

AN IMAGE IS WORTH 16X16 WORDS: TRANSFORMERS FOR IMAGE RECOGNITION AT SCALE

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ABSTRACT

While the Transformer architecture has become the de-facto standard for natural language processing tasks, its applications to computer vision remain limited. In vision, attention is either applied in conjunction with convolutional networks, or used to replace certain components of convolutional networks while keeping their overall structure in place. We show that this reliance on CNNs is not necessary and a pure transformer applied directly to sequences of image patches can perform very well on image classification tasks. When pre-trained on large amounts of data and transferred to multiple mid-sized or small image recognition benchmarks (ImageNet, CIFAR-100, VTAB, etc.), Vision Transformer (ViT) attains excellent results compared to state-of-the-art convolutional networks while requiring substantially fewer computational resources to train.¹

1 INTRODUCTION

Self-attention-based architectures, in particular Transformers (Vaswani et al., 2017), have become the model of choice in natural language processing (NLP). The dominant approach is to pre-train on a large text corpus and then fine-tune on a smaller task-specific dataset (Devlin et al., 2019). Thanks to Transformers’ computational efficiency and scalability, it has become possible to train models of unprecedented size, with over 100B parameters (Brown et al., 2020; Lepikhin et al., 2020). With the models and datasets growing, there is still no sign of saturating performance.

In computer vision, however, convolutional architectures remain dominant (LeCun et al., 1989; Krizhevsky et al., 2012; He et al., 2016). Inspired by NLP successes, multiple works try combining CNN-like architectures with self-attention (Wang et al., 2018; Carion et al., 2020), some replacing the convolutions entirely (Ramachandran et al., 2019; Wang et al., 2020a). The latter models, while theoretically efficient, have not yet been scaled effectively on modern hardware accelerators due to the use of specialized attention patterns. Therefore, in large-scale image recognition, classic ResNet-like architectures are still state of the art (Mahajan et al., 2018; Xie et al., 2020; Kolesnikov et al., 2020).

Inspired by the Transformer scaling successes in NLP, we experiment with applying a standard Transformer directly to images, with the fewest possible modifications. To do so, we split an image into patches and provide the sequence of linear embeddings of these patches as an input to a Transformer. Image patches are treated the same way as tokens (words) in an NLP application. We train the model on image classification in supervised fashion.

When trained on mid-sized datasets such as ImageNet without strong regularization, these mod-

Ai Papers 1988

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Institutions Richard Ennals, 2012-12-06 Artificial Intelligence and Human Institutions argues that successful applications of artificial intelligence are possible only within an understanding of human institutions and the limitations of technology. Products of artificial intelligence research are becoming widely available to non specialists using low cost computer systems but there has been a lack of communication between researchers and community groups. Taking the weak AI position, the book explores the way insights and tools from artificial intelligence can be valuable in coming to terms with real world problems. Drawing on the author's extensive practical experience in AI research and research management, the book brings together case studies from the fields of education, training, business, engineering, defence, health and community work, and suggests future directions. This book deals with advanced concepts of artificial intelligence for non specialist readers while providing an introduction to state of the art developments. It seeks to use AI concepts to illuminate the practical and theoretical concerns of institutions and organisations, opening up possibilities for new areas of collaborative work and revealing new sources of references and ideas. This is the latest title in the Artificial Intelligence and Society series and will be of interest to lecturers and students in AI, education, social and political sciences and business studies.

The 1995 Goddard Conference on Space Applications of Artificial Intelligence and Emerging Information Technologies

Intelligence in Real-Time Control 1989 Hua-Tian Li, Shi-Quan Su, M.G. Rodd, 2014-07-04 Papers presented at the workshop are representative of the state of the art of artificial intelligence in real time control The issues covered included the use of AI methods in the design implementation testing maintenance and operation of real time control systems While the focus was on the fundamental aspects of the methodologies and technologies there were some applications papers which helped to put emerging theories into perspective The four main subjects were architectural issues knowledge acquisition and learning techniques and scheduling monitoring and management Monthly Catalogue, United States Public Documents

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different architectures that have been developed over the past few years for organizing robots. These architectures have led to major breakthroughs that promise to revolutionize the study of autonomous agents and perhaps artificial intelligence in general. The new architectures emphasize more direct coupling of sensing to action, distributedness and decentralization, dynamic interaction with the environment and intrinsic mechanisms to cope with limited resources and incomplete knowledge. The research discussed here encompasses such important ideas as emergent functionality, task level decomposition and reasoning methods such as analogical representations and visual operations that make the task of perception more realistic.

Contents

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Comprehensive Organic Functional Group Transformations Alan R. Katritzky, Gordon W. Kirby, Otto Meth-Cohn, Charles Wayne Rees, 2003-03-21

In this Volume containing 24 chapters devoted to carbon attached by single bonds to two heteroatoms, the reader will find several chapters reviewing the synthesis of familiar functional groups, notably acetals, dithioacetals, aminals and the various mixed species. The derivatives with tetracoordinated saturated carbon are described in Part I and those eg ketene acetals of tricoordinated carbon in Part II. However, the treatment is comprehensive and the authors have uncovered much fascinating chemistry concerning less familiar groups including some like geminal halohydrins, halo amines and diols that are often unstable. Again a surprisingly large number of compounds having two metals attached to the same carbon have been located in the literature and the abundance of phosphorus derivatives eg those with geminal nitrogen functions reflects their importance as biologically active species and as intermediates in synthesis. Part III consists of a single short chapter describing dicoordinate carbon, carbenes and examples of carbon cations, anions and radicals. Here the treatment is deliberately selective since throughout the work as a whole emphasis is placed on the synthesis of isolable species rather than the transient intermediates of organic reactions.

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Uncertain Information Processing In Expert Systems Petr Hajek, Tomas Havranek, Radim Jirousek, 1992-06-29

Uncertain Information Processing in Expert Systems systematically and critically examines probabilistic and rule based compositional MYCIN like systems, the two most important families of expert systems dealing with uncertainty. The book features a detailed introduction to probabilistic systems including methods using graphical models and methods of knowledge integration, an analysis of compositional systems based on algebraic considerations, an application of graphical models and the Dempster Shafer theory of evidence.

and its use in expert systems The book will be useful to anyone working in artificial intelligence statistical computing symbolic logic and expert systems **Modelling for Added Value** Robert Macredie, Ray Paul, Dervarajan Anketell, Brian Lehaney, Shamim Warwick, 2012-12-06 This book gathers together research from three key application themes of modelling in operational research modelling to support evaluation and change in organisations modelling within the development and use of organisational information systems and the use of modelling approaches to support enable and enhance decision support in organisational contexts The issues raised provide valuable insight into the range of ways in which operational research techniques and practices are being successfully applied in today s information centred business world Modelling for Added Value provides a window onto current research and practise in modelling techniques and highlights their rising importance across the business industrial and commercial sectors The book contains contributions from a mix of academics and practitioners and covers a range of complex and diverse modelling issues highlighting the broad appeal of this increasingly important subject area

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