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CCDM: Continuous Conditional Diffusion Models for Image Generation

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Abstract—Continuous Conditional Generative Modeling (CCGM) aims to estimate the distribution of high-dimensional data, typically images, conditioned on scalar continuous variables known as regression labels. While Continuous Conditional Generative Adversarial Networks (CeGANs) were initially designed for this task, their adversarial training mechanism remains vulnerable to extremely sparse or imbalanced data, resulting in suboptimal outcomes. To enhance the quality of generated images, a promising alternative is to replace CeGANs with Conditional Diffusion Models (CDMs), renowned for their stable training process and ability to produce more realistic images. However, existing CDMs encounter challenges when applied to CCGM tasks due to several limitations such as inadequate U-Net architectures and deficient model fitting mechanisms for handling regression labels. In this paper, we introduce Continuous Conditional Diffusion Models (CCDMs), the first CDM designed specifically for the CCGM task. CCDMs address the limitations of existing CDMs by introducing specially designed conditional diffusion processes, a modified denoising U-Net with a custom-made conditioning mechanism, a novel hard vicinal loss for model fitting, and an efficient conditional sampling procedure. With comprehensive experiments on four datasets with varying resolutions ranging from 64×64 to 102×102 , we demonstrate the superiority of the proposed CCDM over state-of-the-art CCGM models, establishing new benchmarks in CCGM. Extensive ablation studies validate the model design and implementation configuration of the proposed CCDM. Our code is publicly available at <https://github.com/UBCdingXin/CCDM>.

Index Terms—Continuous conditional generative modeling, conditional diffusion models, continuous scalar conditions.

I. INTRODUCTION

Continuous Conditional Generative Modeling (CCGM), as depicted in Fig. 1, aims to estimate the probability distribution of images conditioned on scalar continuous variables. These variables, often termed regression labels, can encompass ages, temperatures, counting numbers, and more. The scarcity of training samples for certain regression labels and the lack of a suitable label input mechanism render CCGM a highly challenging task.

As a recent advancement, Ding et al. [1] introduced the first feasible model to the CCGM task, termed Continuous Conditional Generative Adversarial Networks (CeGANs). CeGANs address existing challenges in CCGM by devising novel vicinal discriminator losses and label input mechanisms. Consequently,

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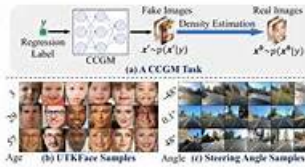


Fig. 1. Illustration of the CCGM task with sample images from the UTKFace and Steering Angle datasets.

CeGANs have been extensively applied across various domains requiring precise control over generative modeling of high-dimensional data. These applications comprise engineering inverse design [2]–[4], data augmentation for hyperspectral imaging [5], remote sensing image processing [6], model compression [7], controllable point cloud generation [8], carbon sequestration [9], data-driven solutions for poroelasticity [10], and more. However, as reported in [1], the training process of CeGANs remains susceptible to extremely sparse or imbalanced training data due to the unstable adversarial mechanism, resulting in suboptimal outcomes.

Diffusion models, emerging as another class of generative models, have garnered significant attention recently. Compared to Generative Adversarial Networks (GANs) [12]–[17], diffusion models offer a substantially more stable training process and produce more realistic samples [18]–[21]. Given this, it seems logical to abandon the unstable adversarial mechanism in favor of diffusion models to stabilize model training and produce more realistic samples in the CCGM task. Nonetheless, as mentioned by Ding et al. [1], Conditional Diffusion Models (CDMs), including classifier guidance models [18] and classifier-free guidance models [19]–[21], encounter challenges when dealing with regression labels. These challenges stem from several factors: (1) Their U-Net architectures do not adequately support scalar continuous conditions; (2) Their model fitting does not account for scenarios with very few or zero training data points for certain regression labels; (3) Some configurations of CDMs, originally designed for discrete conditions or multi-dimensional continuous conditions, are inapplicable to regression labels. Hence, current CDMs are inapplicable to the CCGM task.

Motivated by the aforementioned issues, we propose in this paper the Continuous Conditional Diffusion Models (CCDMs),

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SCDM Certified Clinical Data Manager Sample Questions (Q36-Q41):

NEW QUESTION # 36

Which statement is true regarding User Acceptance Testing (UAT) in an EDC application?

- A. The extent of UAT (i.e., the number of test cases and rules) cannot be risk-based
- B. Every rule should be tested with at least one "pass" and one "fail" scenario
- C. System tools in EDC do not remove the need for UAT
- **D. Data should not be collected in a production environment until UAT is completed**

Answer: D

Explanation:

In Electronic Data Capture (EDC) system validation, User Acceptance Testing (UAT) is a mandatory phase that must be completed before data collection begins in the production environment.

According to the GCDMP (Chapter: Database Design, Validation, and Testing) and FDA 21 CFR Part 11, UAT ensures that the EDC system meets all protocol-specific, functional, and regulatory requirements before it is deployed for live use. The goal is to verify that the system performs exactly as intended by simulating real-world user interactions with test data in a validated test environment.

Data collection prior to UAT completion would violate validation requirements and risk noncompliance with ICH E6 (R2) GCP Section 5.5.3, which mandates that all computerized systems be validated and tested before use.

While options A and C describe correct components of testing strategy, the key regulatory requirement is that UAT must be completed and approved before live data entry begins. Option D is incorrect - risk-based UAT is an accepted modern validation approach under both FDA and GAMP5 principles.

Reference (CCDM-Verified Sources):

SCDM Good Clinical Data Management Practices (GCDMP), Chapter: Database Design and Validation, Section 5.3 - User Acceptance Testing FDA 21 CFR Part 11 - Validation of Electronic Systems (Section 11.10(a)) ICH E6 (R2) GCP, Section 5.5.3 - Validation Before Use in Production Environment

NEW QUESTION # 37

For clinical investigational sites on an EDC trial, which of the following archival options allows traceability of changes made to data?

- **A. ASCII files of the site's data and related audit trails**
- B. PDF images of the final eCRF screens for each patient
- C. Storing the computer used at the clinical investigational site
- D. Paper copies of the source documents

Answer: A

Explanation:

Regulatory agencies such as the FDA and ICH require that electronic data be retained in a format that preserves audit trails and traceability.

While PDF images (option C) provide a static representation of data, they do not preserve the underlying audit trail (i.e., who changed what, when, and why). The ASCII data files with corresponding audit trails (option D) provide complete transparency and comply with 21 CFR Part 11 and GCDMP archival standards.

Option A (storing computers) is unnecessary and impractical, and Option B (paper source documents) are site records, not system archives.

Hence, option D is correct - ASCII data files with audit trails meet traceability and compliance standards.

Reference (CCDM-Verified Sources):

SCDM GCDMP, Chapter: Database Lock and Archiving, Section 5.4 - Archival Formats and Audit Trail Retention ICH E6(R2) GCP, Section 5.5.3 - Data Integrity, Audit Trails, and Record Retention FDA 21 CFR Part 11 - Electronic Records; Audit Trail and Retention Requirements

NEW QUESTION # 38

Which is the best way to see site variability in eligibility screening?

- A. List eligibility waivers by site
- B. Graph enrollment by site
- C. Summarize screening rate by site
- **D. Plot eligibility rate by site**

Answer: D

Explanation:

To identify site variability in eligibility screening, the most effective approach is to plot eligibility rate by site. This allows visual detection of differences in how well each site screens subjects according to protocol-defined inclusion and exclusion criteria. The GCDMP (Chapter: Data Quality Assurance and Metrics) emphasizes the importance of graphical analysis for identifying anomalies and site-level performance variability. By plotting the eligibility rate by site, data managers and clinical operations teams can quickly identify outliers-sites that screen too many or too few eligible subjects-indicating potential training issues, misunderstanding of inclusion/exclusion criteria, or even possible protocol deviations.

While summarizing screening rate (B) provides useful numeric data, it lacks visual comparability. Listing waivers (A) or enrollment counts (C) provide limited insights into eligibility consistency.

Therefore, option D-Plot eligibility rate by site-is the best analytic and visualization practice to assess site variability in screening outcomes.

Reference (CCDM-Verified Sources):

SCDM GCDMP, Chapter: Data Quality Assurance and Control, Section 6.1 - Use of Metrics and Graphical Review for Site Performance ICH E6(R2) GCP, Section 5.18.4 - Identification of Systematic or Site-Specific Issues

NEW QUESTION # 39

The result set from the query below would be which of the following?

```
SELECT Pt_ID, MRN, SSN FROM patient
```

- A. Shorter than the patient table
- **B. Narrower than the patient table**
- C. Wider than the patient table
- D. Longer than the patient table

Answer: B

Explanation:

In a SQL (Structured Query Language) database, the SELECT statement specifies which columns to display from a table. In this query, only three columns - Pt_ID, MRN, and SSN - are being selected from the patient table.

This means the resulting dataset will contain:

The same number of rows (records) as the original table (assuming no WHERE filter), and Fewer columns than the full table.

In database terminology:

"Wider" refers to more columns (fields).

"Narrower" refers to fewer columns (fields).

Since this query retrieves only 3 columns (out of potentially many in the original table), the result set is narrower than the patient table, making option D correct.

Reference (CCDM-Verified Sources):

SCDM GCDMP, Chapter: Database Design and Build, Section 5.1 - Relational Databases and Query Logic ICH E6(R2) GCP, Section 5.5.3 - Data Retrieval and Integrity Principles FDA Guidance for Industry: Computerized Systems Used in Clinical Investigations, Section 6.4 - Database Query Controls

NEW QUESTION # 40

Which type of edit check would be implemented to check the correctness of data present in a text box?

- A. Manual Check
- B. Programmed check
- **C. Front-end check**
- D. Back-end check

Answer: C

Explanation:

A front-end check is a type of real-time validation performed at the point of data entry-typically within an Electronic Data Capture (EDC) system or data entry interface-designed to ensure that the data entered in a text box (or any input field) is valid, logically correct, and within expected parameters before the user can proceed or save the record.

According to the Good Clinical Data Management Practices (GCDMP, Chapter on Data Validation and Cleaning), edit checks are essential components of data validation that ensure data accuracy, consistency, and completeness. Front-end checks are implemented within the data collection interface and are triggered immediately when data are entered. They prevent invalid entries (such as letters in numeric fields, out-of-range values, or improper date formats) from being accepted by the system.

Examples of front-end checks include:

Ensuring a numeric field accepts only numbers (e.g., weight cannot include text characters).

Validating that a date is within an allowable range (e.g., not before the subject's date of birth).

Requiring mandatory fields to be completed before moving forward.

This differs from back-end checks or programmed checks, which are typically run later in batch processes to identify data inconsistencies after entry. Manual checks are human-performed reviews, often for context or data that cannot be validated automatically (e.g., narrative assessments).

Front-end edit checks are preferred wherever possible because they prevent errors at the source, reducing the number of downstream data queries and cleaning cycles. They contribute significantly to data quality assurance, regulatory compliance, and efficiency in data management operations.

Reference (CCDM-Verified Sources):

Society for Clinical Data Management (SCDM), Good Clinical Data Management Practices (GCDMP), Chapter: Data Validation and Cleaning, Section 6.2 - Edit Checks and Real-Time Data Validation FDA Guidance for Industry: Computerized Systems Used in Clinical Investigations, Section 6 - Data Entry and Verification Controls ICH E6 (R2) Good Clinical Practice, Section 5.5 - Data Handling and Record Integrity CDISC Operational Data Model (ODM) Specification - Edit Check Implementation Standards

NEW QUESTION # 41

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