TUG

Graz University of Technology

Institute for Computer Graphics and Vision

Dissertation

OBJECT DETECTION
BY PARTIAL SHAPE MATCHING, CATEGORY
MODELS AND JOINT SEGMENTATION

Hayko Riemenschneider

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Thesis supervisors
Prof. Dr. Horst Bischof
Prof. Dr. Aleš Leonardis

To my mom.

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Abstract

In this thesis three fundamental tasks in computer vision for object detection are addressed: a) shape-based feature extraction, description and matching, b) object category modeling for detection, and c) joining detection, localization and segmentation for improving performance. All of these topics are highly related to each other and novel and faster solutions are provided for the task of object detection.

The goal of this thesis is in partial shape description and matching, category model learning, as well as joining the multiple stages of the object detection into a coherent optimization. The focus is placed on the following underlying challenges. First, feature extraction for shape-based recognition is investigated. The extraction is brought from single pixel evidence to a method integrating mid-level information based on regions. This context integration helps to better distinguish local edge information by considering the underlying region boundaries. Second, considering the essential cue of shape one requires a description, which captures the geometry of the object in a structured and efficient form. This description is built on the sequential information derived from Gestalt laws such as continuity and connectedness. Third, the recognition of shape features requires partial matching. A balance between partiality and similarity is achieved by efficiently evaluating all correspondences and lengths in a 3D similarity tensor for matches between two sequences of points. Fourth, the partial matching of shape is then investigates for rigid template models and learning implicit category models for object detection. Fifth, a method for joining bottom-up processes for semantic detection is investigated. The low-level features are used for classification, detection and segmentation of object instances by combining their evidence from multiple stages into a single optimization.

State-of-the-art results are achieved for edge extraction, shape retrieval, shape-based object detection and localization of overlapping and distorted object instances, each evaluated on respective reference datasets.

Kurzzusammenfassung

In der vorliegenden Arbeit werden drei fundamentale Aufgaben für Objektdetektion in der Bildverarbeitung behandelt: Extraktion und strukturierte Beschreibung von Formen für das Finden von partiellen Ähnlichkeiten, die Modelling von Objektkategorien, sowie das Verbinden von Lokalisierung und Segmentierung für Objektdetektion. Alle diese Themen sind eng miteinander verknüpft und neue und schnellere Lösungen für den Bereich Objektdetektion werden gezeigt.

Das Ziel dieser Arbeit ist die partielle Beschreibung und der Abgleich von Formen sowie das Verbinden mehrere Stufen der Objektdetektion zu einer vereinheitlichten Optimierung. Der Fokus ist daher auf den folgenden zugrunde liegenden Herausforderung: Erstens wird die Extraktion von Merkmalen für die automatische Erkennung untersucht. Die Extraktion basierend auf einzelnen Pixeln wird auf eine Methode erweitert, welche Informationen aus Regionen integriert. Zweitens wird eine Beschreibung von Form vorgestellt, welche die Geometrie in einer strukturierten und effizienten Weise beschreibt. Dies baut auf Sequenzinformationen auf, die durch Gestaltregeln wie Kontinuität abgeleitet werden. Drittens verlangt die Erkennung von Formen einen partiellen Abgleich. Es wird eine Balance zwischen Teillänge und Ähnlichkeit durch einen Abgleich aller Korrespondenzen und Längen erzielt. Viertens, diese partiellen Korrespondenzen werden für Objektdetektion und Kategorie-Lernen gezeigt. Fünftens wird eine Methode zur Verbindung der einzelnen Schritte für eine semantische Detektion untersucht. Die Bildmerkmale werden durch Klassifikation, Detektion und Segmentierung von Objektinstanzen in einer gemeinsamen Optimierung kombiniert.

State-of-the-art Ergebnisse werden in den Bereichen Kantendetektion, Form-Suche sowieso Detektion von Objekten erzielt, was durch Evaluierungen auf Referenzdatensätzen für die jeweiligen Aufgaben gezeigt wird.

So Long, and Thanks for All the Fish.

Douglas Adams

Acknowledgments

Thanks.

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Lorem ipsum

1

A Meatier Lorem Ipsum Generator

Contents

1.1   Ipsum

Bacon ipsum dolor sit amet veniam velit strip steak t-bone ut sint, frankfurter tail eiusmod tri-tip drumstick. Fugiat consectetur short ribs officia venison. Ut veniam dolore labore, incididunt ham eu sint enim tail laboris mollit non ex. Sint nulla shank voluptate short ribs. Excepteur ad dolor, sint laborum ut frankfurter aliqua brisket tri-tip ribeye. Irure ribeye sausage, nostrud short ribs sirloin duis ut ham. Boudin pork loin sed shankle consequat.

Ribeye minim beef, sirloin veniam aliqua corned beef turkey et tongue pork loin rump flank mollit. Nulla chicken aute, tri-tip nostrud pariatur cupidatat. Swine prosci-

utto bacon, mollit meatball pariatur short loin consectetur anim. Excepteur rump esse non. Tempor meatloaf ut beef meatball, minim drumstick shank corned beef swine pariatur prosciutto fatback qui. Incididunt jowl reprehenderit spare ribs in. Bacon ham aliqua veniam, turducken deserunt boudin elit drumstick sunt.

Sunt ullamco t-bone, flank laborum irure ham rump. Meatloaf andouille chicken enim. In adipisicing cow drumstick do, non spare ribs pork belly shoulder. Consectetur occaecat in ham cow. Boudin t-bone salami ut et pork consectetur. Qui adipisicing pork belly do fugiat elit. Pariatur salami ham, adipisicing veniam meatball fatback dolor tongue et.

1.2   Steak

Strip steak flank pig aliquip esse laboris t-bone, shank meatloaf spare ribs chicken tail short loin. Drumstick turducken dolor tempor, prosciutto bresaola meatloaf eu short loin rump est eiusmod qui. Sunt fugiat id voluptate. Filet mignon dolore tongue et. Pork belly frankfurter swine, mollit ball tip commodo dolor in. Pancetta meatloaf beef ribs consectetur esse, ullamco laboris. Nisi consectetur esse rump, flank sausage pork chop ullamco ad laborum adipisicing shankle.

Tempor excepteur dolore turducken, filet mignon frankfurter dolore pastrami sausage. Labore occaecat pastrami ham hock, voluptate mollit qui meatball sed jowl ea anim excepteur. Adipisicing labore corned beef, sausage aliquip sirloin eu tempor. Consectetur pork belly chicken, ribeye capicola labore dolore boudin tail. Beef mollit sunt frankfurter dolor pork loin. Ut ground round ad culpa sed, occaecat shank venison. Esse deserunt do nostrud.

Ea capicola pork belly sausage tenderloin pancetta, ribeye beef ribs fugiat bacon rump duis. Quis shankle ribeye magna, pig frankfurter chicken laborum. Filet mignon velit swine pork chop sed. Sausage filet mignon irure non fugiat nostrud, est eu jerky shankle. T-bone voluptate reprehenderit, cillum in filet mignon aliqua deserunt tail mollit boudin proident pork chop. Swine occaecat reprehenderit pork loin dolor. Eu spare ribs anim, rump ham hock fatback pig consectetur eiusmod.

Ad in do, nulla prosciutto voluptate shankle. Dolore eiusmod ea, pork belly chuck culpa ut pariatur turducken exercitation ut eu. Do rump bacon duis aliqua, ground round sunt velit turducken voluptate pancetta. Tenderloin pork spare ribs, dolore ball tip turkey deserunt rump eiusmod excepteur jerky chicken ut flank. Chuck pastrami pork loin, drumstick fugiat dolore ut beef tri-tip cow tongue jerky swine. Chuck mollit

reprehenderit, ham strip steak turkey andouille prosciutto ex venison. Jerky strip steak frankfurter cupidatat dolore, sed tempor venison sirloin consequat id biltong adipisicing.

Short loin pork loin swine, chuck andouille ea dolore. Pig commodo fugiat, sint nisi esse ad filet mignon qui andouille ut. Turducken ea eu pork chop, flank do tri-tip shoulder laboris fugiat sirloin andouille. Velit flank veniam shankle sausage eiusmod. Venison excepteur ut, culpa fatback in beef ribs labore eu. Filet mignon shank tail sausage ex pariatur. Cillum nisi meatloaf est, boudin flank spare ribs non excepteur ribeye capicola cupidatat shankle ea.

Velit short loin ham, aliqua tenderloin dolore anim tail. Ball tip veniam cupidatat, jerky beef nulla cillum fugiat salami incididunt. Flank magna ut, fatback ea nostrud sint tri-tip tenderloin do incididunt in. Pariatur magna minim meatloaf deserunt. Ham t-bone tongue, ullamco tempor spare ribs turkey jowl in excepteur ut. Sint do filet mignon aliquip culpa pariatur. Nulla jowl ullamco cow nisi.

Voluptate nostrud ad tail in, deserunt proident aliqua. Ut pork belly adipisicing tempor cillum, laborum quis ea meatball reprehenderit ham magna. Pork belly prosciutto reprehenderit fatback tempor ball tip. Est ribeye sirloin ea, cillum hamburger jowl fugiat biltong elit ham hock nulla. In corned beef commodo id. Id ut ullamco veniam nulla, velit jowl short ribs ex tempor. Rump in ex pariatur.

1.3 Ribs

Nostrud tongue beef ribs, sint in dolore laboris elit ham hock qui in filet mignon enim. Elit beef pork loin beef ribs biltong. Elit labore dolore, quis turkey id velit turducken anim reprehenderit fugiat venison chicken eu nulla. Filet mignon dolor officia excepteur boudin esse. Qui shankle boudin non, excepteur velit duis aute dolore laborum et shoulder ullamco filet mignon. Sint dolor duis aute, nostrud jerky boudin chicken ex ut veniam venison sausage nisi. Ea quis adipisicing, boudin in anim frankfurter reprehenderit chicken.

Short loin venison do dolore ut. Pariatur cillum flank strip steak ground round. In aliquip salami, fatback eu pancetta enim. Strip steak swine t-bone, ground round flank pariatur hamburger. Frankfurter fatback jowl, in ground round velit laboris meatloaf tail t-bone duis. Laboris ex boudin ut. Rump andouille cupidatat eiusmod tri-tip in.

Ground round occaecat pariatur et sunt shankle, eu irure enim meatball. Meatloaf jowl boudin pancetta, culpa ut rump flank nulla. Rump commodo fugiat in. Dolor jowl

andouille, ham pork loin proident pancetta rump. Adipisicing aliquip swine, short ribs ut spare ribs kielbasa exercitation cillum eu in biltong sausage. Drumstick venison quis, short loin non pork chop incididunt esse short ribs et nulla. Pork swine dolor, bacon voluptate rump officia veniam aliquip andouille in labore pastrami excepteur ad.

Jowl ut turkey, kielbasa dolore voluptate adipisicing. Nisi commodo ex, tail elit laborum officia turducken shankle pork loin aliquip sed velit sint. Irure cillum corned beef, ribeye nostrud voluptate tenderloin elit turducken drumstick leberkase prosciutto non. Proident velit shankle, ham hock tempor beef ribs boudin reprehenderit shoulder tail eiusmod bacon. Pork chop aliquip occaecat beef ribs adipisicing, ball tip t-bone in. Dolor bacon fatback ut. Dolore esse tenderloin boudin tempor sint, aliquip brisket eiusmod id quis deserunt ex occaecat.

Tenderloin prosciutto fugiat minim et in. Ad strip steak andouille sirloin, pork deserunt et commodo salami filet mignon qui flank pork loin. Brisket sint consectetur nisi ground round. Tail brisket corned beef, in cupidatat consequat ribeye anim. Pancetta capicola exercitation sausage, qui ball tip consectetur turducken in sed andouille duis. Tempor cow tail ham hock, filet mignon short loin short ribs spare ribs dolore pig jerky. Adipisicing strip steak jerky, biltong ullamco ribeye minim pig fatback tenderloin eiusmod ad brisket sausage.

Mollit sunt salami veniam ut. Dolore tempor exercitation, pancetta commodo reprehenderit ex in. Turkey fugiat ribeye, laborum non bresaola leberkase mollit dolore. Pork chop dolor pastrami leberkase, reprehenderit sirloin mollit ullamco elit ea in excepteur. Eu ham hock nostrud ex, aliquip elit ground round consectetur do pastrami jowl et corned beef. In eu fatback, enim spare ribs aliqua shankle. Aliqua voluptate pork loin, pariatur prosciutto in anim spare ribs brisket in occaecat ut commodo meatloaf shoulder.

Ad ham hock commodo drumstick, veniam jerky laboris consectetur short loin hamburger in cillum pork belly pig. Non esse ribeye, deserunt qui nulla venison drumstick eiusmod pariatur. Ut do consectetur culpa t-bone corned beef. Meatball bresaola dolore et mollit deserunt aliqua, ground round flank pariatur meatloaf aliquip. Quis est kielbasa, anim sed turkey pork belly excepteur boudin esse. Shankle spare ribs officia tongue bacon tri-tip biltong bresaola, nulla cow reprehenderit sed commodo venison. Ground round ut tempor laboris, nisi bresaola sausage prosciutto aliquip pancetta rump biltong.

Tri-tip jowl prosciutto non nulla eu, pastrami ground round bresaola. Velit dolor laborum chuck voluptate non aute boudin. Ribeye sint pork anim. Tongue tail in adip-

isicing cillum do. Cillum ham aliquip, occaecat aute duis prosciutto proident. Quis filet mignon pastrami, ut flank esse incididunt sirloin ad swine pig culpa. Aliquip turducken prosciutto non, ullamco beef ribs ball tip rump cillum.

1.4 Burger

Hamburger ullamco sunt, frankfurter elit nostrud filet mignon labore. Pork belly fatback pig tenderloin ribeye officia. Strip steak pancetta pork loin, excepteur tenderloin nostrud officia prosciutto ut veniam filet mignon swine short ribs ullamco culpa. Sirloin consectetur anim salami corned beef ground round. Rump ball tip minim tenderloin, elit sausage flank consectetur. Bresaola pork belly duis quis eiusmod tail incididunt fugiat, short loin pork loin ut. Shankle magna filet mignon, dolor non bresaola chuck pork belly.

Pork loin culpa minim incididunt sirloin, do nostrud spare ribs aliqua rump pork belly. Occaecat turkey frankfurter, sausage quis irure cow incididunt est. Ullamco in meatloaf qui veniam, swine aute non sausage ham hock pariatur proident. Hamburger consequat in pariatur, short loin tail commodo turducken. T-bone deserunt cillum tongue flank salami, cupidatat aute ad non brisket eiusmod. Aliquip beef ribs fatback culpa, kielbasa consequat ground round drumstick qui jowl ball tip. Dolore shoulder kielbasa et.

Ribeye tri-tip turkey, hamburger venison ut dolor eu ground round ad chuck labore. Ea labore boudin, meatloaf sausage in dolore shoulder minim in prosciutto capicola sirloin. Short loin elit frankfurter, pork pastrami chuck in turkey tempor. Ham andouille commodo, consequat dolore magna ullamco turkey tongue pork. Mollit aliqua jowl excepteur. Beef ribs boudin sed, tri-tip shankle exercitation ground round. Dolor aute rump aliqua beef ribs.

Pig ut in, consectetur cupidatat aliquip sirloin dolore officia deserunt. Ham hock corned beef turkey brisket sausage. Laborum boudin mollit magna eu, in short loin jowl t-bone chicken. Est id laborum biltong meatball. Reprehenderit officia ullamco ham hock chuck, kielbasa aute excepteur mollit ad tempor bacon culpa. Reprehenderit sunt enim jerky magna. Incididunt ground round exercitation, duis tempor eu jerky ut anim nostrud venison.

Tri-tip veniam shank pig dolor, pork loin velit tail drumstick do. Shoulder ea nisi turkey tail. Sed aliqua qui fatback tenderloin duis, eiusmod tongue ad beef corned beef. In pork ham, cupidatat sausage ex chuck ut ut esse nulla short loin sint meatball.

Pancetta meatloaf prosciutto, bacon chicken drumstick capicola filet mignon incididunt laboris aliquip jowl. Proident occaecat nulla esse in. Spare ribs pork belly andouille, tri-tip culpa aliquip mollit frankfurter consectetur anim veniam in.

Dolore nulla veniam, ea qui mollit sirloin tempor bacon ad adipisicing filet mignon in strip steak. Voluptate flank sirloin shankle cillum, capicola ad nulla. Sint magna dolor, ad brisket ut swine in laboris shank. Est labore non in ut commodo. Elit quis pork loin chuck shoulder pancetta. Eiusmod turkey turducken nostrud, fatback ut aliqua ullamco cillum. Swine exercitation pastrami, velit ea drumstick enim.

Nulla salami cow meatball occaecat, boudin ex qui. Labore fugiat aute, corned beef tongue chicken ullamco reprehenderit ham hock shoulder pork belly deserunt pork loin short ribs do. Laborum meatloaf id aliquip, sirloin beef turkey voluptate excepteur shankle boudin irure minim. Shank pariatur filet mignon, irure ground round jerky cow nulla ut exercitation. Meatloaf biltong ex ut tempor. Velit in id cow brisket deserunt. Strip steak ground round in laboris incididunt in.

In irure proident aliqua pork loin, excepteur eiusmod laboris. Proident commodo bacon pancetta mollit. Eiusmod ground round qui, frankfurter shoulder brisket salami in swine pancetta excepteur sirloin. In ex reprehenderit ea leberkase id. Adipisicing aliqua est swine, nisi pariatur cupidatat. Ut occaecat adipisicing, tongue laborum aute enim in venison pork. Fugiat laboris deserunt tenderloin consectetur, cillum cow enim adipisicing.

Careful. We don't want to learn from this.

Bill Watterson, "Calvin and Hobbes"

A
Publications

If I have seen further it is by standing on the shoulders of giants.

Isaac Newton

B
Bibliography