** of **patterns** network has trained to recognize

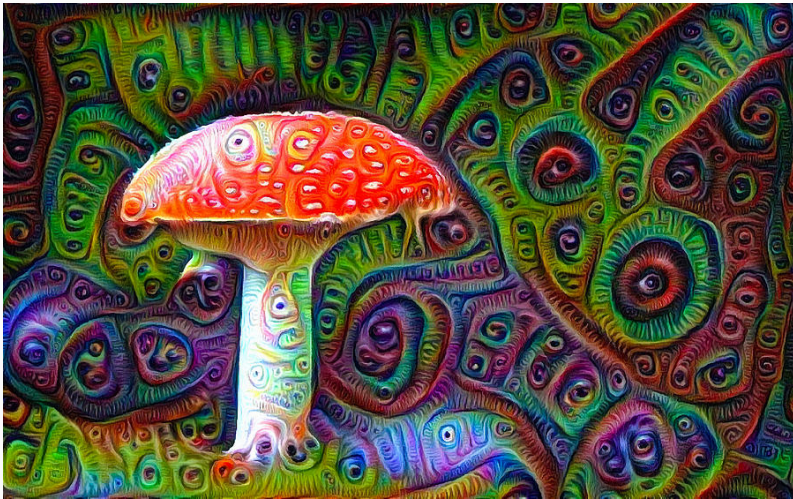**Figure 16:** DeepDream applied to random person

DeepDream examples

DeepDream examples

DeepDream examples

Questions?