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# Using GANs to optimize Pose Estimation on Art Collections

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Master of Science in Information Engineering Technology

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# Preface

I've been interested in Art my entire life. In fact, I've a degree in the Fine Arts from LUCA School of Arts. There, I was known for my technical ability and one of my professors at the time asked me why I didn't do anything with that in my artworks. That remark has since stuck with me and was part of my motivation to apply for readmission for my Master of Science. With all the advancements in AI, I started thinking more and more about doing work with that. Like Matisse and Turner, I'm not satisfied with the tools available, but want to create my own.

It was therefore to my delight that I was able to work on this thesis which has provided me the opportunity to acquire more insight in the subject. I would like to thank my supervisors Dieter De Witte and Steven Verstockt for this wonderful opportunity, and my counsellor Kenzo Milleville for his great guidance. As well as all the other people at IDLab for their feedback. I also want to thank Karine Lacaracina, Lies Van De Cappelle and the other people at RMFAB for providing help with the artistic sensibilities of the thesis.

Enjoy the read,

Tristan Verheecke  
Ghent, June 2023

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Fig. 1. Example of a figure caption.

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#### ACKNOWLEDGMENT

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# List of Acronyms

## A

ASMs Active Shape Models , 3

## C

cGAN conditional Generative Adversarial Network , 5  
CNN Convolutional Neural Network , 3, 4  
CPMs Convolutional Pose Machines viii, 4, 9

## G

GAN Generative Adversarial Network , 5

## H

HPE Human Pose Estimation , 2–5

## M

MPII Max Planck Institute for Informatics viii, 6

## R

RMFAB Royal Museums of Fine Arts of Belgium , 1

S

SMPL

Skinned Multi-Person Linear ,3

# List of Code Fragments

4.1      Functie is_isbn . . . . .	16
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# 1

## Introduction

### 1.1 Problem definition

To make art collections more accessible, museums put a huge effort in digitalizing their catalogue. However, they don't contain much metadata about the content and it is time-consuming to enhance them manually. To make this process easier, they want to utilize computer vision. Art collections (paintings, statues, drawings, etc.) turn out to be less interpretable by the algorithms that were developed for photography over the last few decades. These scan the images in search of recognizable objects and add their labels to the metadata. Even the latest state-of-the-art technology (Yolov5), struggles to recognize objects when pointed at a painting in a museum. A solution may be to start over and have paintings annotated by humans.

This has been done in 2 recent projects: Saint-George-On-A-Bike [9] and INSIGHT [10]. However, paintings are very complex and manual annotation doesn't scale and is very expensive. For example, 10,000 paintings were annotated by Royal Museums of Fine Arts of Belgium (RMFAB) with no clear return on investment. They spent a year on this and this is not something they want to repeat. How can we automate this process and ensure that state-of-the-art computer vision models give good results on paintings and artworks?

Specifically for this thesis, pose estimation will be investigated.

# 2

## Literature study

We will first examine the effectiveness of existing models on a collection of paintings from 2 different movements. For this we will need to have a pose estimator, a style transformer and a collection of test data.

A first method: We will first convert the test data with the style transformer to a painting and then we will apply pose estimation. The test data will have coordinates of the joints, which we will compare with the results of the pose estimation. However, the joints are of the original image. How do we convert those coordinates to map to the styled image? Problem: This method does not use any real paintings and will be susceptible to the accuracy of the style transformer.

A second method: We can apply pose estimation to real paintings and then convert them to a realistic image with style transfer. We can then use pose estimation to the realistic images and compare them with the style transformed results. This will also require a way to map the results of the real painting to that of the style transformed. Problem: While we're using real paintings now, the results will still depend on the accuracy of style transformer.

A third method: We can annotate the paintings ourselves and use pose estimation to assess the pose estimation algorithms. Problem: We must annotate the paintings ourselves.

### 2.1 Human Pose estimation

Human Pose Estimation (HPE) aims to detect human features from input data such as images and videos. It's an elementary part of computer vision with many applications among which are human action recognition (sign language), human tracking (surveillance), and human-computer interaction (video games). This is an extensively researched area with a diverse range of different techniques. This chapter will try to give an overview of all the many challenges and proposed solutions. The focus will be on deep learning models, which have surpassed classical solutions significantly. Specifically, around 2D monocular HPE.[11][3][12][13]

The human body has a high degree-of-freedom due to all the limbs, self-similar parts and body types, which may cause self-occlusion or rare/complex poses. The variations in configuration are made even larger due to clothing, lighting, foreground occlusion, as well as viewing angles and truncation, among others, as shown in fig. 2.1. This makes HPE one of the most difficult tasks in computer vision.[14][2]

#### 2.1.1 Representation

An important factor in HPE is how the pose will be represented. Depending on the needs of the problem you can have a skeleton-base, contour-base, or volume-base solution.2.2[2]

### **Skeleton-based model**

The skeleton is build of a tree-structured set of keypoints that represent the joints of the human body. These can be explicitly described by their coordinates in 2D or 3D space.[4] More suitable for a Convolutional Neural Network (CNN) however is a heatmap which constructs a 2D Gaussian kernel around a keypoint.[12][15] They are easily implemented and became the dominant representation. While the skeleton-based model is a compact and flexible representation it suffers in this aspect by not being able to hold texture or shape information.[3]

### **Contour representation**

To capture the shape of the body parts, contour representation uses rectangles to estimate the body contours. These methods include cardboard models[16] and Active Shape Models (ASMs)[17] and were mainly in use in earlier HPE methods.[2]

### **Volume representation**

Volumetric geometric shapes can also be used as a method of representation. Earlier methods used simple shapes like cylinders, conics, and other shapes.[18] Volume representation is a 3D mesh that represents the human body. The most used model is Skinned Multi-Person Linear (SMPL), which includes natural pose-dependent deformations imitating soft-tissue dynamics.[19]

For the purpose of our research, a simple model is the only thing we need. We only need to be aware of the most essential joints to label a pose. This makes the skeleton-based model the ideal representation to work with and will be the focus of further study.

#### **2.1.2 Discriminative Methods and Generative Methods**

Before deep learning became prominent in HPE there were already a number of different methods in use. Some of these methods are compatible with the deep learning methods and were thus adopted. An early distinction is between generative and discriminative methods.

##### **Generative Model**

A generative method will work with prior beliefs about the pose. More information about this can be found in the section about representation.2.1.1 It will project the pose on the image and verify it with the image data. If they don't comply, the pose is adjusted using the descent direction found by minimizing an error function.[20]

##### **Discriminative Model**

Discriminative methods on the other hand, try to map the pose on the image data with learned models. There are several methods in this category, among which are the deep learning-based methods. The deep-learning methods are further categorized by the following sections.

### 2.1.3 Single-Person Methods

Single-person pose estimation will try to evaluate only one pose from an image. There are 2 major methods that are in use: regression methods and detection-based methods.

#### Regression-based Methods

The regression-based methods learn a network that maps all the body keypoints to the image-data directly as shown in 2.3a.

The first successful deep learning model came from Toshev and Svedely[4] and is considered the switch in paradigm from classic approaches to deep learning HPE. Toshev et al. uses a 7-layered model with 5 convolution layers and 2 fully-connected layers for the pose regressor, based on AlexNet for its simple but effective architecture. [21]. They then cascade the resulting found keypoints of this model to itself where it refines it using the area around the keypoints. While the network is the same, the different stages will have different learned parameters. With every stage the found keypoints become more accurate.

Carreira et al.[22] introduce an Iterative Error Feedback which is a self-correcting model using top-down feedback. Using the image-data and a starting pose modeled as a heatmap, the model, based on GoogLeNet[23], will predict an error for each keypoint. The pose is then corrected based on the error and fed back into the model as a heatmap with the image. With each iteration it converges towards the solution instead of making the prediction in one go. Regression-based methods map the keypoints directly on the image, making it a non-linear problem. This will cause less robust generalization.[12]

#### Heatmap/Detection-based Methods

The detection-based methods will first estimate the individual body parts using heatmaps, which leads to an easier optimization and a more robust generalization.[13] Most of the latest HPE methods use heatmaps because of this. After the joints are found they are then assembled to fit a human skeleton. This process is shown in 2.3b.

Tompson et al.[24] proposed a hybrid architecture where the detection of body parts is handled by a CNN and a Spatial-Model to bring those together. The first step produces many false-positives and these are removed in the second step by restricting joint inter-connectivity to enforce correct anatomy. They build on this in [25], where they used a cascade to refine predictions.

A fundamental work written by Wei et al.[6] combines convolution networks with Pose Machines[5]. Pose Machines is an iterative architecture which consists of 2 models: the first is used for stage 1 where it extracts potential heatmaps for the joints. The second model is used for subsequent stages where the result of the previous stage is fed in together with the results of its own convolution network on the input image. This gradually refines the predictions for the joints and their positioning. 2.5 shows this process.

Another influential work was being written at the same time by Newell et al.[7] Similar to CPMs, this is also an iterative architecture. They suggest what they call a "stacked hourglass" network, where "hourglass" modules are repeated.2.6a In an "hourglass" module, first, the features are downsampled and afterwards upsampled again.2.6b This network captures different spatial relationships between joints at different resolutions. Several other works [26][? ][27] have since improved on the network design.

Both these use intermediate supervision to tackle the problem of vanishing gradients.

A more recent work by Sun et al.[8] maintains the high-resolution representations instead of working the high-resolution from the low-to-high sub-network. After a first high-resolution sub-network, it gradually adds high-to-low sub-networks in parallel to predict multi-resolution features. Before each branch, they apply multi-scale fusion, which joins the predicted features from each scale on each scale. Both are shown in 2.7. This network has proven very effective and inspired several variations [28][29][30].

With the emergence of neural networks also came Generative Adversarial Networks (GANs)[31], which proved useful for HPE. They are employed to improve constraints of joint inter-connectivity and infer occluded body parts.

Chen et al.[32] propose a structure-aware convolution network using a stacked hourglass as generator which generates heatmaps for each joint. They use 2 discriminators, one to discriminate between low- and high-confidence predictions, another for real and fake poses. The network is designed as a conditional Generative Adversarial Network (cGAN)[33], which allows it to generate pose heatmaps as well as occlusion heatmaps.

A more classic GAN is used by Chou et al.[34], where it used an hourglass network for both the generator as the discriminator. The generator predicts the heatmaps for each joint and the discriminator distinguished between the real and fake ones.

#### 2.1.4 Multi-Person Methods

**Bottom-Up Methods**

**Top-Down Methods**

There are several ways that the human body joints/keypoints are represented. A first distinction is 2D and 3D

Top-Down Regression-based, Heatmap-based, video-based, model compression-based.

Bottom-Up One stage, two-stage

## 2.2 Image Style Transfer



Figure 2.1: The various challenges HPE solutions face. Images from MPII dataset. [1][2]

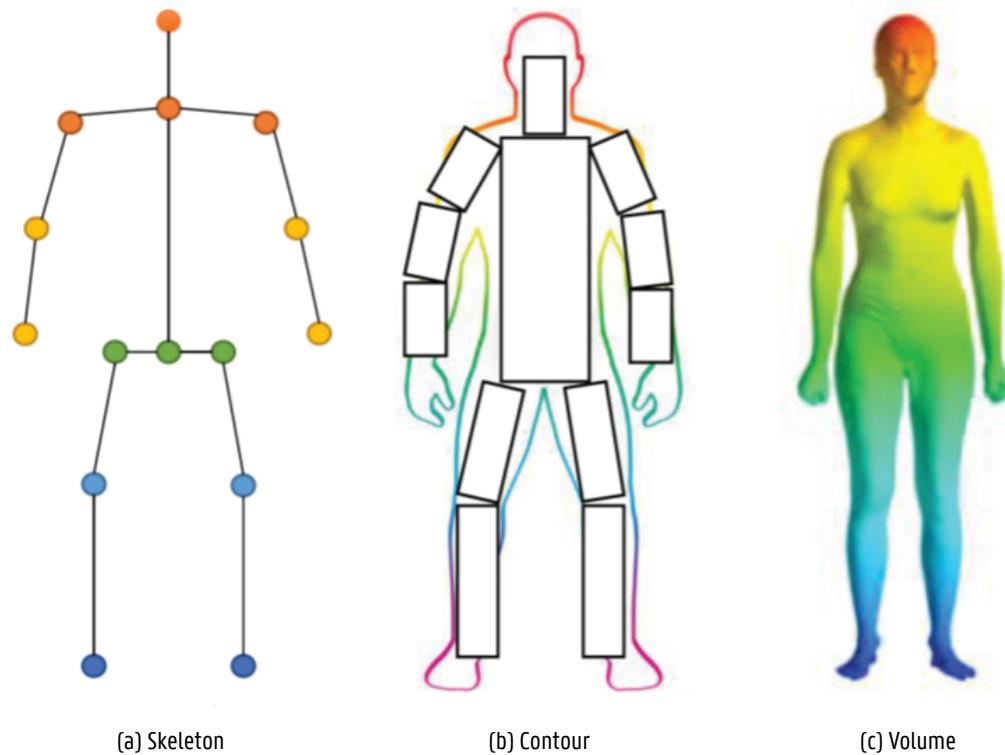


Figure 2.2: Models for pose representation [3]

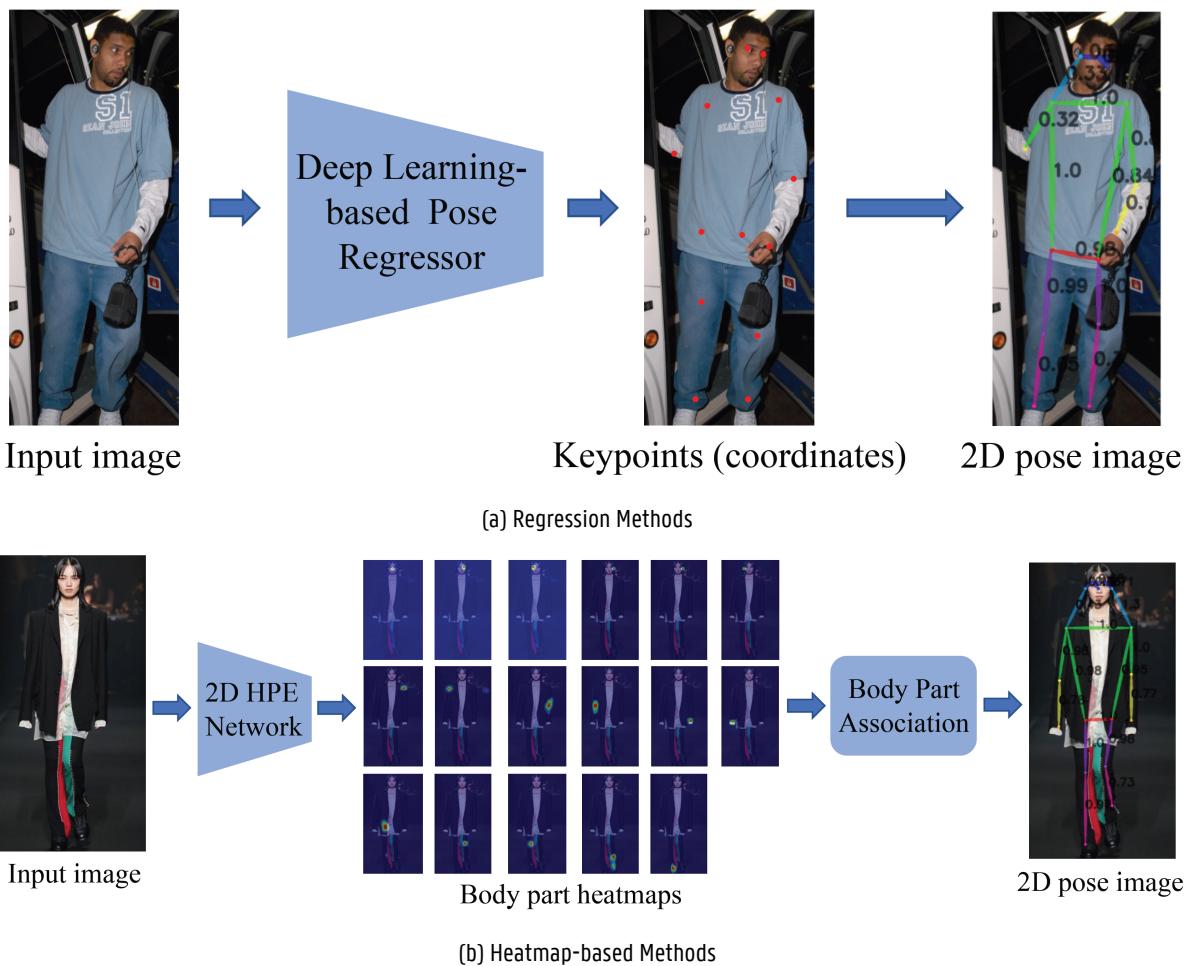
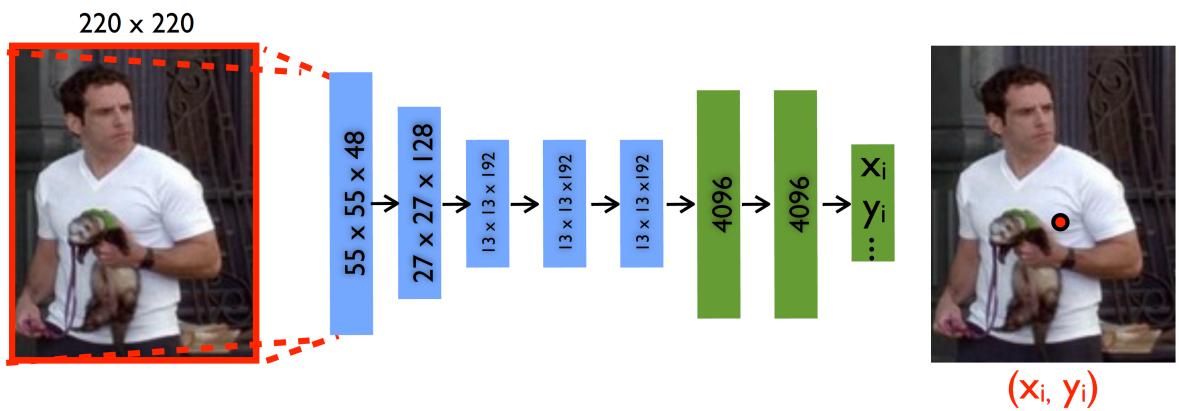
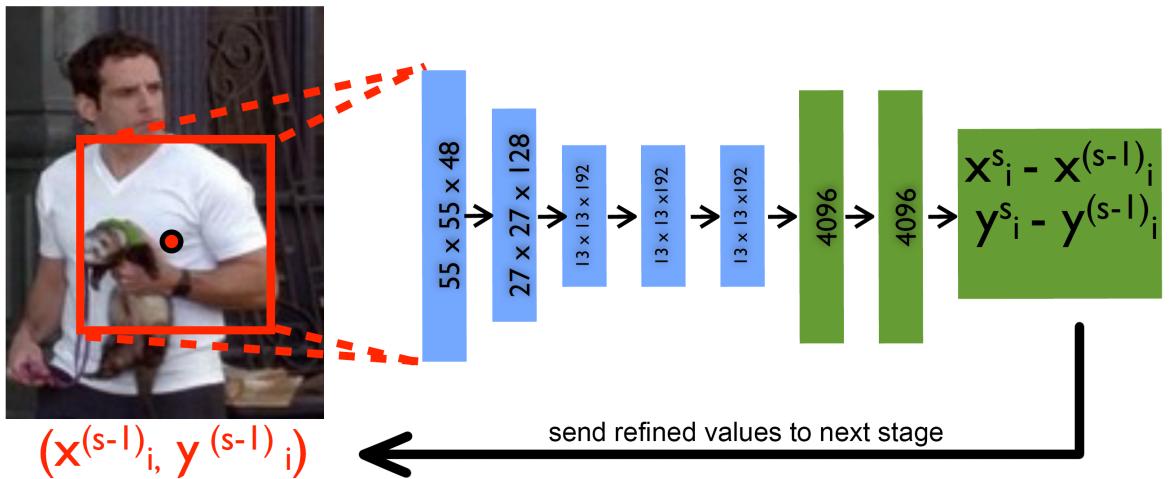


Figure 2.3: The different methods of single-person human pose estimation.[3]



(a) Initial stage



(b) Stage s

Figure 2.4: Convolution layers in blue and fully connected layers in green. The initial stage is applied to the whole images, while in stage  $s$  it will work on a sub-image based on the result of the previous stage.[4]

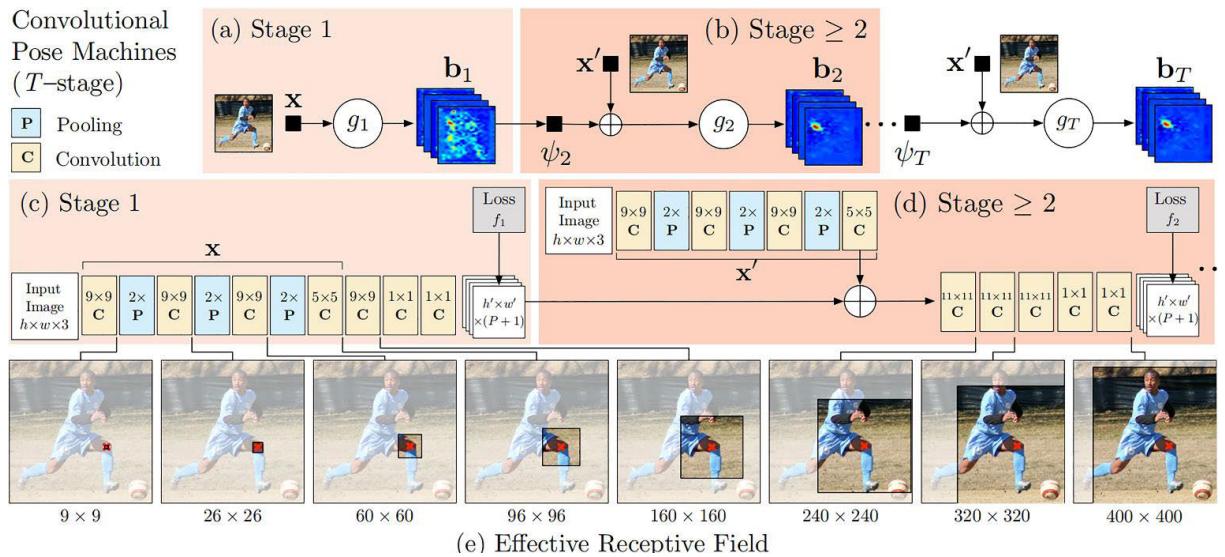
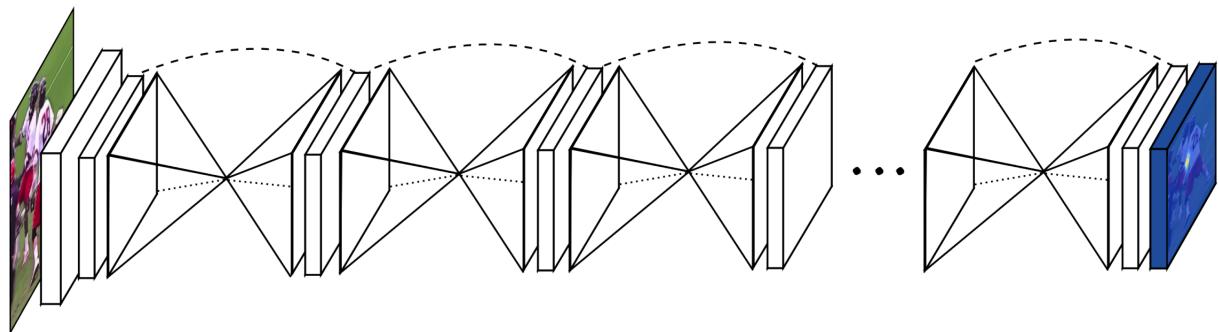
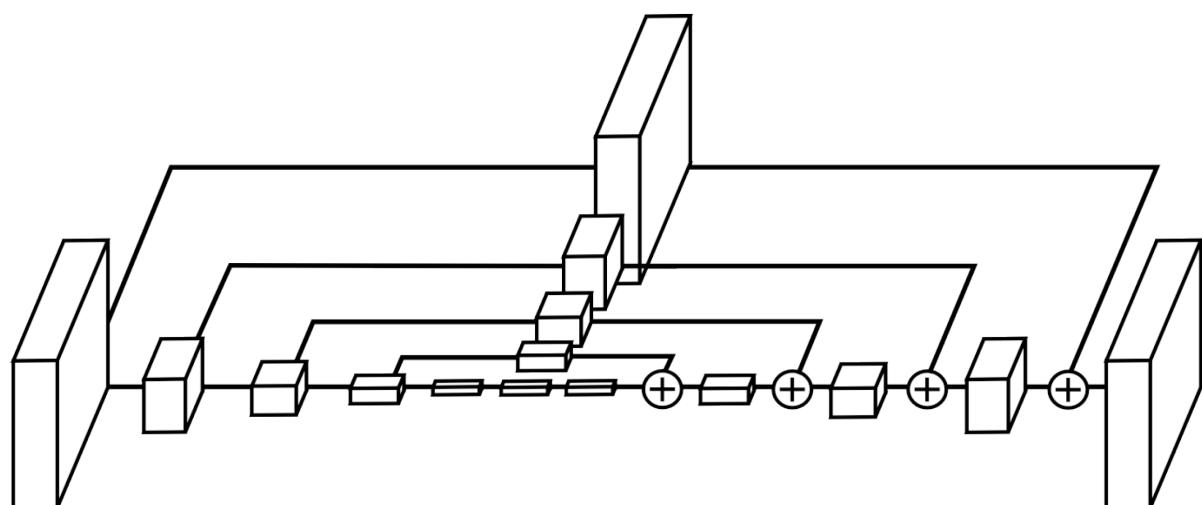


Figure 2.5: Architecture and receptive fields of CPMs. (a) and (b) represent the pose machine architecture.[5] (c) and (d) show the corresponding convolutional networks used by CPMs.[6]

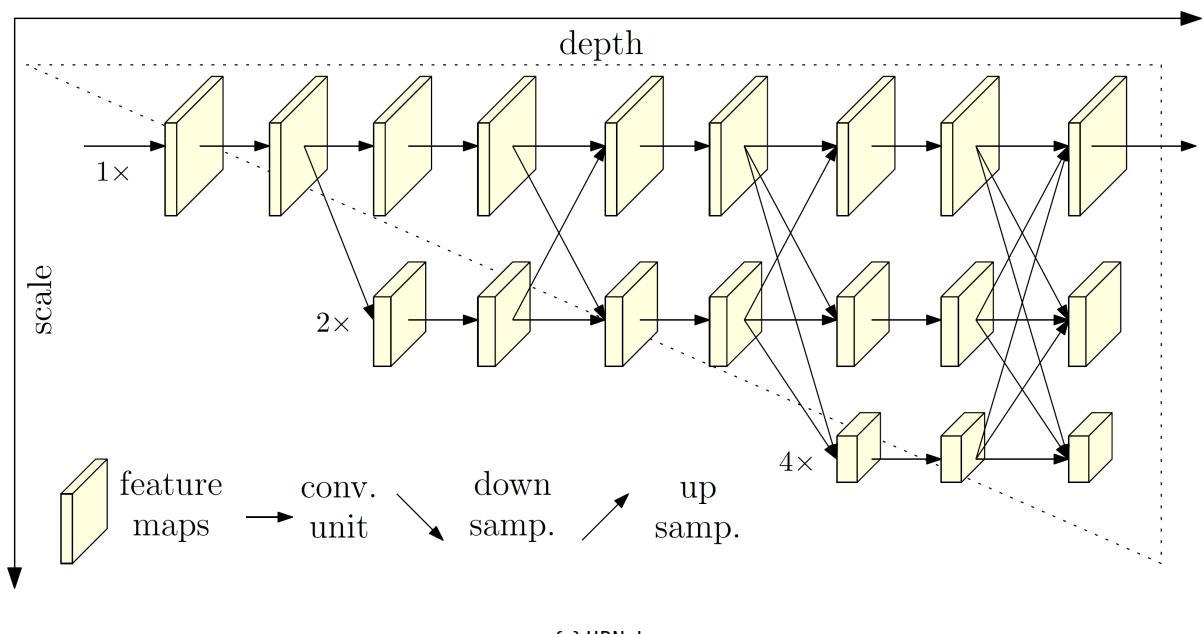


(a) Stacked Hourglass

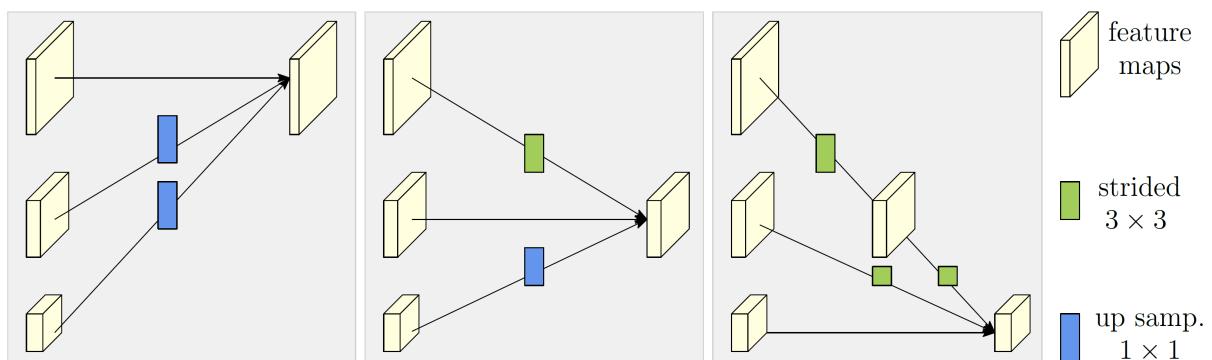


(b) Hourglass Module

Figure 2.6: The structure of a "stacked hourglass" network and a single "hourglass" module.[7]



(a) HRNet



(b) Multi-Scale Fusion

Figure 2.7: The architecute of the High-Resolution network and how it applies multi-scale fusion.[8]

# 3

## **Titel tweede hoofdstuk**

Vul aan.

Morbi luctus, wisi viverra faucibus pretium, nibh est placerat odio, nec commodo wisi enim eget quam. Quisque libero justo, consectetur a, feugiat vitae, porttitor eu, libero. Suspendisse sed mauris vitae elit sollicitudin malesuada. Maecenas ultricies eros sit amet ante. Ut venenatis velit. Maecenas sed mi eget dui varius euismod. Phasellus aliquet volutpat odio. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Pellentesque sit amet pede ac sem eleifend consectetur. Nullam elementum, urna vel imperdiet sodales, elit ipsum pharetra ligula, ac pretium ante justo a nulla. Curabitur tristique arcu eu metus. Vestibulum lectus. Proin mauris. Proin eu nunc eu urna hendrerit faucibus. Aliquam auctor, pede consequat laoreet varius, eros tellus scelerisque quam, pellentesque hendrerit ipsum dolor sed augue. Nulla nec lacus.

Suspendisse vitae elit. Aliquam arcu neque, ornare in, ullamcorper quis, commodo eu, libero. Fusce sagittis erat at erat tristique mollis. Maecenas sapien libero, molestie et, lobortis in, sodales eget, dui. Morbi ultrices rutrum lorem. Nam elementum ullamcorper leo. Morbi dui. Aliquam sagittis. Nunc placerat. Pellentesque tristique sodales est. Maecenas imperdiet lacinia velit. Cras non urna. Morbi eros pede, suscipit ac, varius vel, egestas non, eros. Praesent malesuada, diam id pretium elementum, eros sem dictum tortor, vel consectetur odio sem sed wisi.

### **3.1 Sectie titel**

Vul aan.

Suspendisse vitae elit. Aliquam arcu neque, ornare in, ullamcorper quis, commodo eu, libero. Fusce sagittis erat at erat tristique mollis. Maecenas sapien libero, molestie et, lobortis in, sodales eget, dui. Morbi ultrices rutrum lorem. Nam elementum ullamcorper leo. Morbi dui. Aliquam sagittis. Nunc placerat. Pellentesque tristique sodales est. Maecenas imperdiet lacinia velit. Cras non urna. Morbi eros pede, suscipit ac, varius vel, egestas non, eros. Praesent malesuada, diam id pretium elementum, eros sem dictum tortor, vel consectetur odio sem sed wisi.

Sed feugiat. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Ut pellentesque augue sed urna. Vestibulum diam eros, fringilla et, consectetur eu, nonummy id, sapien. Nullam at lectus. In sagittis ultrices mauris. Curabitur malesuada erat sit amet massa. Fusce blandit. Aliquam erat volutpat. Aliquam euismod. Aenean vel lectus. Nunc imperdiet justo nec dolor.

Etiam euismod. Fusce facilisis lacinia dui. Suspendisse potenti. In mi erat, cursus id, nonummy sed, ullamcorper eget, sapien. Praesent pretium, magna in eleifend egestas, pede pede pretium lorem, quis consectetur tortor sapien facilisis magna. Mauris quis magna varius nulla scelerisque imperdiet. Aliquam non quam. Aliquam porttitor quam a lacus. Praesent

vel arcu ut tortor cursus volutpat. In vitae pede quis diam bibendum placerat. Fusce elementum convallis neque. Sed dolor  
orci, scelerisque ac, dapibus nec, ultricies ut, mi. Duis nec dui quis leo sagittis commodo. Voorbeeld figuur.

# 4

## **Titel derde hoofdstuk**

Vul aan.

Nulla ac nisl. Nullam urna nulla, ullamcorper in, interdum sit amet, gravida ut, risus. Aenean ac enim. In luctus. Phasellus eu quam vitae turpis viverra pellentesque. Duis feugiat felis ut enim. Phasellus pharetra, sem id porttitor sodales, magna nunc aliquet nibh, nec blandit nisl mauris at pede. Suspendisse risus risus, lobortis eget, semper at, imperdiet sit amet, quam. Quisque scelerisque dapibus nibh. Nam enim. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nunc ut metus. Ut metus justo, auctor at, ultrices eu, sagittis ut, purus. Aliquam aliquam.

Etiam pede massa, dapibus vitae, rhoncus in, placerat posuere, odio. Vestibulum luctus commodo lacus. Morbi lacus dui, tempor sed, euismod eget, condimentum at, tortor. Phasellus aliquet odio ac lacus tempor faucibus. Praesent sed sem. Praesent iaculis. Cras rhoncus tellus sed justo ullamcorper sagittis. Donec quis orci. Sed ut tortor quis tellus euismod tincidunt. Suspendisse congue nisl eu elit. Aliquam tortor diam, tempus id, tristique eget, sodales vel, nulla. Praesent tellus mi, condimentum sed, viverra at, consectetur quis, lectus. In auctor vehicula orci. Sed pede sapien, euismod in, suscipit in, pharetra placerat, metus. Vivamus commodo dui non odio. Donec et felis.

Etiam suscipit aliquam arcu. Aliquam sit amet est ac purus bibendum congue. Sed in eros. Morbi non orci. Pellentesque mattis lacinia elit. Fusce molestie velit in ligula. Nullam et orci vitae nibh vulputate auctor. Aliquam eget purus. Nulla auctor wisi sed ipsum. Morbi porttitor tellus ac enim. Fusce ornare. Proin ipsum enim, tincidunt in, ornare venenatis, molestie a, augue. Donec vel pede in lacus sagittis porta. Sed hendrerit ipsum quis nisl. Suspendisse quis massa ac nibh pretium cursus. Sed sodales. Nam eu neque quis pede dignissim ornare. Maecenas eu purus ac urna tincidunt congue.

Donec et nisl id sapien blandit mattis. Aenean dictum odio sit amet risus. Morbi purus. Nulla a est sit amet purus venenatis iaculis. Vivamus viverra purus vel magna. Donec in justo sed odio malesuada dapibus. Nunc ultrices aliquam nunc. Vivamus facilisis pellentesque velit. Nulla nunc velit, vulputate dapibus, vulputate id, mattis ac, justo. Nam mattis elit dapibus purus. Quisque enim risus, congue non, elementum ut, mattis quis, sem. Quisque elit.

Maecenas non massa. Vestibulum pharetra nulla at lorem. Duis quis quam id lacus dapibus interdum. Nulla lorem. Donec ut ante quis dolor bibendum condimentum. Etiam egestas tortor vitae lacus. Praesent cursus. Mauris bibendum pede at elit. Morbi et felis a lectus interdum facilisis. Sed suscipit gravida turpis. Nulla at lectus. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Praesent nonummy luctus nibh. Proin turpis nunc, congue eu, egestas ut, fringilla at, tellus. In hac habitasse platea dictumst.

### **4.1 Sectie titel**

Vul aan.

Phasellus id magna. Duis malesuada interdum arcu. Integer metus. Morbi pulvinar pellentesque mi. Suspendisse sed est eu magna molestie egestas. Quisque mi lorem, pulvinar eget, egestas quis, luctus at, ante. Proin auctor vehicula purus. Fusce ac nisl aliquam ante hendrerit pellentesque. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Morbi wisi. Etiam arcu mauris, facilisis sed, eleifend non, nonummy ut, pede. Cras ut lacus tempor metus mollis placerat. Vivamus eu tortor vel metus interdum malesuada.

Sed eleifend, eros sit amet faucibus elementum, urna sapien consectetur mauris, quis egestas leo justo non risus. Morbi non felis ac libero vulputate fringilla. Mauris libero eros, lacinia non, sodales quis, dapibus porttitor, pede. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Morbi dapibus mauris condimentum nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Etiam sit amet erat. Nulla varius. Etiam tincidunt dui vitae turpis. Donec leo. Morbi vulputate convallis est. Integer aliquet. Pellentesque aliquet sodales urna.

Nullam eleifend justo in nisl. In hac habitasse platea dictumst. Morbi nonummy. Aliquam ut felis. In velit leo, dictum vitae, posuere id, vulputate nec, ante. Maecenas vitae pede nec dui dignissim suscipit. Morbi magna. Vestibulum id purus eget velit laoreet laoreet. Praesent sed leo vel nibh convallis blandit. Ut rutrum. Donec nibh. Donec interdum. Fusce sed pede sit amet elit rhoncus ultrices. Nullam at enim vitae pede vehicula iaculis.

## 4.2 Sectie titel2

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

Sed commodo posuere pede. Mauris ut est. Ut quis purus. Sed ac odio. Sed vehicula hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse platea dictumst. Pellentesque non elit. Fusce sed justo eu urna porta tincidunt. Mauris felis odio, sollicitudin sed, volutpat a, ornare ac, erat. Morbi quis dolor. Donec pellentesque, erat ac sagittis semper, nunc dui lobortis purus, quis congue purus metus ultricies tellus. Proin et quam. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Praesent sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacus.

Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Donec odio elit, dictum in, hendrerit sit amet, egestas sed, leo. Praesent feugiat sapien aliquet odio. Integer vitae justo. Aliquam vestibulum fringilla lorem. Sed neque lectus, consectetur at, consectetur sed, eleifend ac, lectus. Nulla facilisi. Pellentesque eget lectus. Proin eu metus. Sed porttitor. In hac habitasse platea dictumst. Suspendisse eu lectus. Ut mi mi, lacinia sit amet, placerat et, mollis vitae, dui. Sed ante tellus, tristique ut, iaculis eu, malesuada ac, dui. Mauris nibh leo, facilisis non, adipiscing quis, ultrices a, dui.

Voorbeeld figuur.

### Subtitel

Vul aan

#### 4.2.1 Functie is\_isbn

Voorbeeld listing.

```
def is_isbn(isbn: str) -> bool:
    if not type(isbn) is str:
        return False
    if len(isbn) != 10:
        return False
    if not isbn[:9].isdigit():
        return False
    if not isbn[9] in "0123456789X":
        return False
    som = 0
    for i in range(9):
        cijfer = int(isbn[i])
        som += (i + 1) * cijfer
    if isbn[9] == "X":
        laatste_cijfer = 10
    else:
        laatste_cijfer = int(isbn[9])
    return laatste_cijfer == som % 11
```

Code Fragment 4.1: Functie is\_isbn

# Conclusie

Vul aan.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

## Ethische en maatschappelijke reflectie

Vul aan.

Meer informatie kan je opzoeken op <https://www.sdgs.be/nl/sdgs>

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

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## **Bijlagen**

## Bijlage 1

Toelichting bijlage.

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

Sed commodo posuere pede. Mauris ut est. Ut quis purus. Sed ac odio. Sed vehicula hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse platea dictumst. Pellentesque non elit. Fusce sed justo eu urna porta tincidunt. Mauris felis odio, sollicitudin sed, volutpat a, ornare ac, erat. Morbi quis dolor. Donec pellentesque, erat ac sagittis semper, nunc dui lobortis purus, quis congue purus metus ultricies tellus. Proin et quam. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Praesent sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacus.

Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Donec odio elit, dictum in, hendrerit sit amet, egestas sed, leo. Praesent feugiat sapien aliquet odio. Integer vitae justo. Aliquam vestibulum fringilla lorem. Sed neque lectus, consectetur at, consectetur sed, eleifend ac, lectus. Nulla facilisi. Pellentesque eget lectus. Proin eu metus. Sed porttitor. In hac habitasse platea dictumst. Suspendisse eu lectus. Ut mi mi, lacinia sit amet, placerat et, mollis vitae, dui. Sed ante tellus, tristique ut, iaculis eu, malesuada ac, dui. Mauris nibh leo, facilisis non, adipiscing quis, ultrices a, dui.

## Bijlage 2

Toelichting bijlage.

Nulla mattis luctus nulla. Duis commodo velit at leo. Aliquam vulputate magna et leo. Nam vestibulum ullamcorper leo. Vestibulum condimentum rutrum mauris. Donec id mauris. Morbi molestie justo et pede. Vivamus eget turpis sed nisl cursus tempor. Curabitur mollis sapien condimentum nunc. In wisi nisl, malesuada at, dignissim sit amet, lobortis in, odio. Aenean consequat arcu a ante. Pellentesque porta elit sit amet orci. Etiam at turpis nec elit ultricies imperdiet. Nulla facilisi. In hac habitasse platea dictumst. Suspendisse viverra aliquam risus. Nullam pede justo, molestie nonummy, scelerisque eu, facilisis vel, arcu.

Curabitur tellus magna, porttitor a, commodo a, commodo in, tortor. Donec interdum. Praesent scelerisque. Maecenas posuere sodales odio. Vivamus metus lacus, varius quis, imperdiet quis, rhoncus a, turpis. Etiam ligula arcu, elementum a, venenatis quis, sollicitudin sed, metus. Donec nunc pede, tincidunt in, venenatis vitae, faucibus vel, nibh. Pellentesque wisi. Nullam malesuada. Morbi ut tellus ut pede tincidunt porta. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam congue neque id dolor.

Donec et nisl at wisi luctus bibendum. Nam interdum tellus ac libero. Sed sem justo, laoreet vitae, fringilla at, adipiscing ut, nibh. Maecenas non sem quis tortor eleifend fermentum. Etiam id tortor ac mauris porta vulputate. Integer porta neque vitae massa. Maecenas tempus libero a libero posuere dictum. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Aenean quis mauris sed elit commodo placerat. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Vivamus rhoncus tincidunt libero. Etiam elementum pretium justo. Vivamus est. Morbi a tellus eget pede tristique commodo. Nulla nisl. Vestibulum sed nisl eu sapien cursus rutrum.

Nulla non mauris vitae wisi posuere convallis. Sed eu nulla nec eros scelerisque pharetra. Nullam varius. Etiam dignissim elementum metus. Vestibulum faucibus, metus sit amet mattis rhoncus, sapien dui laoreet odio, nec ultricies nibh augue a enim. Fusce in ligula. Quisque at magna et nulla commodo consequat. Proin accumsan imperdiet sem. Nunc porta. Donec feugiat mi at justo. Phasellus facilisis ipsum quis ante. In ac elit eget ipsum pharetra faucibus. Maecenas viverra nulla in massa.

Nulla ac nisl. Nullam urna nulla, ullamcorper in, interdum sit amet, gravida ut, risus. Aenean ac enim. In luctus. Phasellus eu quam vitae turpis viverra pellentesque. Duis feugiat felis ut enim. Phasellus pharetra, sem id porttitor sodales, magna nunc aliquet nibh, nec blandit nisl mauris at pede. Suspendisse risus risus, lobortis eget, semper at, imperdiet sit amet, quam. Quisque scelerisque dapibus nibh. Nam enim. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nunc ut metus. Ut metus justo, auctor at, ultrices eu, sagittis ut, purus. Aliquam aliquam.

Etiam pede massa, dapibus vitae, rhoncus in, placerat posuere, odio. Vestibulum luctus commodo lacus. Morbi lacus duis, tempor sed, euismod eget, condimentum at, tortor. Phasellus aliquet odio ac lacus tempor faucibus. Praesent sed sem. Praesent iaculis. Cras rhoncus tellus sed justo ullamcorper sagittis. Donec quis orci. Sed ut tortor quis tellus euismod tincidunt. Suspendisse congue nisl eu elit. Aliquam tortor diam, tempus id, tristique eget, sodales vel, nulla. Praesent tellus mi, condimentum sed, viverra at, consectetur quis, lectus. In auctor vehicula orci. Sed pede sapien, euismod in, suscipit in, pharetra placerat, metus. Vivamus commodo dui non odio. Donec et felis.

Etiam suscipit aliquam arcu. Aliquam sit amet est ac purus bibendum congue. Sed in eros. Morbi non orci. Pellentesque mattis lacinia elit. Fusce molestie velit in ligula. Nullam et orci vitae nibh vulputate auctor. Aliquam eget purus. Nulla auctor wisi sed ipsum. Morbi porttitor tellus ac enim. Fusce ornare. Proin ipsum enim, tincidunt in, ornare venenatis, molestie a,

augue. Donec vel pede in lacus sagittis porta. Sed hendrerit ipsum quis nisl. Suspendisse quis massa ac nibh pretium cursus. Sed sodales. Nam eu neque quis pede dignissim ornare. Maecenas eu purus ac urna tincidunt congue.

Donec et nisl id sapien blandit mattis. Aenean dictum odio sit amet risus. Morbi purus. Nulla a est sit amet purus venenatis iaculis. Vivamus viverra purus vel magna. Donec in justo sed odio malesuada dapibus. Nunc ultrices aliquam nunc. Vivamus facilisis pellentesque velit. Nulla nunc velit, vulputate dapibus, vulputate id, mattis ac, justo. Nam mattis elit dapibus purus. Quisque enim risus, congue non, elementum ut, mattis quis, sem. Quisque elit.

Maecenas non massa. Vestibulum pharetra nulla at lorem. Duis quis quam id lacus dapibus interdum. Nulla lorem. Donec ut ante quis dolor bibendum condimentum. Etiam egestas tortor vitae lacus. Praesent cursus. Mauris bibendum pede at elit. Morbi et felis a lectus interdum facilisis. Sed suscipit gravida turpis. Nulla at lectus. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Praesent nonummy luctus nibh. Proin turpis nunc, congue eu, egestas ut, fringilla at, tellus. In hac habitasse platea dictumst.

Vivamus eu tellus sed tellus consequat suscipit. Nam orci orci, malesuada id, gravida nec, ultricies vitae, erat. Donec risus turpis, luctus sit amet, interdum quis, porta sed, ipsum. Suspendisse condimentum, tortor at egestas posuere, neque metus tempor orci, et tincidunt urna nunc a purus. Sed facilisis blandit tellus. Nunc risus sem, suscipit nec, eleifend quis, cursus quis, libero. Curabitur et dolor. Sed vitae sem. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Maecenas ante. Duis ullamcorper enim. Donec tristique enim eu leo. Nullam molestie elit eu dolor. Nullam bibendum, turpis vitae tristique gravida, quam sapien tempor lectus, quis pretium tellus purus ac quam. Nulla facilisi.

Duis aliquet dui in est. Donec eget est. Nunc lectus odio, varius at, fermentum in, accumsan non, enim. Aliquam erat volutpat. Proin sit amet nulla ut eros consectetur cursus. Phasellus dapibus aliquam justo. Nunc laoreet. Donec consequat placerat magna. Duis pretium tincidunt justo. Sed sollicitudin vestibulum quam. Nam quis ligula. Vivamus at metus. Etiam imperdiet imperdiet pede. Aenean turpis. Fusce augue velit, scelerisque sollicitudin, dictum vitae, tempor et, pede. Donec wisi sapien, feugiat in, fermentum ut, sollicitudin adipiscing, metus.

Donec vel nibh ut felis consectetur laoreet. Donec pede. Sed id quam id wisi laoreet suscipit. Nulla lectus dolor, aliquam ac, fringilla eget, mollis ut, orci. In pellentesque justo in ligula. Maecenas turpis. Donec eleifend leo at felis tincidunt consequat. Aenean turpis metus, malesuada sed, condimentum sit amet, auctor a, wisi. Pellentesque sapien elit, bibendum ac, posuere et, congue eu, felis. Vestibulum mattis libero quis metus scelerisque ultrices. Sed purus.

Donec molestie, magna ut luctus ultrices, tellus arcu nonummy velit, sit amet pulvinar elit justo et mauris. In pede. Maecenas euismod elit eu erat. Aliquam augue wisi, facilisis congue, suscipit in, adipiscing et, ante. In justo. Cras lobortis neque ac ipsum. Nunc fermentum massa at ante. Donec orci tortor, egestas sit amet, ultrices eget, venenatis eget, mi. Maecenas vehicula leo semper est. Mauris vel metus. Aliquam erat volutpat. In rhoncus sapien ac tellus. Pellentesque ligula.