数据驱动的卡通人脸夸张表现方法研究

摘　要

由计算机生成卡通人脸是多媒体技术与计算机图形学领域的热点研究问题，其关键点在于如何对目标人脸的有效特征进行夸张。但传统的手工夸张方法和基于规则的夸张方法都存在一些实际问题，如无法满足实时性要求、需要很强的艺术背景知识或成本太高等。本文采用数据驱动的思想，基于艺术家手工作品数据，用主成分分析、流形学习等方法对卡通夸张模式进行挖掘与描述。提出了基于子空间的映射学习方法、流形迁移方法以及层次流形回归方法，分别解决了人脸多特征发现与卡通协同夸张问题、卡通夸张风格重建的问题以及稀疏数据条件下的夸张模式学习问题等。相比已有工作，在生成卡通人脸的夸张性、艺术性、相似性等指标方面均有提高。

具体包括以下几方面工作：

1．对涉及的多种人脸数据集进行了特性分析和处理。基于 MAYA 软件人工建立了容量为 100 幅的三维卡通人脸数据集。对二维真实人脸、二维卡通人脸及三维卡通人脸数据集进行了特征提取与特征对齐。

2．提出了基于子空间多特征发现的卡通协同夸张方法，并应用于二维卡通人脸合成问题。卡通人脸由多种特征协同夸张来共同表现，但传统规则法在人脸多特征发现和同步夸张方面存在不足。本文针对真实人脸与卡通人脸两个数据集之间共享主成分这一特点，采用子空间映射学习的方法实现了人脸多特征的发现和协同夸张。首先按一定比例关系组成真实人脸与卡通人脸的混合数据集，对其进行主成分分析来发现其共同特征空间。然后基于该特征空间，利用一一映射的真实人脸与卡通人脸“数据对”学习二者的非线性映射关系，最后根据获得的映射模型预测输入人脸的卡通形状特征。

3．提出了流形约束下的夸张风格重建方法，并用于解决只有单张卡通图片的三维卡通重建问题。需要多张照片的三维人脸重建算法无法适用于本问题，而基于单张照片的线性重建方法对三维卡通人脸的细节信息表达不足。本文针对二维卡通人脸与三维卡通人脸两个数据集都具有流形分布，且来源于同一流形的特性，采用迁移学习的思想对共享流形进行挖掘，然后基于共享流形来重建三维卡通人脸。流形迁移迭代算法包括三个步骤：首先对二维卡通人脸与初始化的三维卡通人脸进行双层流形降维，然后基于获得的共享流形对三维数据进行重建，最后应用克里金插值法对重建模型给予修正。此算法正常收敛，比线性重建方法更好保持了原始数据所具有的整体夸张风格。

4．提出了面向稀疏数据学习的夸张模式层次回归方法，并应用于三维卡通人脸生成问题。现实中的三维卡通人脸数据十分稀少，导致常规学习方法回归精度较低。针对二

维真实人脸、二维卡通人脸与三维卡通人脸都具有流形分布，且三者之间具有层次函数关系这一特点，本文首先提出了一种基于三个数据集的层次流形回归方法（HMR），然后对三维卡通人脸进行流形降维获得三维夸张模式，再基于一一对应的二维真实人脸与三维夸张模式，采用 HMR 方法学习两个流形之间的非线性回归模型。对新输入的人脸数据，则可用该回归模型预测其三维夸张模式，进而通过流形升维即可得到最后的三维卡通人脸。

5．形成了面向实际应用的两个系统，即基于互联网与移动通信网络的手机彩信生成系统和基于虚拟游戏场景的个性化三维虚拟人化身（Avatar）生成系统。

关键词：人脸合成；三维卡通人脸；计算机图形学；数据驱动；层次流形回归

Data-Driven Exaggeration of Cartoon Face

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Cartoon faces are favorite resources of creative multimedia in digital life. The most important task of automatic generation of cartoon face is to exaggerate the principle features of the human face. However, the traditional exaggeration methods have raised many problems in practical applications. This dissertation addresses cartoon face exaggeration based on Data-Driven and machine learning techniques. Principal Component Analysis (PCA) and Manifold learning are employed to mine and describe the cartoon patterns. Three methods are proposed in this dissertation including mapping learning in shared subspace, manifold transfer learning and hierarchical manifold regression. Corresponsively, these methods are utilized to discover multiple features and exaggerate the features harmoniously, to reconstruct realistic 3D cartoon faces, and to learn the cartoon patterns effectively from sparse data set. Compared with previous works, this dissertation results in a higher performance when evaluated with the merits of Similarity, Artistry and Exaggeration.

The more details of the works are as follows.

1) Three kinds of data sets have been involved and processed in this work. First, we build manually a 3D cartoon face data set with 100 3D MAYA models. Feature extraction and alignment are carried out for the data sets including 2D real faces, 2D cartoon faces and 3D cartoon faces.

2) Mapping learning in shared linear subspace is proposed for multi-features mining and representing, and applied to generate 2D cartoon faces successfully. The traditional methods cannot discover and represent facial multi-features well. According to the characteristic that the real faces and the cartoon faces share the same subspace, we perform PCA for the mixed data set to discover the shared feature subspace. Based on that subspace, we perform regression learning based on some pairs of real faces and corresponsive cartoon faces. The obtained regression model can predict the cartoon feature for the input faces, which reflects facial multi-features in the result cartoon faces effectively.

3) The manifold transfer algorithm is proposed to reconstruct the 3D cartoon faces. Some previous methods perform well in realistic 3D face reconstruction based on multiple facial photos. But they are not fit for our problem for only one frontal 2D photo is provided here. Some methods work based on one single photo, but cannot represent much the details of the 3D cartoon faces for the models of the methods are

linear. According to the characteristic that two data sets share the same manifold distribution, we adopt the strategy of transfer learning to mine the shared manifold, based on which the 3D data set can be reconstructed. The transfer learning algorithm is an iterative procedure consisting of three steps. The first step is dimensionality reduction of double-layer manifold, and the second step is to reconstruct the 3D cartoon face based on the low-dimensional manifold of the first step. The third step is to refine the 3D cartoon face by Kriging interpolation algorithm. The manifold transfer algorithm converges well, and simulates the details of the cartoon face effectively.

4) The hierarchical manifold regression algorithm is proposed to learn the cartoon pattern, and is applied to generate 3D cartoon faces. There are very limited 3D cartoon face data in reality, which leads to low accuracy of traditional regression algorithms. According to the characteristic that the real faces and 3D cartoon faces both are distributed in manifold, and the 2D cartoon faces contain additional information, this dissertation first proposed HMR (the Hierarchical Manifold Regression algorithm), which can gather information well from three data set. Then, the cartoon pattern is obtained by manifold dimensionality reduction of 3D cartoon faces. Taking the training pairs as labeled data, a regressional model is learnt by HMR. Each pair contains a real 2D face and corresponsive 3D cartoon face. Finally, the new real face can be transformed into 3D cartoon face by the regressional model.

5) Two systems have been developed based on the results of this work. The first system provides Multimedia Message Service (MMS) with cartoon animation based on the Internet and the mobile communication networks, and the second system is to generate personalized avatars for the players in online 3D games.

Keywords: Face Synthesis; 3D Cartoon Face; Computer Graphics; Data-Driven; Hierarchical Manifold Regression