FINAL PROJECT REPORT: DEVELOPING AN AI-ASSISTED GRADING SYSTEM USING LARGE LANGUAGE MODELS

by

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FINAL PROJECT REPORT: DEVELOPING AN AI-ASSISTED GRADING SYSTEM USING LARGE LANGUAGE MODELS

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We present an instructor-in-the-loop grading system that accelerates evaluation of open-ended student work across scanned and digital workflows. The system crops answer regions from PDFs, assigns submissions via OCR on identity regions only, and groups answers by visual semantics using a vision LLM. Instructors review and edit groups, apply rubric items once per group, and export grades from an on-screen table. The solution integrates Ghostscript rasterization, PdfPig page orchestration, SkiaSharp region extraction, Tesseract identity OCR, and GPT-4o Vision for grouping[1, 2, 3, 4, 5]. We detail the architecture, token-budgeted batching strategy, and persistence design, then describe a testing plan for grouping quality, time-on-task, and usability. The approach avoids brittle handwriting OCR while preserving instructor control, fairness, and auditability. We conclude with limitations, risks, and suggested future work.

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Chapter 1

Introduction and Motivation

1.1 Problem Statement

Grading open-ended student work (handwritten or typed) is time-consuming, repetitive, and error-prone under deadline pressure. In large classes, feedback latency diminishes learning value. Typical bottlenecks include: (i) organizing mixed-format submissions (bulk scans vs. individual PDFs), (ii) locating answer regions for consistent review, and (iii) repeatedly applying identical rubric deductions to similar mistakes. Handwriting OCR is brittle, often forcing manual review even for simple cases.

1.2 Specific Project Goals/Requirements

The project delivers a practical, instructor-in-the-loop grading system that:

- *Bulk Scans (Filled-form):* PDFs are split by known page counts. Ghostscript rasterizes pages; PdfPig validates page counts; SkiaSharp crops defined regions to PNGs.

- *Identity OCR (filled-form only):* Tesseract extracts name/ID from a designated identity region to auto-assign submissions; unresolved items fall back to a manual pick-list. No OCR is performed on answers; grouping uses GPT-4o Vision directly on the cropped images.
- *Identity Matching:* (filled-form) identity text is matched to the class roster; (free-form) uploads are automatically tied to the uploader's account.
- *Editable AI Assistance:* Vision LLM proposes semantic groups; instructors can merge/split groups, move answers, and apply rubric items per-group.
- *Traceability:* All actions and groupings are persisted with timestamps for audit; grades are summarized in an on-screen table for review/copy.

1.3 Motivation and Benefits

- **Faster feedback:** Instructors grade clusters of similar answers once, reducing turnaround time.
- **Consistency:** Per-group rubric application reduces drift across similar answers and sessions.
- **Lower cognitive load:** The system automates extraction, grouping suggestions, and grade totals; instructors focus on judgment.
- **Reduced brittleness:** Avoiding handwriting OCR on answers eliminates a major failure mode.
- **Privacy-aware:** Only identity crops contain PII; answer crops are devoid of names or IDs.

1.4 Contributions

- An **OCR-minimal**, vision-first pipeline that uses OCR only for identity assignment.
- A **token-budgeted batching** strategy (downscale + tiling) to bound latency/-cost at class scale.
- A **traceable data model & APIs** with idempotent re-uploads and stable crop filenames.
- An **instructor-in-the-loop** UX with editable groups, explicit review status, and rubric-first grading.

1.5 Assumptions and Scope

We target short-answer problems with recognizable visual structure (boxes/lines). Free-form essays are supported via uploaded PDFs but are not auto-scored; the system focuses on grouping to speed human grading. We assume class rosters are available and that instructors can define answer regions once per assignment.

1.6 Report Organization

Chapter 2 reviews related work and context. Chapter 3 details the system, Chapter 4 presents the evaluation plan, Chapter 5 reports results, and the final chapter concludes with future work.

Chapter 2

Background and Context

2.1 AI in Education

AI has long promised efficiency gains and personalization in education, from adaptive tutoring to analytics that help instructors intervene earlier. Reviews highlight benefits such as individualized practice, faster feedback, and administrative automation when deployed with appropriate oversight[6, 7, 8, 9]. Teacher agency, transparency, and contestability remain essential for trust and learning effectiveness.

2.2 Automated Grading of Short Answers and Essays

Pre-LLM systems typically relied on feature engineering, keyword overlap, or supervised models trained on labeled answers. These reduce load but struggle with paraphrase and reasoning variance[10, 11]. Clustering similar answers to grade in batches is a recurring theme: once clusters form, instructors can assign rubrics at the group level.

2.3 LLMs and GPT-4/4o for Assessment

Recent work investigates LLMs for grading and feedback across STEM and writing tasks. Studies report promising alignment with human graders for mathematical reasoning and physics solutions when prompts focus evaluation criteria and preserve human oversight[12, 13, 14]. LLMs can also aid instructional design and rubric drafting[15]. We leverage GPT-4o Vision for grouping by meaning from images, bypassing handwriting OCR.

2.4 Bias, Fairness, and Student Perceptions

Bias can propagate into grading unless monitored and mitigated[16]. Student acceptance depends on clear processes, contestability, and fairness[17]. Effective formative feedback principles—timely, specific, actionable—remain central whether drafted by AI or humans[18].

2.5 Similar Implementations

To situate this project, we survey adjacent tools and how our system compares. In short, *we have not found public documentation of a production system that groups handwritten short answers directly from images using a general-purpose vision LLM without first OCRing the answer content*. Existing offerings fall into four families:

Commercial paper-exam graders (e.g., Gradescope, Crowdmark). Gradescope [19] supports fixed-template paper exams with region-based workflows and "Answer Groups" that let instructors grade clusters of similar responses at once. However, the grouping method is not publicly documented and is presented at a high level as similarity-based. Crowdmark [20] provides strong scanning workflows (QR-coded booklets, automated student matching via OCR on cover pages) and can auto-grade multiple choice, but does not claim semantic grouping of open-ended answers. **Similarity:** our work also supports fixed templates, grouping, and rubrics-first grading. **Difference:** we group from *images only* (no handwriting OCR of answers), use a token-budgeted vision-LLM pipeline to bound cost/latency, and archive prompts + model versions for auditability.

OMR/MCQ scanning (e.g., Akindi, ZipGrade). Akindi [21] and ZipGrade [22] excel at high-throughput multiple-choice grading from bubble sheets (including mobile scanning) and logistics like sheet sorting. **Similarity:** we likewise handle identity intake for large cohorts. **Difference:** OMR tools target selected-response scoring, not clustering of free-form handwritten work.

LMS graders (e.g., Canvas SpeedGrader). Platform-native graders such as Canvas SpeedGrader [23] offer annotation and rubric workflows for uploaded files. **Similarity:** we present rubric-based grading and feedback at scale. **Difference:** LMS graders do not automatically cluster semantically similar answers for batch grading.

Autograding/algorithmic assessment (e.g., PrairieLearn, Möbius, CodeRunner/CodeGrade). Systems like PrairieLearn [24], Möbius [25], CodeRunner [26], and CodeGrade [27] autograde parameterized or code questions (randomized variants, unit tests, CAS checks) with excellent coverage in constrained domains. **Similarity:** automation reduces repetitive grader effort. **Difference:** their strength is *automatic scoring* of structured responses; they do not aim to *group* heterogeneous, handwritten short answers for a human-in-the-loop rubric pass.

Positioning. Our system is closest in spirit to the "answer grouping" idea in commercial paper-graders, but our distinctives are: (1) **image-only** grouping of handwritten content to avoid brittle OCR, (2) a **cost/latency–bounded** vision-LLM pipeline (downscale + tiling + batching), and (3) an explicitly **auditable, instructor-in-the-loop** workflow (merge/split/move, neutral labels, review status), integrated end-to-end with our site.

2.6 Takeaways for This Project

(1) Group-based grading is an effective accelerator; (2) LLMs help when auditable and editable; (3) OCR of handwriting is fragile—visual grouping bypasses failure modes; (4) fairness and oversight practices must be designed-in.

Chapter 3

Project Solution and Approach

3.1 Overview

The system comprises an ASP.NET Razor Pages app (instructor workflow), a Python FastAPI microservice (AI grouping), a MySQL database (persistence), and a file store (crops/exports). Tools include Ghostscript (rasterization), PdfPig (PDF orchestration), SkiaSharp (region extraction), and Tesseract (identity OCR). GPT-4o Vision provides semantic grouping over cropped answer images.

3.2 High-Level Architecture

3.3 Sequence of Operations

1. Web app posts `/autogroup` with per-answer image paths and per-question max points.
2. FastAPI converts PNG→JPEG (quality 50), computes a token budget at 50% downscale, and sends images with `detail:auto`.

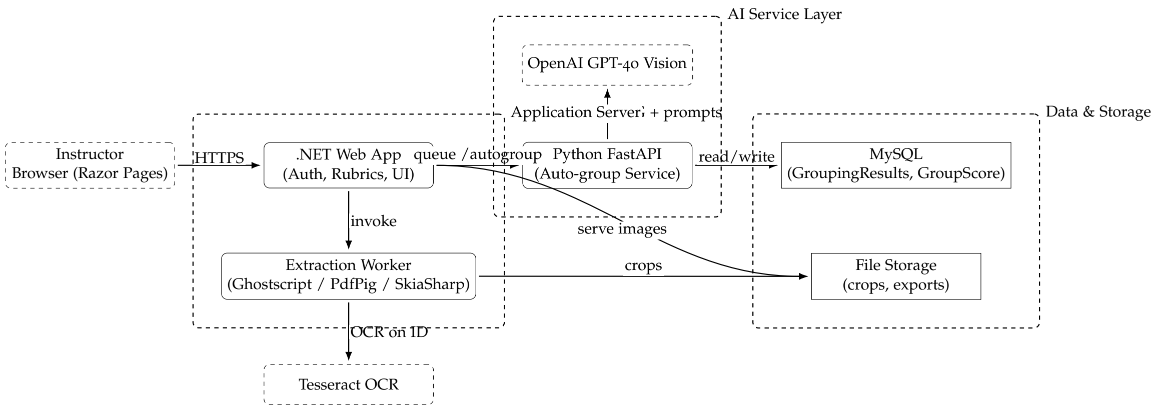

AI Service Layer
OpenAI GPT-4o Vision
Application Server + prompts
Data & Storage
Instructor Browser (Razor Pages)
HTTPS
.NET Web App (Auth, Rubrics, UI)
queue /autogroup
Python FastAPI (Auto-group Service)
read/write
MySQL (GroupingResults, GroupScore)
invoke
serve images
Extraction Worker (Ghostscript / PdfPig / SkiaSharp)
crops
File Storage (crops, exports)
OCR on ID
Tesseract OCR

Figure 3.1: High-level components and data flow.

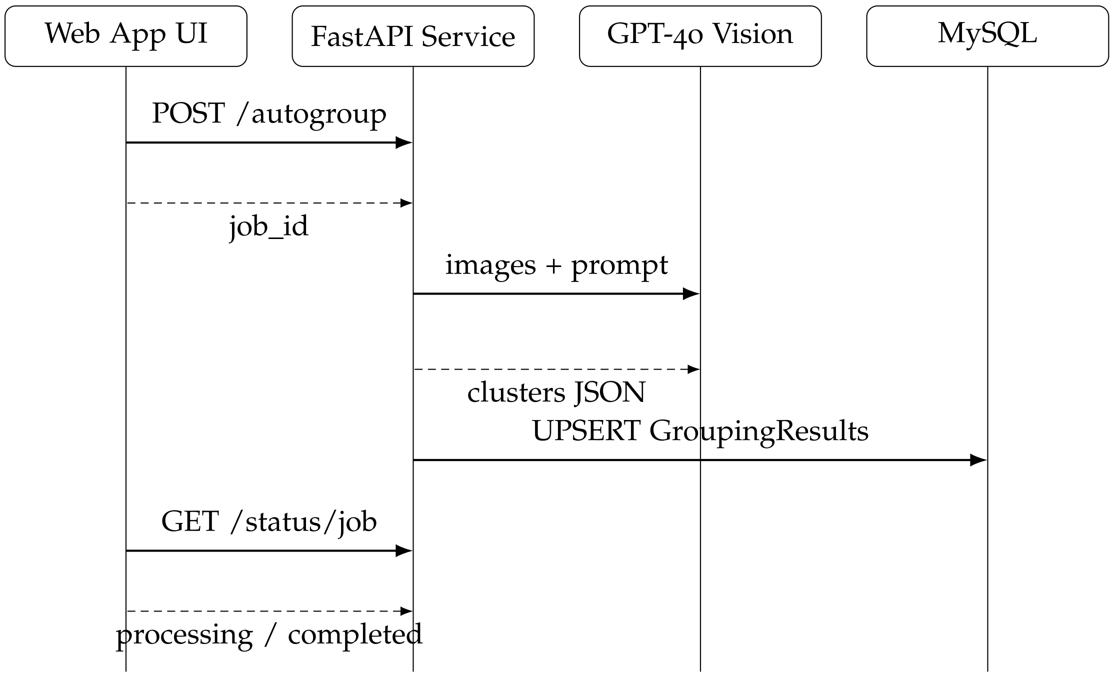


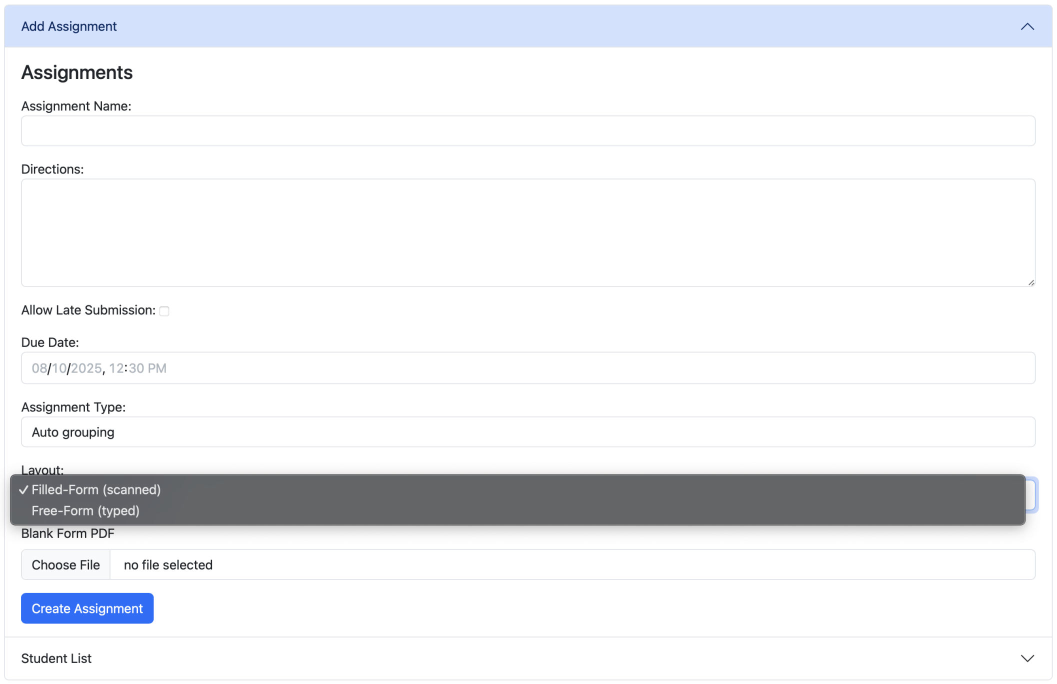
Figure 3.2: Sequence for an auto-grouping job.

3. GPT-4o Vision proposes clusters; service shapes results (UUIDs, neutral descriptions, collapse tiny groups, add *Ungrouped*).
4. Results persist to MySQL (one row/question); UI polls `/status/{job_id}` then renders groups for review and grading.

3.4 Instructor-Facing UI Snapshots

Assignment creation. Instructors configure the submission layout (*filled-form* vs. *free-form*), directions, and dates. The authoring surface then adapts:

- **Free-form:** the instructor enters *only* the question labels (e.g., `Q1`, `Q2a`) and max points per question. No region editor is shown here because students will upload a PDF and *define their own answer regions* in the next step.
- **Filled-form:** in addition to questions/points, the instructor binds an exam template and draws the *identity* and *answer* regions once. Those regions are then used to crop all submissions automatically.



Assignment Name:

Directions:

Allow Late Submission: ☐

Due Date: 08/10/2025, 12:30 PM

Assignment Type: Auto grouping

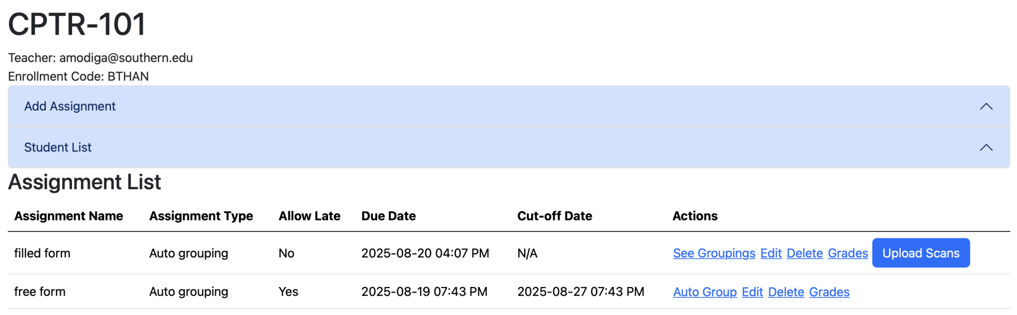
Layout:
✓ Filled-Form (scanned)
Free-Form (typed)

Blank Form PDF

Choose File no file selected

Figure 3.3: Assignment creation form. For free-form, authors enter questions and points only; for filled-form, authors also define identity/answer regions against a template.

Course assignments page. The course view summarizes assignment state (open/closed, submissions, grading progress) and links to grouping/grading.



CPTR-101

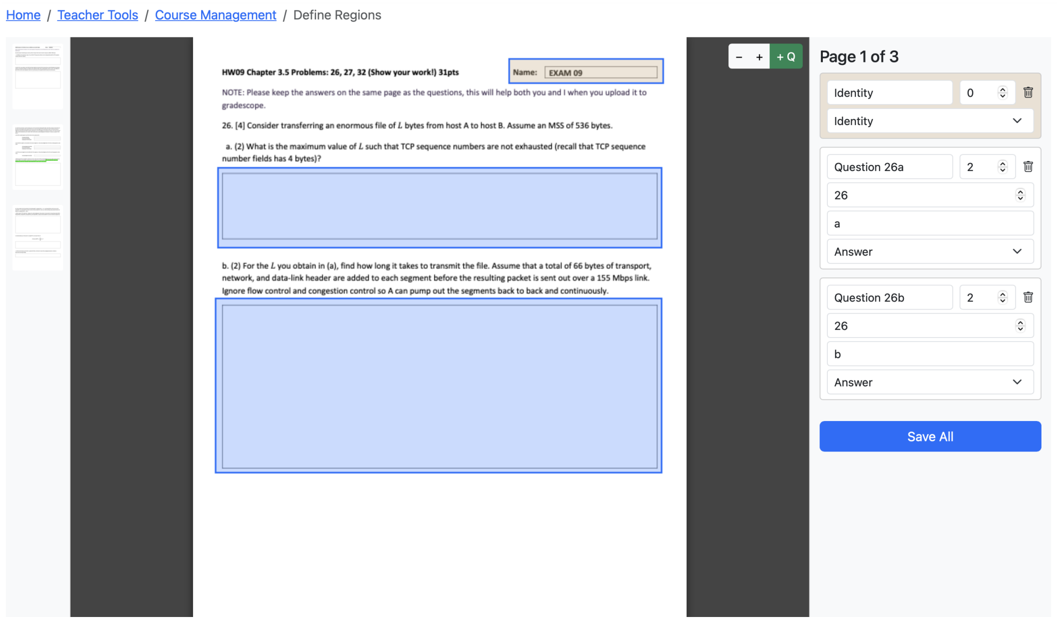
Teacher: amodiga@southern.edu
Enrollment Code: BTHAN

Assignment List

Assignment Name	Assignment Type	Allow Late	Due Date	Cut-off Date	Actions
filled form	Auto grouping	No	2025-08-20 04:07 PM	N/A	See Groupings Edit Delete Grades Upload Scans
free form	Auto grouping	Yes	2025-08-19 07:43 PM	2025-08-27 07:43 PM	Auto Group Edit Delete Grades

Figure 3.4: Course assignments overview with status indicators and quick actions.

Region extraction (shared tool). The same cropping widget is used to verify identity/answer regions for filled-form scans and, in free-form flows, to let students mark their own answer areas.



HW09 Chapter 3.5 Problems: 26, 27, 32 (Show your work!) 31pts

Name: EXAM 09

NOTE: Please keep the answers on the same page as the questions, this will help both you and I when you upload it to gradescope.

26. [4] Consider transferring an enormous file of L bytes from host A to host B. Assume an MSS of 536 bytes.

a. (2) What is the maximum value of L such that TCP sequence numbers are not exhausted (recall that TCP sequence number fields has 4 bytes)?

b. (2) For the L you obtain in (a), find how long it takes to transmit the file. Assume that a total of 66 bytes of transport, network, and data-link header are added to each segment before the resulting packet is sent out over a 155 Mbps link. Ignore flow control and congestion control so A can pump out the segments back to back and continuously.

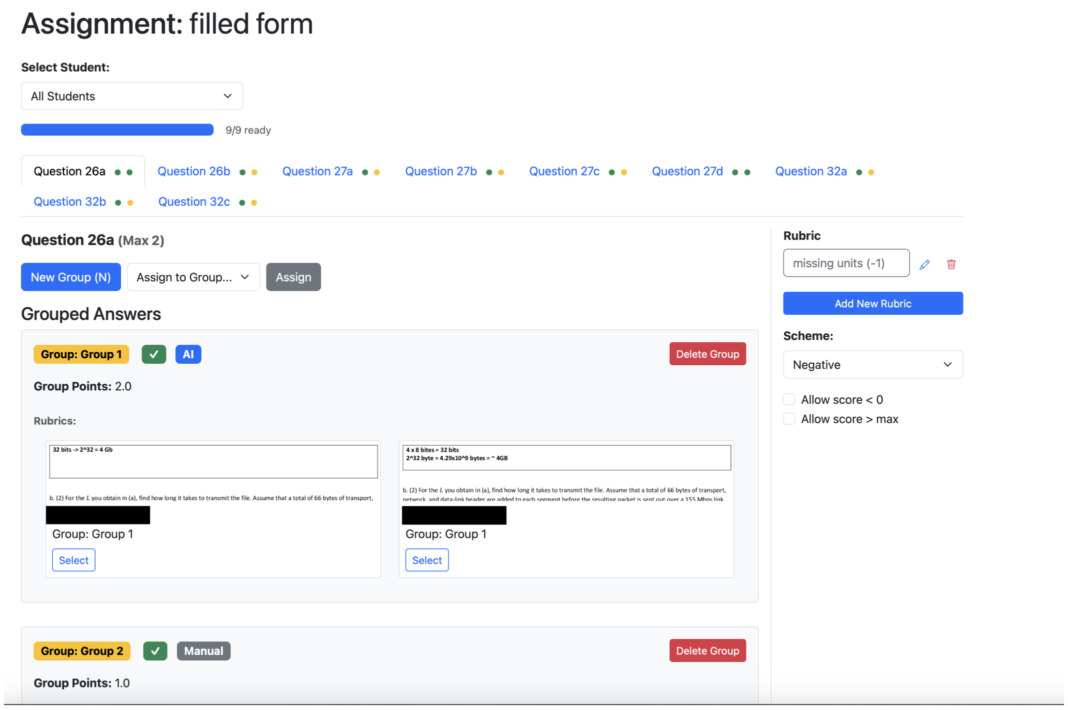
Identity 0
Identity

Question 26a 2
26
a
Answer

Question 26b 2
26
b
Answer

Figure 3.5: Region cropping widget used in two contexts: (i) instructor verification for filled-form scans and (ii) student free-form "mark your answers" flow.

Auto-grouping UI. After crops are generated, the grouping page proposes semantic clusters; instructors can merge/split groups, move items, and apply rubric items per group.


Assignment: filled form

Select Student:

All Students

9/9 ready

Question 26a ● ● Question 26b ● ● Question 27a ● ● Question 27b ● ● Question 27c ● ● Question 27d ● ● Question 32a ● ● Question 32b ● ● Question 32c ● ●

Question 26a (Max 2)

New Group (N) | Assign to Group... | Assign

Grouped Answers

Group: Group 1 ✓ AI — Delete Group

Group Points: 2.0

Rubrics:

32 bits -> 2^32 = 4 Gb

b. (2) For the L you obtain in (a), find how long it takes to transmit the file. Assume that a total of 66 bytes of transport,

[redacted]

Group: Group 1

Select

4 x 8 bites = 32 bits
2^32 byte = 4.29x10^9 bytes = ~ 4GB

b. (2) For the L you obtain in (a), find how long it takes to transmit the file. Assume that a total of 66 bytes of transport, network, and data-link header are added to each segment before the resulting packet is sent out over a 155 Mbps link.

[redacted]

Group: Group 1

Select

Group: Group 2 ✓ Manual — Delete Group

Group Points: 1.0

Rubric

missing units (-1)

Add New Rubric

Scheme:

Negative

Allow score < 0

Allow score > max

Figure 3.6: Auto-grouping page with proposed clusters, edit tools, and rubric-first grading.

3.5 Region Extraction and File Lifecycle

For **filled-form** assignments, instructors define identity and answer regions once per assignment; the worker then applies those regions to every scanned booklet and enforces stable filenames (e.g., `Q27a.png`) for reproducibility and idempotent re-uploads. For **free-form**, students upload a PDF and mark their own answer regions; the saved boxes are used to generate per-question crops for grouping and grading. Debug images are suppressed outside development builds. Re-uploads replace prior crops and metadata to avoid drift.

3.6 Identity Assignment

Filled-form batches use Tesseract to extract roster identifiers from the identity region. Low-confidence matches are flagged for manual resolution with a roster pick-list and thumbnail preview. Free-form uploads are tied to the uploader's account; no answer OCR is executed.

3.7 Grouping Heuristics

We instruct the model to produce *fewer, larger clusters*, to route unreadable/singletons into *Ungrouped*, and to emit neutral descriptions ("Group 1", "Group 2"). Tiny groups under a threshold are collapsed into *Ungrouped*. Groups are sequentially re-numbered for clarity. All prompts and model versions are archived with the `job_id`.

3.8 Data Model

Table 3.1: Key table: `GroupingResults`.

Column	**Type**	**Notes**
Id	BIGINT (PK)	Surrogate primary key.
AssignmentId	BIGINT (FK)	Links to the assignment entity.
AssignmentQuestionId	BIGINT (FK)	Equals `template_region_id` sent by client.
GroupData	JSON	Array of groups with files, description, `is_correct`, `points`.
CreatedAt UpdatedAt	DATETIME	Audit timestamps (UTC).

3.9 Prompting & JSON Schema

The service uses a system message with practical grouping guidelines (fewer, larger clusters; neutral labels; unreadable/singletons $\rightarrow$ *Ungrouped*). We archive the exact prompts and model/version with the `job_id` for reproducibility. The model returns JSON of the following form (abbrev.):

```
{
  "groups": [
    {
      "group_id": "uuid",
      "files": [{ "file_path": "...", "user_id": "...",
                  "template_region_id": "...", "question_label": "...",
                  "content_type": "image/jpeg", "user_name": "..." }],
      "description": "Group 1",
      "is_correct": true | false | null,
      "points": 5.0
    }
  ]
}
```

3.10 Token Budget, Cost & Rate Limiting

For an image of width w and height h, the service estimates tokens after a 50% downscale: $w' = \lfloor w/2 \rfloor$, $h' = \lfloor h/2 \rfloor$. The number of 512×512 tiles is $T = \lceil w'/512 \rceil \cdot \lceil h'/512 \rceil$, and the cost estimate is $85 + 170\,T$ tokens/image. Batches exceeding a threshold are split. On rate limits, the client retries up to 10 times with exponential backoff. For a representative 768×768 downscaled image ($T = 3$), the estimate is $\sim$ 595 tokens/image.

3.11 Integration with ASP.NET

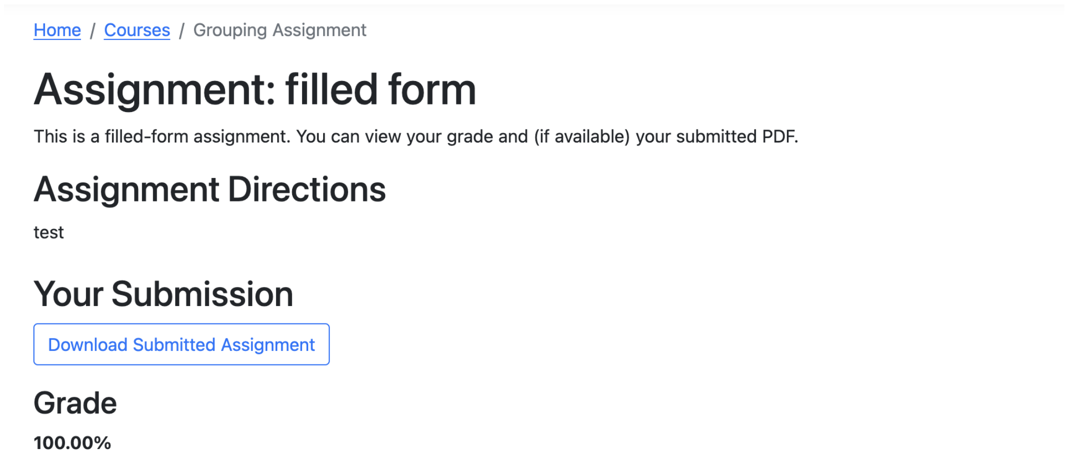
The web app calls `QueueAutoGroupAsync` (server) to POST to `/autogroup`, records a `GroupingJob`, and renders a progress UI that polls `/status/{job_id}`; when the background job completes, the page automatically refreshes into the results view. Subsequent instructor actions (save groups, apply/remove rubric items, scoring method toggles) are persisted in the relational database and mirrored in a `GroupScore` table; a background grade recalculator keeps submission grades in sync.

3.12 Student-Facing Assignment UI

Students reach an assignment-specific page that adapts to the configured layout:

Filled-form (read-only). Students cannot upload; they can download the submitted booklet (when present) and view the grade once posted. The page surfaces `Directions` and a simple status panel.

Free-form (student upload). Students upload a single PDF, then are routed to a `DefineAnswerRegions` step to mark answer boxes. When submissions are open (`DueDate/AllowLateWork/CutoffDate` enforced via `CanSubmit()`), they can resubmit; otherwise the page displays a "Resubmissions have closed" notice. *Note:* The region-marking widget for free-form uploads reuses the same cropping interface shown in Figure 3.5; we avoid duplicating the screenshot here.



Home / Courses / Grouping Assignment

Assignment: filled form

This is a filled-form assignment. You can view your grade and (if available) your submitted PDF.

Assignment Directions

test

Your Submission

Grade

100.00%

Figure 3.7: Student assignment page: layout indicator (filled vs. free-form), PDF upload (free-form only), download of submitted file, and grade display.

3.13 Rubrics and Grading UX

While grading a group, instructors select and apply rubric items; zoom/pan is supported where available. Changing a rubric value propagates to all affected answers. The Question tab surfaces review status: each group displays a status badge ("Graded" or "Needs grading"). Instructors can either apply at least one rubric item or, if none are needed, click `Save All Groups for Question` to mark the question as reviewed.

3.14 Security & Privacy

Only course roster identifiers and per-answer images are processed; no plaintext student content is transmitted for grouping. Access is limited to authenticated instructor actions. The design aligns with FERPA expectations around access control and least-privilege handling of student records [28].

3.15 Threat Model & Data Handling

Table 3.2: Abbreviated threat model and mitigations

Threat	Risk	Mitigation
Unauthorized access	Disclosure of student data	Role-based auth; per-course ACLs; audit logs
Model data exposure	PII leakage to third party	Only identity crops contain PII; answer crops exclude names
Prompt injection	Manipulated grouping suggestions	Server-side prompts; normalize outputs; edit/override tools
Data retention	Oversharing over time	Rotation policy; per-course retention config; export/purge

3.16 Limitations & Risks

- **Generalization:** Prompts tuned on one course may not transfer perfectly to other subjects; mitigated by neutral labels and editable groups.
- **Model drift:** Vision model updates can shift behavior; we pin model/version and archive prompts with run IDs.
- **Edge cases:** Faint pencil, skew, or multiple answers in one crop reduce grouping confidence; flagged to *Ungrouped*.
- **Human factors:** Instructor trust varies; we surface why/where groups changed and keep full override tools.

Chapter 4

Testing and Evaluation Plan

Chapter 5

Results

Chapter 6

Conclusion

6.1 Summary of Problem and Goals

We addressed the effort and inconsistency of grading open-ended work by building an instructor-in-the-loop system that extracts regions, assigns identity via OCR, groups answers with a vision LLM, and enables rubric-first grading with auditability.

6.2 Evaluation Summary (Aligned to Proposal Tests)

6.3 Final Outcomes and Deliverables

We delivered the integrated web app, background services, reproducible prompts/model versions, and a grade export flow compatible with LMS import. Documentation includes an instructor guide and technical deployment notes.

6.4 Lessons Learned and Future Work

- Visual pre-processing (downscale/tiling) mattered more for stability than minor prompt tuning.
- Instructors preferred neutral group names and an explicit *Ungrouped* bin.
- Future: domain-tuned prompts for math diagrams, adaptive thresholding for faint pencil, pre-clustering to cut LLM calls, regrade workflow, and CSV/Excel export automation to specific LMS formats.

Chapter 7

Ethics, Privacy, and Compliance

We minimize student-data exposure by: (1) processing only identity regions with OCR; (2) sending cropped answer images to GPT-4o Vision without student names; (3) restricting access to authenticated instructors; and (4) logging access for audit. The design aligns with FERPA expectations[28]. We also monitor for potential bias by auditing cluster assignments across demographic-neutral cohorts and provide full instructor override mechanisms.

Appendix A

Configuration and Deployment

This appendix captures the minimum configuration to run the system on a fresh machine. Replace placeholders (the ALL-CAPS bits) with values for your environment.

A.1 Prerequisites

- Windows 11 / Ubuntu 22.04 / macOS (developed & tested on all three).
- **.NET SDK** (web app).
- **Python 3.10+** (FastAPI grouping service).
- **MySQL/MariaDB**.
- **Ghostscript** (PDF rasterization) available on `PATH` or via `GHOSTSCRIPT_EXE`.
- **Tesseract OCR** (install language data `eng` at minimum).
- Vision LLM API access set via `OPENAI_API_KEY`.

A.2 FastAPI Service: `.env`

Create a `.env` file in the FastAPI project root:

```
# --- OpenAI / Vision LLM ---
OPENAI_API_KEY=YOUR_OPENAI_KEY

# --- Database used by the service ---
DB_HOST=YOUR_DB_HOST
DB_NAME=OICLearning
DB_USER=YOUR_DB_USER
DB_PASSWORD=YOUR_DB_PASSWORD

# --- Optional service bind (defaults shown) ---
HOST=0.0.0.0
PORT=8000
```

Start the service:

```
python -m venv .venv
# Windows: .venv\Scripts\activate
# macOS/Linux: source .venv/bin/activate
pip install -r requirements.txt
uvicorn app:app --host 0.0.0.0 --port 8000
```

A.3 Web App: `appsettings.json`

Use this structure for both `appsettings.json` and `appsettings.Development.json`. Only update the hostnames, passwords, folders, and API base URL; keep DB name and UID as shown.

```
{
  "ConnectionStrings": {
    "MySqlConnection":
```

```
    "Server=YOUR_DB_HOST;Database=OICLearning;Uid=www_oiclearning;Pwd=YOUR_DB_PASSWORD",
    "MySQLTestSite":

    "Server=YOUR_TEST_DB_HOST;Database=OICLearning;Uid=www_oiclearning;Pwd=YOUR_TEST_DB_PASSWORD
  },

  "Logging": {
    "LogLevel": {
      "Default": "Information",
      "Microsoft.AspNetCore": "Warning"
    }
  },

  "AllowedHosts": "*",

  "RoleStrings": {
    "Teacher": ["Admin", "Teacher"],
    "Admin":   ["Admin"],
    "Student": ["Student"]
  },

  "FileRepository": {
    "SubmissionFolder": "/path/to/submissions",
    "AutoGraderFolder": "/path/to/autograders"
  },

  "PythonApi": {
    "BaseUrl": "http://YOUR_FASTAPI_HOST:8000"
  }
}
```

Point the callers at `PythonApi:BaseUrl`

Update the two callers to use `PythonApi:BaseUrl` *without* a localhost fallback.

CourseService.cs (snippet)

```
var client  = _httpClientFactory.CreateClient();
var baseUrl = _configuration.GetValue<string>("PythonApi:BaseUrl");
client.BaseAddress = new Uri(baseUrl);

var response = await client.PostAsJsonAsync("/autogroup", requestBody);
response.EnsureSuccessStatusCode();
```

GroupingService.cs (snippet)

```
var client  = _httpClientFactory.CreateClient();
var baseUrl = _configuration.GetValue<string>("PythonApi:BaseUrl");
client.BaseAddress = new Uri(baseUrl);

// ...status polling / error handling continues...
```

A.4 Ghostscript Location

If Ghostscript is not on `PATH`, set `GHOSTSCRIPT_EXE`.

macOS (Homebrew):

```
export GHOSTSCRIPT_EXE=/opt/homebrew/bin/gs
```

Ubuntu/Debian:

```
export GHOSTSCRIPT_EXE=/usr/bin/gs
```

Windows (PowerShell):

```
$env:GHOSTSCRIPT_EXE="C:\Program Files\gs\gs10.03.0\bin\gswin64c.exe"
```

The extractor prefers the env var and falls back if needed:

```
var gsExe = Environment.GetEnvironmentVariable("GHOSTSCRIPT_EXE")
           ?? "/opt/homebrew/bin/gs"; // adjust per OS
```

A.5 Tesseract on macOS (dev builds)

If you hit dylib resolution issues with Homebrew installs, use this post-build step:

```
<!-- OICLearning.csproj (snippet) -->
<Target Name="link_deps" AfterTargets="AfterBuild">
  <Exec Command="ln -sf /opt/homebrew/lib/libleptonica.dylib
                 $(OutDir)x64/libleptonica-1.82.0.dylib" />
  <Exec Command="ln -sf /opt/homebrew/lib/libtesseract.dylib
                 $(OutDir)x64/libtesseract50.dylib" />
</Target>
```

A.6 Build and Run (Web App)

1. Restore NuGet packages and build.
2. Apply EF Core migrations:

   ```
   dotnet tool restore
   dotnet ef database update
   ```

3. Launch the app:

   ```
   dotnet run
   ```

4. Ensure `FileRepository.SubmissionFolder` exists and is writable.

A.7 Operational Notes

- Re-uploads are idempotent; crops use stable names (e.g., `Q27a.png`).
- Only identity regions are OCR'd; answer crops go to the vision model.
- Groupings are editable; an *Ungrouped* bucket catches outliers.
- Grades appear in an on-screen table; CSV/Excel export is available.

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