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PHD THESIS

SUMMARY

Blending Technology and Education: A Deep Dive into Document Image Analysis, Image Processing and Teaching Engineering

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Chapter 1

Introduction

Edsger Dijkstra once remarked: "*A picture may be worth a thousand words, a formula is worth a thousand pictures.*" Is it still considered a valid statement?

The digital world's rapid evolution is marked by data exchange and advancing technology, leading to reliance on smaller, powerful devices. Communication is changing, with images and videos supplementing words. An interdisciplinary thesis explores how this era impacts work, learning, and collaboration, focusing on Human-Computer Interaction, Computer-Supported Collaborative Learning/Working (CSCL/CSLW), Image Processing, and Teaching Engineering. CSCL/CSLW involves using digital tech to promote collaborative learning, emphasizing social interaction and skill development.

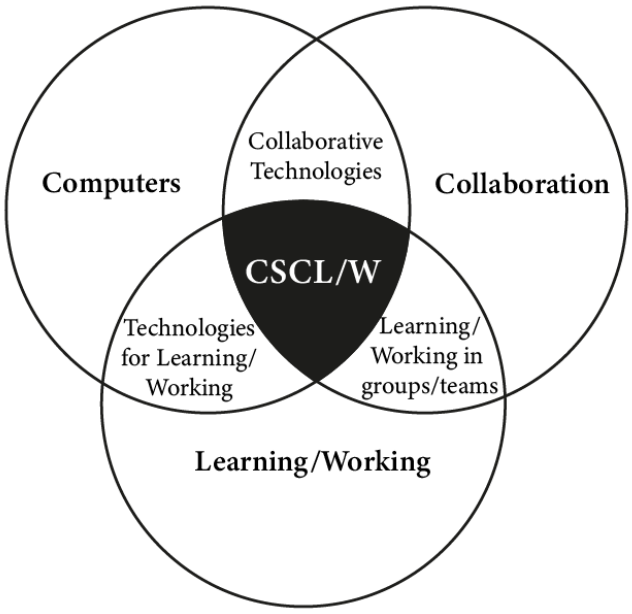

Figure 1.1: Multidisciplinary of CSCL/CSLW

Digitalization is vital for traditional libraries, housing old manuscripts and documents. Computer-Supported Collaborative Learning/Working (CSCL/CSLW) offers opportunities like retroconversion solutions, accelerating the digitization of historical material. This approach is embodied in a modular Document Image Analysis System, promoting interactive learning and collaboration for system enhancement. Individual contributions drive collective success in this CSCL/CSLW environment.

The first step in building a retroconversion system involves understanding the input and applying pre-processing for Optical Character Recognition. The thesis explores pre-processing methods, aiming to create a configurable modular system in Chapter 3. Also, it explores into Image Processing techniques like Binarization and Segmentation, discussing their applications in detail in Chapter 4.

Teaching engineering with a focus on CSCL/W emphasizes hands-on learning, practical experiences, and lifelong learning. It promotes diverse skills, software tools, and ethics awareness. In Chapter 5, a series of surveys were conducted. The first survey examines collaborative and competitive learning's impact on project-based learning in software development, and it continues with decision-making in managerial teams.

Moreover, the research conducted highlights the importance of sleep on developer productivity, evaluates startup vs. tech transfer approaches, and addresses diversity in Romania's tech startup scene.

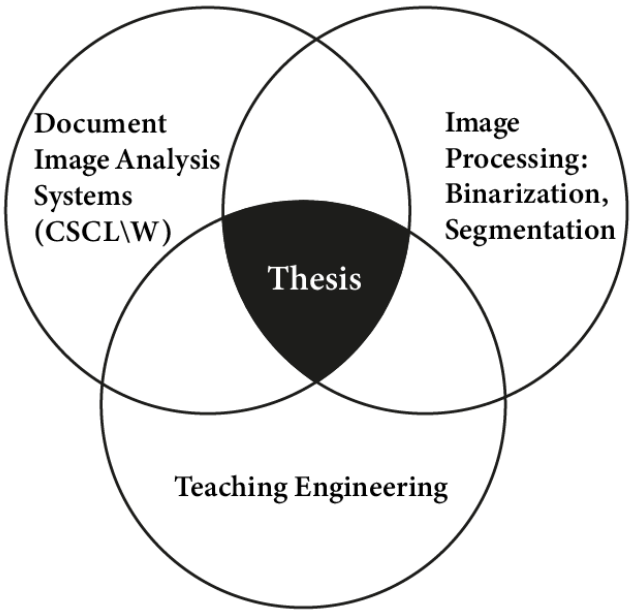

Figure 1.2: Multidisciplinary of the thesis

This thesis embarks on addressing contemporary educational demands, exploring them through the prism of technological integration within learning and working environments, as observed in Figure 1.2. It champions not only the active engagement of students in research initiatives to nurture both hard and soft skill development, but also meticulously examines the team's involvement throughout the development journey. Fusing these considerations, the thesis offers a holistic view of these converging elements, shaping an all-encompassing perspective of their synergies. In this vein, the thesis encapsulates an array of experiments in image processing methods and retroconversion systems, highlighting their implications for education, research, and performance. Concurrently, it delves into aspects of software development, management and development that underpin the project.

Complementing these technical components, the thesis also unravels the impact on business structures, spotlighting the organization and diversity of the team involved, thereby creating a unique blend of educational, technical, and organizational exploration.

1.1 Thesis Structure

The thesis is structured as follows:

Chapter 2 presents the state of the art in the literature with respect to Document Image Analysis Systems and Image Analysis and Processing, with a focus on methods and evaluation metrics for Binarization and Segmentation.

Chapter 3 presents our contributions regarding retroconversion systems, proposing a modular Document Image Analysis System which incorporates Optical Character Recognition, and a series of pre-processing and post-processing techniques. We also present our work on how a Document Image Analysis System can have an approach on 3 axes: education, research and performance.

Chapter 4 presents our contributions with respect to a series of voting strategies applied in Image Binarization and Image Segmentation and Edge detection. With the extraction of information from the images in mind, we propose an experiment in AR to allow users to experience different architectural styles and cultural heritages by altering the appearance of buildings in their environment.

Chapter 5 presents our work on the management and development side of the software projects. We proposed a survey to evaluate the process of decision-making in teams. Also, we run a study on the impact of sleep quality on the developers. Another topic involved in the discussion is on the business side, where we included a comparison between startup and tech transfers. We also presented a radiography of diversity in the Romanian tech startup ecosystem.

Chapter 6 concludes and presents the list of publications.

Chapter 2

State of the Art

2.1 Overview of Document Image Analysis Systems

Technological progress has transformed sectors like engineering, education, and medicine, rendering old devices obsolete. Printed media, while enduring, is also moving towards digital representation due to advantages like accessibility and preservation. However, converting print to digital faces challenges such as damage, fonts, and data extraction. Document Image Analysis Systems (DIAS) address this, using Optical Character Recognition (OCR) as a part of a larger process. DIAS can digitize various documents, offering advantages like recognition and granularity. The following sections explore DIAS methodologies and technologies.

2.1.1 Document Image Analysis System Solutions

With the intricate nature of image analysis, which involves various operations at multiple levels, software applications designed to process these documents tend to be task-specific rather than universally applicable for information extraction from any document type. Such specificity is rational to ensure optimal performance from a document image analysis system. These limitations could pertain to the system's application domain, language support, document layout, or paper quality.

In an ideal world, a single comprehensive application could extract data from any document type. Realistically though, each specialized application tends to target a specific problem, with its components and analysis system inherently limiting their applicability. These limitations might include specific processing steps, document quality prerequisites, language restrictions, or a confined document layout applicable only to a series of similarly styled documents [1][2]. Even with a restricted input structure, the processing steps require different sets of parameters due to various factors, such as paper color variations, non-standard document layouts, and diverse handwriting styles, among others.

To enhance their efficiency, document image analysis systems may further narrow their scope by focusing on specific document features such as name extraction [3], table, chart, or image isolation [4]. These refinements hinge on the assumption that only certain data is relevant for document indexing. The system proposed by Likforman-Sulem et al. [4] completely bypasses character recognition by extracting "word images" and matching them in a composite way with dictionary entries and machine learning-derived name-like probability.

Certain systems struggle to adapt to the poor quality of the documents they process, leading to the development of new systems reliant on user feedback. As indicated by Holley [5], the outcomes without human input are less than ideal, thereby underscoring the necessity of user feedback for result enhancement. Other systems take the converse approach by providing the user with complete control over the document analysis. While specific human interventions prove beneficial when batch mode processing fails to yield standard results, a hybrid model combining automatic processing [6] with human involvement can offer the best possible solution without redundant efforts [7].

In the contemporary era, large-scale initiatives are emerging to digitize the contents of national libraries, such as those in Australia, Finland, and the US. Alongside the hardware support for document scanning, these projects employ robust software for information extraction. The following sections describe some of these systems and evaluate their design choices comparatively.

It's no secret that the domain of retroconversion software applications and services is becoming increasingly saturated. Likewise, the collections of books, newspapers, and historical documents are growing larger, more meaningful, and are providing information that is more accurate and better structured than ever before. Yet, this only scratches the surface, as most valuable literature and document collections remain in paper format. The transition from paper to digital format is a task that will span many more years.

Despite the complexities associated with retroconversion solutions, the demand for reliable systems remains high. Bearing this in mind, our aim as a subproject in [8] was to put forward a versatile, modular system capable of addressing individual operations or entire workflows. In Chapter 3, we will delve into the challenges related to implementing a Document Image Analysis System - DIAS, along with some necessary pre-processing steps involved. This approach will provide a comprehensive understanding of both the broad scope and intricate details involved in the retroconversion process.

2.2 Image Analysis and Processing for Binarization

Image binarization consists of the process of converting a gray-scale image into binary format, delineating objects of interest from the background [9]. It plays a pivotal role in document image analysis and other computer vision tasks, serving as a foundational preprocessing step [10]. It simplifies complex images by reducing multilevel intensity information to two levels, foreground and background, thus accentuating regions of interest and making subsequent analyses more manageable. The quality of binarization can significantly impact the performance of these subsequent processes. Numerous algorithms have been proposed to conduct this task, starting from classic methods like Otsu's method [11], Niblack's method [12], and Kapur's entropy-based method [10], up to more recent deep learning-based approaches [13].

The efficacy of the binarization process must be evaluated because the quality of binarization can have a substantial impact on downstream tasks such as object identification,

recognition, and tracking. Several evaluation metrics have been proposed to quantify the performance of binarization methods [14][15][16][17]. Metrics such as the Mean Squared Error (MSE), Peak Signal-to-Noise Ratio (PSNR), and F-measure provide a quantitative analysis of the binarization output, thus facilitating the comparison and selection of optimal binarization algorithms for different applications. Additionally, metrics like Distance-Reciprocal Distortion Measure (DRD) and Pseudo F-measure have also been introduced to address specific limitations of previous metrics [14][15]. These metrics offer different insights into the binarization performance, including the accuracy of foreground-background separation, noise reduction, and preservation of details.

Numerous algorithms have been developed to address the issues associated with image binarization. Some of the early techniques include Otsu's method, which uses the threshold that minimizes the within-class variance of black and white pixels [11], and Niblack's method, which employs local mean and standard deviation to adaptively select the threshold [12]. Kapur et al. devised an entropy-based method that utilizes the entropy of the histogram for threshold selection [10].

Other notable methods include a recursive thresholding technique proposed by Cheriet et al. [16] and Howe's document binarization technique that automatically tunes the parameters [17]. In the era of deep learning, Tensmeyer and Martinez [13] proposed a fully convolutional neural network approach to binarization, demonstrating superior performance over many traditional methods.

The future of image binarization evaluation holds much potential. As machine learning and AI continue to permeate image processing, we expect these technologies to play a substantial role in enhancing image binarization evaluation [17]. New methodologies could emerge that learn from a diverse range of image data to predict binarization quality, leading to more reliable and adaptive evaluation processes.

Furthermore, as the image binarization field continues to evolve, we anticipate a growing interest in specialized metrics tailored to specific applications, such as document analysis or medical imaging. The continuing development and expansion of benchmark datasets and competitions, like DIBCO, will also be instrumental in driving this research forward [15].

As we move forward, it's vital to continue questioning and refining our approaches to ensure we are effectively evaluating and improving image binarization techniques.

2.3 Image Analysis and Processing for Segmentation

Image segmentation is an essential process in computer vision in which an image is partitioned into multiple regions and segments, with each segment corresponding to a distinct object or region of interest. It plays a crucial role in various applications, including object recognition, scene understanding, medical imaging, autonomous driving, and more. By segmenting images, valuable information can be extracted, allowing for targeted analysis

and facilitating higher-level computer vision tasks. In the domain of document segmentation, this processing involves partitioning a document image into meaningful regions, such as text, images, tables, headers, footers, and other structural components. Segmenting document images makes it possible to extract and analyze individual elements, enabling tasks like text recognition, document understanding, and layout analysis.

These are just a couple of examples of the many algorithms available for image segmentation. Some notable methods include U-Net [18] used in biomedical image analysis, GrabCut [19] an iterative graph-cut-based algorithm that combines interactive user input and graph optimization, Watershed segmentation, Mean-Shift, Random Walker [20], and Mask R-CNN [21]. The choice of algorithm depends on factors such as the specific segmentation task, image characteristics, computational efficiency, and the availability of labeled training data.

Evaluation metrics play a crucial role in image segmentation, as they provide a quantitative and objective assessment of the performance and quality of segmentation algorithms. They are essential for comparing different segmentation methods, fine-tuning algorithm parameters, and measuring progress in the field of computer vision.

In terms of performance comparison, evaluation metrics allow for comparing the performance of different segmentation algorithms or variations of the same algorithm. By quantitatively assessing metrics such as accuracy, precision, recall, or IoU, it becomes possible to identify which algorithms or techniques yield superior segmentation results. This helps in selecting the most suitable algorithm for a particular task or dataset.

Nonetheless, evaluation metrics provide a standardized way to benchmark segmentation algorithms and track progress in the field. Datasets with ground truth annotations and established evaluation protocols allow researchers to compare their methods against state-of-the-art approaches. This helps in measuring advancements in segmentation algorithms over time and enables the identification of novel techniques that outperform existing ones.

Last but not least, evaluation metrics facilitate dataset analysis by quantifying the quality and consistency of annotations. They help identify challenging image regions, cases of mislabeling or ambiguity, and potential biases in the dataset. Understanding the dataset characteristics through evaluation metrics can guide the development of better segmentation algorithms and highlight areas for dataset improvement.

Overall, evaluation metrics are vital for objective and standardized assessment of segmentation algorithms, aiding in performance comparison, algorithm selection, parameter tuning, benchmarking, and dataset analysis. They help advance the field of image segmentation by promoting the development of more accurate and robust algorithms.

Despite the multitude of proposed image segmentation algorithms, it remains an unresolved challenge. Advancement in this domain hinges on the capability to verify if a new algorithm, or an alteration to a current one, truly signifies an improvement. Techniques for evaluating segmentation facilitate this procedure by providing a platform for comparing various segmentation algorithms and their congruence with human perceptual grouping.

Chapter 3

Document Image Analysis System

A new Document Image Analysis System demands for a configurable and adaptable approach for a modular Optical Character Recognition (OCR) system. The goal is to incorporate various image preprocessing techniques to enhance OCR accuracy. The modularity of this system provides a foundation for building diverse and complex systems for different purposes.

The proposed retroconversion system breaks from traditional designs with its configurable components, providing dynamic runtime customization. Unlike monolithic architectures, it allows users control over processing steps and output formats. Our solution offers educational insight, interactive learning, and research potential, making it adaptable to various scenarios. This approach enhances performance efficiency and caters to diverse user needs, contributing holistically to OCR advancements.

Each function is executed by an independent component. These components, executed through command-line parameters, generate images or files in XML/JSON formats. Every module is finely tuned for a distinct task, accomplished through a sequence of sub-tasks and a final candidate selection via a voting system. The system's flow is user-friendly and adaptable, allowing runtime customization. Users can adjust the system while it operates, enhancing adaptability and usability. Our proposed system organizes modules into classes, each designed for specific tasks. This architecture, built on individual binaries, offers advantages in various domains.

In **education**, this design empowers students to understand, modify, and validate the system, fostering problem-solving skills and creativity. The modular approach provides granular control, enhancing learning.

For **research**, modularity allows extensive experiments, facilitating targeted investigation and optimization. Isolating modules aids understanding and can lead to breakthroughs.

In terms of **production** and performance, module interconnectedness offers flexibility and real-time error feedback. Self-regulation enhances reliability and adaptability, ensuring productivity and future relevance.

Overall, the proposed modular design benefits education, research, and production, advancing the field with enhanced learning, innovation, and productivity.

3.1 On Education - Modular System

Within the scope of education, the benefits of this modular system design become abundantly clear. It provides students with a broad range of opportunities for learning and growth. For instance, students may be given simpler assignments like substituting a single module, or they could be challenged with more complex tasks, such as designing an entire class of modules from scratch.

In either case, students gain the valuable experience of interacting directly with the system, bringing their theoretical knowledge into practical application. They are given the chance to test the system's responses to their modifications, validating their work in a real-world scenario. Such hands-on experiences have a profound effect on their learning, enriching their comprehension of the system's intricacies and enhancing their skill sets.

Therefore, in the educational context, this modular design does more than just simplify complex tasks. It provides a rich, experiential learning platform where students can understand, experiment, and grow, laying a strong foundation for their future in technology and innovation.

3.2 On Research - Explore Image Denoising

The retroconversion solution's success stands in the quality of the image document. In order to enhance the image document, one of the pre-processing steps included in the pipeline is image denoising.

Image noise is typically named after the noise signal's distribution. As a result, noise signals are encountered and can be characterized by a Poisson, Gaussian, or even normal distribution, as well as salt and pepper noise, which represents extremely high and extremely low impulse. The purpose of this method is to explain a simple voting image denoising method that includes various filters specialized in different types of digital image noise. The acquired results are compared to a well-known denoising technique in terms of performance and quality.

The algorithm starts by removing salt and pepper noise. Then, it deeply analyzes the image to eliminate Gaussian noise, addressing each noise type independently for comprehensive denoising. This stepwise approach is core to this solution. Salt and pepper noise stands out as high and low pixel value impulses. A widely used technique to counter it is median filtering. This non-linear method assesses a pixel's surroundings, computing its median and replacing the original pixel. This mitigates extreme values caused by this noise, leading to smoother images. While simple, this technique effectively handles salt and pepper noise by using median values to counter outliers. Incorporating it enhances image quality by reducing noise disruption.

Contrasting salt and pepper noise, Gaussian noise can be reduced using Gaussian or box filters. However, these filters, acting as low-pass filters, inadvertently smooth edges, impacting image sharpness. To counter this, specialized denoise filters like the bilateral filter

preserve edge sharpness.

The next step involves subtracting the filtered image from the noisy one, isolating the high-frequency signal from the noise. Assuming this signal primarily comprises Gaussian noise, we compute its standard deviation from the noise map. This value then guides the bilateral filter's color deviation. Spatial standard deviation and pixel neighborhood diameter remain fixed. Thus, the proposed method offers an efficient and tailored solution for managing different types of image noise, leveraging the specific characteristics of each noise type to enhance the image's overall quality.

The suggested voting-based image denoising algorithm has proven to be effective in eradicating both Gaussian and salt and pepper noise. When juxtaposed with a well-proven algorithm like the Fast Non-Local Mean Denoise (FNLMD), it demonstrates comparable or even superior performance under specific conditions, particularly in the removal of salt and pepper noise or minimal amounts of Gaussian noise.

The proposed algorithm, with its efficacy and adaptability, stands as a valuable contribution to the field of image denoising. Nonetheless, its full potential has yet to be fully tapped, and future work may further enhance its effectiveness, versatility, and integration with other image processing techniques.

3.3 On Performance - Proposing a new method for Connected Components Labeling

The performance of the Document Image Analysis System stands in the research and efforts to improve the existing methods, and creation of new ones, and offers a tailored approach for each scenario and limitations presented. The introduced method swiftly identifies connected components [22] in binary images using efficient data structures. Its memory usage is proportional to run-lengths [23] in the input image. Its simplicity and low complexity make it ideal for intensive component detection tasks.

The proposed method for connected components labeling has the following claims to the studied field:

- CCL Method has static in-memory storage of the entire collection of runs and their equivalent SAP structures. The linked lists and relationships between them do not alter the positions of the constituent elements in memory, but only change the relationships between them by setting the PRIM and URM pointers. This leads to fast processing without memory allocations/deallocations during runtime.
- The proposed solution has an immediate adaptation of the method for 4-way-connectivity or 8-way-connectivity by simply modifying the relationship between two runs on adjacent rows RR1 and RR2. This relationship can be generalized to encourage stronger or weaker connections, by setting an offset, as follows: $RR1.s + \text{offset} \geq RR2.i \;\&\&\; RR1.i - \text{offset} \leq RR2.s$.

- Provides a complete generation, without movements/allocations/deallocations of memory blocks, of each connected component in the case of a merge operation with a new connected component. This is achieved by quickly navigating the shorter list between L1 and L2, associated with the two components that are being merged, and thus setting the new head of the resulting list a minimum number of times. The value of the offset for 4-way-connectivity is set to 1, respectively 0 for 8-way-connectivity.
- The method manages a connected component only by maintaining the convention that its starting SAP is self-referenced by the PRIM pointer.

Below, we list the main contributions of this chapter.

- We provided a comprehensive background regarding Document Image Analysis Systems and Image Processing, with a focus on Binarization and Segmentation, and state-of-the-art metrics for evaluation of the binarization and segmentation algorithms.
- We presented an innovative modular system that incorporates Optical Character Recognition (OCR) functionality, which was used in Lib2Life project [8] for digitalizing 4 million pages.
- We developed a voting strategy for Image Denoising for removing Gaussian and salt and pepper noise, which is 10x faster than Fast Non-Local Mean Denoise (FNLMD) with MSE below 0.01.
- We proposed a method that aims to swiftly identify the connected components within a binary image, which employs straightforward and efficient data structures, using memory that is directly proportional to the number of run-lengths in the input image.

Chapter 4

Image analysis and processing

4.1 Image processing approaches for intelligent combining results of several algorithms

Solutions based on voting propose a different way to combine existing approach that performs on specific scenarios but not on general cases. The goal is to use each solution in the area they work best and combine them to ensure the best results.

4.1.1 Voting Strategy for Image Binarization

Binarization is an essential stage of image pre-processing before text recognition because it improves the performance of the obtained text and reduces the effort required for post-processing to find mistakes, which often requires human intervention. Binarization aims to classify the pixels in two clusters: black and white. Obtaining a black-and-white image means separating the background, which is the text, from the foreground.

We investigated numerous heuristics to identify the most suitable thresholding procedure for our algorithms to establish the appropriate threshold. The suggested voting strategy, mirroring the one mentioned in [24][25], contemplates **several voting rounds** to reach a particular set of apt thresholds for the given image.

The **first election** involved in the voting algorithm is aimed at discarding unimportant candidates that don't qualify as a feasible threshold. We can specify that for any image we consider in this study, the proportion between background and foreground pixels must not exceed a certain ratio.

The **second election** employs a comparable strategy, but it implements it only locally on a window roughly the height of three lines of text. This assures that while the global thresholding is efficient, it can also detect certain anomalies at the local level. Though we can employ static thresholds in the initial phase for now, this approach is likely to falter in the presence of page margins, where we don't have both background and foreground items.

For the **third election** we choose a tournament-styled procedure that occurs in two stages: initially involving all binarizations and then specific groups of binarizations, for example, a batch containing 16 participants. The aim is to remove a proportion of the participants, say, the 25% most unusual ones.

The **final election**, though not an election in itself, processes the residual images, constructs a probability matrix akin to the preceding phase, and treats it as a grayscale image with probabilities stretching from the 0% to 100% range expanded to the 0-255 grayscale range. The ultimate binarized image is then generated by setting a threshold at the midpoint, which is 127.

Binarization Method	Average F-Measure	Average PSNR	STDEV F-Measure	STDEV PSNR	Ranking by F-Measure	Ranking by PSNR
Average	38.10	6.01	14.41	1.08	7	7
Niblack	43.61	7.21	15.32	1.20	6	6
Nick	79.39	16.42	14.70	2.80	3	2
Sauvola	61.14	14.86	27.70	3.53	4	4
Wolf	59.72	11.40	17.47	2.15	5	5
Otsu	80.55	16.07	17.35	4.20	2	3
Proposed method	**82.72**	**16.46**	**11.32**	**2.36**	**1**	**1**

Table 4.1: Comparison between the proposed approach and some representative methods in the field

The tests generally indicated that the proposed voting method discussed here consistently ranks among the top methodologies when dealing with text-based input image documents. Nonetheless, for documents comprising non-traditional handwriting, illustrations, diagrams or decorative elements, the proposed study may not deliver optimal results. This is because the voting selection depends on rejection tests that utilize average font-filling statistics. Additionally, the choice of the local window size is predicated on the average text height.

Table 4.1 provides consolidated statistics for 89 images from the previously mentioned datasets when applying the suggested method in contrast with a series of well-known global and local methods in academic literature. The proposed method stands out, ranking top among all other choices, considering F-Measure and PSNR as metrics. Furthermore, when compared to the next top competitors, the proposed solution has the lowest overall STDEV for F-Measure and the smallest STDEV for PSNR. This not only demonstrates the method's superiority over other approaches, but it also indicates its stability in delivering consistent results. The superior PSNR's STDEV for Average and Niblack binarization methods only implies that these methods consistently provide poorer results, as evidenced by their last-place rankings for both F-Measure and PSNR.

We propose a system for binarization that executes several methodologies to generate feasible candidates for the current issue, then carries out a range of validation tests and voting-based tactics in a tournament-style selection process to determine the most appropriate candidate.

When compared to traditional solutions, the proposed approach outperforms them by demonstrating superior performance, consistent excellence in outcomes, resilience to errors introduced by the candidate binarization algorithms, and the employing of only agile,

technically economical statistics required for making fundamental decisions. When a single threshold value cannot adequately address the binarization problem, such as when illumination conditions vary throughout the same page, the strategy is especially successful. Hence, it can be confidently employed as an unsupervised binarization phase in a project of retroconversion that aims for a mass-digitization operation.

4.1.2 Voting Strategy using a weighted scheme for Image Binarization

In Section 4.1.1, we propose a voting strategy for document images based on tournament. The purpose of this next experiment is to propose a system that incorporates information from earlier publications while taking a somewhat different approach to window placement. As a result, the suggested approach should take less time to calculate while producing satisfactory overall results.

This solution is proposed to target document images that contain handwriting. Starting with the target images, the first step is to convert the image to grayscale using the Color to Grey algorithm [26].

The proposed system utilizes global and local methods in order to give a solution to the problem. The approach is based on the output of the following algorithms: Otsu[11] and Kittler[27] for global binarization; Niblack[28] and Sauvola[29] for local binarization.

The first step entails applying all four previously mentioned algorithms to the grayscale image, resulting in four images (one each from the Otsu[11], Kittler[27], Niblack[28], and Sauvola[29] methods). These four images are then merged into a single image for the next step, using a majority voting system. In this system, each pixel in the resulting image is designated as black if the majority of methods assign the corresponding pixel the same value, otherwise, it's marked as white, signifying it's part of the background.

The proposed method effectively eradicates the binarization noise generated by global algorithms when handling a high volume of elements or variable contrast, and by local algorithms when dealing with regions containing a sparse number of objects. This approach yields a crisp output image, which is suitable for further processing in subsequent OCR stages.

4.1.3 Harnessing Neural Networks For Enhancing Image Binarization Through Threshold Combination

Threshold-based methods are prevalent across numerous domains, with specific relevance to image binarization, which traditionally employs global and local threshold algorithms. This section presents a novel approach to image binarization, where the capacity of neural networks is utilized not just for determining optimal thresholds, but also for combining multiple global thresholds sourced from existing binarization techniques as another approach to obtain the right threshold. The primary objective of our method is to develop a robust binarization strategy capable of managing a wide array of image conditions. By integrating the strengths of various thresholding techniques, our approach aims to establish

a significant connection between traditional thresholding methods and those underpinned by deep learning.

This work introduces an innovative strategy for image binarization, where the power of neural networks is harnessed uniquely. Instead of merely employing neural networks for discerning an optimal threshold value, we utilize them to amalgamate multiple threshold values which are derived from a range of existing image binarization techniques. This not only introduces a level of adaptability in our approach but also builds upon the collective strengths of established methods, hence offering a more comprehensive solution to the image binarization problem. This underscores the versatility of neural networks in handling complex tasks and presents an inventive angle to the image binarization process.

We calculated the thresholds by employing a diverse selection of reputable datasets known for their use in image binarization research. The datasets incorporated in this process include: DIBCO (Document Image Binarization COmpetition): DIBCO [30], H-DIBCO (Hellenic DIBCO), NoisyOffice [31], PHIBD (Printed Historical Indian Books Dataset) [32], BICKLEY DIARY [33], Palm Leaf [34] and Nabucco.

Our study utilized a collected dataset comprising 1,195 images. These images were preprocessed and adjusted with gamma correction (the value for gamma is increased with 0.1 steps in interval 0.5 – 2) and obtained 19,120 images. The dataset obtained is employed for both the training and testing phases. For each image, a set of 15 thresholding values was computed utilizing the suite of algorithms previously delineated. Furthermore, a proprietary optimal threshold value was computed using a solution designed by our research team, serving as the ground truth for our system.

The architecture under review constitutes a feed-forward artificial neural network. For each image in the dataset, we construct a lookup table that details the F-measure for various thresholding intervals based on the image histogram. This method provides a straightforward mechanism for evaluating the F-measure associated with any predicted threshold value. This approach allows us to validate and assess the efficacy of the predicted thresholds directly and efficiently.

For the thresholding evaluation, we applied our model across the entire dataset to generate predicted threshold values. Leveraging the lookup table, we averaged the F-Measure of these predicted thresholds, achieving a result of 77.34. Considering we utilized exclusively global thresholding methods, this result is quite satisfactory.

Method	**Ideal**	**Otsu**	**Kittler**	**Lloyd**	**Sung**	**Ridler**	**Huang**	**Ramesh**
F-Measure	**81.75**	67.11	64.56	63.65	61.68	64.88	53.06	53.67

Li1	**Li2**	**Brink**	**Kapur**	**Sahoo**	**Shabang**	**Yen**	**Tsai**	**Proposed**
66.51	68.59	62.33	60.13	59.91	50.22	58.46	60.24	**77.34**

Table 4.2: Scores for individual methods in the used dataset

As a point of comparison, the maximal value for optimal global thresholding is approximately 81.75% in the dataset we used, as presented in Table 4.2. The results predicted by the proposed solution surpass the individual method. Thus, our model's performance stands up favorably within this context.

This study has successfully demonstrated the potential of neural networks in enhancing the robustness and adaptability of image binarization, a fundamental process in computer vision. By innovatively integrating multiple global thresholding techniques into the learning process, we've managed to navigate the complexity and variability of image conditions, underlining the pivotal role of deep learning methodologies. Our model, trained on a range of diverse datasets and evaluated with robust metrics, has achieved satisfactory results. Going forward, we aim to continue refining our approach and exploring more sophisticated architectures and algorithms to further elevate the process of image binarization.

4.1.4 Voting Strategy for Image Segmentation

We propose a voting method that combines the outputs of several notable segmentation algorithms. The objective is to mitigate the drawbacks of individual algorithms and achieve more accurate results, whenever possible. Our experimental findings demonstrate that the proposed method generally enhances the quality of the output and instills greater confidence in its application.

The primary goal of segmentation is to simplify the image, making it easier to analyze. Its primary application is to recognize components such as lines, curves, and even entire objects inside an input image. Binary segmentation is a type of image segmentation that includes differentiating an object from its background. This is a critical stage in the object recognition process.

The proposed solution builds upon Ana Fred's voting methodology [35] with a custom weight for each considered algorithm named in this work as *voting power*. In the voting process, each algorithm carries a distinct weight. While the prior research gave weights depending on segmentation level, our suggested technique bases the weight on clustering performance indicators such as F-Measure and V-measure.

In its present configuration, our solution is constructed to utilize six distinct methods as input for the process. These algorithms include: Gabor Filter, Graph-Based Segmentation, Histogram Based Segmentation, K-Means, Mean Shift, and Watershed. Each of these techniques brings its own unique strengths and contributes to the overall efficacy of our image segmentation solution.

For the purpose of effectively testing and validating our image segmentation methodology, we selected the well-regarded Berkeley Segmentation Dataset and Benchmark (BSDS500) [36] as our principal testing resource. In terms of performance metrics, we opted to compute the V-measure to evaluate the effectiveness of our segmentation results.

In Table 4.3, we present a comparative analysis of the V-measure values achieved by our proposed method versus those of the individual algorithms employed as inputs. As shown,

Segmentation Algorithm	V-measure
Mean Shift	0.114
Watershed	0.238
Graph Based	0.339
Gabor Filtering	0.313
K-Means	0.255
Histogram	0.155
Proposed method	**0.435**

Table 4.3: V-measure comparison for the used methods and the proposed system

the V-measure score associated with our method is consistently higher than that of any single algorithm, demonstrating the enhanced performance and effectiveness of our multi-algorithm voting technique in image segmentation. This successful outcome underlines the strength and potential of our proposed method in providing more accurate and nuanced image segmentation.

The innovative voting algorithm that we've introduced and discussed in detail throughout this work exhibits substantial promise. The resulting image segmentation outcomes were visually impressive, demonstrating a high degree of detail and nuance. Moreover, these visually-pleasing results were reinforced and corroborated by our numerical performance metrics, lending quantitative validity to our qualitative observations.

4.1.5 Voting Strategy for Edge Detection

Edge detection algorithms operate by convolving the input image with a specific directional filter. Given the current landscape, no single solution can guarantee optimal output for varying types of input images. Hence, multiple algorithms have been deployed for a specific purpose and are effective only on a specific dataset and a selected filter. We can assess the performance of an algorithm across different image types, which allows us to select the best candidate from the accumulated results. The voting algorithm employs weighted, majority, and unanimous votes with the primary aim of enhancing the accuracy of the output.

We introduce a voting mechanism designed to identify the best candidates from all possible options and select the most pertinent result from a collection of intermediate outputs derived from established techniques.

Edges can be defined as the lines connecting points where there are sudden changes or discontinuities **in intensity**. Edges usually are found **on the borderline** of different sectors in the image [37]. Edge detection represents a crucial first step in image processing[38], so it is present in multiple domains regarding robotics, computer vision and medical.

In order to combine the results of multiple edge detection algorithms, a voting system is used for combining Sobel, Scharr, Prewitt and Laplacian operators. We propose using the

following voting techniques, explained in detail below, majority voting, unanimous voting, and weighted voting.

An abstract way of looking at the presented scenario is that each edge detection algorithm represents a voter who casts a vote for each pixel in the image. The vote is to decide whether the pixel is part of an edge or not. Since most algorithms give a grayscale result of the edge having gray values, in order to keep consistency, we apply a simple threshold to the resulting image to have only black and white pixels to make the voting more streamlined. The final resulting image is created pixel by pixel. Each pixel is read from each edge detection algorithm's resulting image and interpreted. If the pixel is white, that's a vote in favor of the edge, if the pixel is black, the vote is against the edge. Depending on the voting system used, there are multiple ways to interpret the votes.

4.1.5.0.1 Majority Voting

For the majority voting algorithm, we have used the Boyer-Moore majority voting algorithm [39]. It is the simplest voting logic as all votes have the same weight and no previous data must be analyzed before the algorithm can be executed. As long as half +1 of the edge detection algorithms cast a vote in favor of the pixel being part of the edge, the pixel in the final resulting image will be an edge pixel. The advantage of this voting system is that extreme case edge pixels are eliminated and if enough edge detection algorithms give an edge as a result, the chance that the edge is an actual edge and not a misinterpretation is very high.

4.1.5.0.2 Unanimous Voting

In the case of the unanimous voting algorithm, an edge pixel in the final resulting image occurs only in the case where all the edge detection algorithms have voted in favor, in other words, where there is an edge pixel in all the resulting images, therefore, a unanimous decision. This voting system is quite strict as absolutely all edge detection algorithms must give the same result, this way, errors are eliminated, but there is the risk that valid features are eliminated as well as not all edge detection algorithms produce similar results, and some are specialized on specific features which will be completely overlooked by using this voting system. In our case, it doesn't produce a usable result.

4.1.5.0.3 Weighted voting

For the weighted voting system, we have used the Banzhaf power index [40] concept, in which each participant's vote has a different weight. In order to implement this, each participant is given several votes and the number of votes determines the weight. A quota is also defined which, if attained, the election is won.

The main drawback of this algorithm is that previous knowledge is needed before applying this voting system, so it cannot be implemented on the go. We need the weight of each voter, for this, it's necessary to have some knowledge about the voters, and the edge detection algorithms.

Image Name	MSE	SSIM
handGuide.png	0.00	1.00
unanimousVoteResult.png	3403.65	0.71
majorityVoteResult.png	3221.77	0.80
weightedVoteResult.png	1537.39	0.91

Table 4.4: Voting results image comparison

In order to compare the results, we have used two metrics: the mean squared error and the structural similarity index. From the table 4.4, we can conclude that the image resulting from the weighted voting algorithm has the highest similarity with the edges drawn by hand, higher even than the best standalone edge detection algorithm, as expected.

As a further development, a programmatic way of assigning weights for each voter should be developed. This will give the highest flexibility and obtain the best results.

4.2 ARchitect

One objective in image processing and analysis is to extract information from the image and use it in different contexts. The approach presented in this section alters the style of a building detected by the phone's camera and retrieves information such as its current style, age, and distance from the user.

An architectural style comprises a distinct set of features and characteristics that enables the identification of buildings or structures with a particular historical period. Over time, architectural styles evolve, reflecting the cultural development of a region.

The challenge at hand, however, lies in the classification of these architectural styles. This task becomes increasingly complex due to the gradual process of changes in style and the cultural variation within a given style. Added to this, the architectural vision of the creator often bridges styles, blurring boundaries and adding another layer of complexity to their relationships, leading to classification issues [41].

The style categorization method employs transfer learning with EfficientNet [42], using EfficientNet-B0 as the base model. Pre-trained models save computation and time for deep learning tasks. The dataset [43] has around 5000 images in 25 styles. Data augmentation with BING [44] proposes regions of interest, enhancing accuracy. Initial network layers involve resizing input to 224x224 and data augmentation like random flips. To combat overfitting, EfficientNet output passes through batch normalization, global average pooling, and dropout. Softmax acts as the final activation function for class distribution.

To alter image architectural styles, a styleGAN-based GAN is used, allowing control over building style output. Input images are projected into W latent space, the source of generated images. Linear interpolation of latent vectors blends styles of two images, transforming input image's architectural style. The training dataset [45] has 10113 building images

DPM+LSVM	DPM+MLLR	MLLR+SP	DPM+IEP+LR	DPM+IEP+SVM	Proposed solution
37.69%	42.55%	46.21%	53.52%	55.35%	**81.00**%

Table 4.5: Validation accuracy comparison

in 25 styles, balanced with around 400 images per category.

Validation accuracy and Fréchet Inception Distance (FID) score were used in measurements. FID assesses generative model image quality. The architectural style classifier achieves about 81% accuracy. The classifier training involves two steps. The first was training with EfficientNet-B0's frozen weights initialized from ImageNet, and the second, fine-tuning by unfreezing the last 20 layers (except batch normalization) with a lower initial learning rate.

The projected images using the proposed trained GAN on the gothic dataset (approximately 300 images) didn't have enough quality to use them in the facade generation pipeline.

Further study could involve hyperparameter tuning, limited by hardware. Exploring different depth estimation models may enhance distant facade reconstructions. Investigating 3D GANs could simplify pipelines by integrating depth estimation and surface reconstruction steps.

Below, we list the main contributions of this chapter.

- We recommended a strategy for voting mechanism in Image Binarization, which combines a series of classic threshold algorithms with the scope to obtain better results than the individual performance of the candidates. The strategy ranked 1st in terms of F-Measure and PSNR than the individual candidates: Averange, Niblack, Nick, Sauvola, Wolf, Otsu.
- In addition to this, the second strategy used in the Image Binarization sector combines two global and two local algorithms into a weighted scheme.
- We came up with a method to develop a robust binarization strategy capable of managing a wide array of image conditions by integrating the strengths of various thresholding techniques. Our model learns and establishes a significant connection between traditional thresholding methods and proposes a threshold candidate. The model has 77.34% F-Measure, close to the ideal threshold, which has 81.75%. The next individual threshold technique is 68.59% for Li2 and the last one Huang has 53.06%.
- We implemented a voting strategy for Image Segmentation by combining a series of segmentation algorithms based on entropy that obtain a value of 0.435 for V-Measure greater than the individual scores, which are between 0.114 and 0.339.
- We elaborated a voting strategy for Edge Detection in which we combined Sobel, Scharr, Prewitt, Laplacian, and Canny operators with 3 different perspectives: unanimous vote, majority vote, and weighted vote which obtained SSIM equal with 0.71,

0.8, and 0.91. The weighted voting approach surpasses all individual results, which are in the interval of 0.54 to 0.90.

- We implemented a solution that involves capturing a picture of a facade, generating a facade image in a different architectural style, and then estimating depth information per pixel to successfully reconstruct a 3D mesh of a facade in another architectural style.

Chapter 5

Software Development

Creating a software product implies a process of software development where the abilities of the team, the well-being of them, the used tools, and the form of organization can describe the success of the product or send it to die. It's not a mystery to say that a product is more than the code behind it.

We explore how competitive and cooperative approaches can optimize the learning process. Also, we focus on the management side of the software development process. We continue with how the decision-making process impacts the dynamic of the teams. On that note, we enter a field of good practices with a focus on how sleep can affect the quality of the developer's work.

Next, we move to explore the tech start-up ecosystem and the differences between them and tech transfers. Also, we try to expand the status of the Romanian tech startup ecosystem in terms of the teams behind, how diversity impacts the performance of the team and propose a metric for evaluation of diverse teams.

5.1 Modern teaching methods

Competition and cooperation are explored in many dimensions, and understanding the relationship along the two can grasp interconnectedness and distinctions, and a study on this relationship has attracted attention from various disciplines.

As a student engages in solving a task, there's an inherent necessity to collaborate and interact with peers. This sharing and exchange of ideas, navigating misunderstandings to reach a common outcome, can deepen the assimilation of the subject and enhance mutual comprehension. A cooperative environment encourages group involvement and fosters comprehensive development, emphasizing listening, idea exchange, and confrontation of individual approaches. Students are able to present their perspectives and reasoning. Importantly, this engagement exposes them to diverse strategies and thought processes, and allows them to gain valuable experience in managing the challenges associated with group work.

So, what does competition entail? It embodies two aspects: competition against others and self-competition. In our daily lives, competition drives innovation, while among students, it can be a catalyst for converting potential into achievement. Competition is a significant component of our existence, with many technological advancements owing to its existence.

In order to individually test each approach, and later, their combination, we examined the feedback and performance of students in various activities. Given the significance we place on self-assessments and reports, we constructed a survey. These were completed by a group of students aged 20 to 24, who responded to nine questions. These questions were designed to uncover the students' favored learning techniques and the real-world scenarios where they utilize or interact with these strategies.

Initially, the students were asked to indicate which learning environment—cooperative or competitive—they find most conducive to learning efficiency. Following this, they were asked to list at least one advantage and one disadvantage of both a cooperative and a competitive learning environment. This allowed them to freely articulate their understanding of what these two approaches entail and imply in an educational context.

The results of this study were, to a certain extent, consistent with our initial predictions. When offered a choice among the three alternatives, the combination of competitive and cooperative approaches emerged as the most popular, garnering 48.8% of the votes. In the context of competitive learning, the majority of participants (around 80%) expressed that they view this approach as the most stimulating learning method, providing individuals the best opportunity for self-expression.

It's worth noting that cooperative methods were favored over competitive ones by the survey participants, with 53.5% versus 46.5%. The most intriguing aspect arose when participants were asked to share their views on the fusion of the two learning models, thereby enabling us to determine which approach held more sway in determining the preferred methodology. Despite certain challenges, a substantial majority of participants valued the integration of both educational approaches. Specifically, 62.7% of them emphasized the merits of collaboration, 21% underscored the importance of leadership and accountability, while the rest attributed the positive aspects of this blend to the social competencies it cultivates, including altruism, mutual support, camaraderie, and motivation.

To sum up, cooperative learning is a well-regarded and fascinating approach, built upon five fundamental elements. However, it can pose a significant challenge for teachers or group leaders, necessitating careful management by all members involved in cooperation.

Competition, in and of itself, isn't harmful. Rather, one's attitude towards competition shapes the outcome. Competitiveness can bolster motivation within a group, encouraging individuals to assert themselves for the group's development and respond positively to a variety of challenges.

While the fusion of both methods might increase the likelihood of conflict, the proper regulation of interaction can yield remarkable results in a conducive environment. This combination can enhance competitive positions within a framework of cooperation. By tempering competitiveness with cooperation, the learning environment becomes more diverse and offers opportunities for the discovery of hidden talents in those who excel in either cooperative or competitive settings.

5.2 On the management side

An idea without execution remains an idea. A plan without execution remains a plan. Doing the right thing and keeping it going can decide the sanity of a solution. The management process ensures the solution can be planned, monitored, and conducted into a successful project. We explore how decisions are taken in the teams and how prior experiences impact the team's dynamic and process. On the management side, we are moving next to explore how sleep affects the performance of the developers.

5.2.1 Decision-making process in Software Projects

This investigation aims to dissect situations where external and personal elements sway decision-making mechanisms, subsequently causing inefficient decisions. The critical inquiry of this research revolves around: What aspects convince software project leaders in their decision-making process? The factors that influence software project managers' deductions and probable outcomes deserve special consideration because the state of the project (setbacks, triumphs, or failures) is primarily the result of a series of poor judgments. The primary purpose of this study is to determine how these categories of elements influence decision-making: external factors (team members, stakeholders) and personal factors (previous experiences, feedback obtained, risk management) to improve project management performance.

This study aims to discern the variables that shape the decision-making process in the context of software project management. The research strategy employed herein leverages the survey methodology. All the necessary data has been accumulated through the distribution of questionnaires. The survey is designed to explore two specific categories of factors: contextual and individual factors. For contextual factors, we can consider team members and stakeholders, and for the second category risk management, received feedback and of course past experiences.

These elements were chosen as examination variables owing to their prevalent influence on the way a company makes decisions. To evaluate how decisions are made, a survey was devised and disseminated. The responses to this survey are going to provide insights into the cognitive processes of various software project managers, anchored in their past experiences.

Participants were questioned about their level of experience in the industry. The data indicated that 70% of the participants had fewer than 5 years of expertise. The participants in this group had an average of 4.84 years of experience in the industry. The standard deviation for this is 3.60.

Approximately 55% of the participants work in companies with more than 1000 employees, and a further 25% reported working in companies with employee counts between 100 and 1000. To delve deeper into the respondents' level of experience, we inquired about the number of different teams they have managed. Around 53% of the respondents stated they had managed more than 3 teams, while only 12.2% reported managing just one team.

A defining aspect of agile software development is the active participation of members of the team in making choices. To assess the extent to which a project manager incorporates teammates in this procedure, participants were asked, "`How frequently do you convene the entire team for collective decision-making?`". Over half of the respondents (52.2%) indicated that they did so *most of the time*, 13.9% responded with *always*, 27% indicated *sometimes*, and a mere 7% reported *rarely*. These responses suggest that a majority of managers highly value and often consider their team's input in decision-making.

The significance of team involvement in decision-making within software projects was further examined through the question, "`How much does the team's opinion usually impact the final decision? Choose the answer that fits you the best`". The data shows that collectively, 67% of the project managers who responded to the questionnaire prefer a democratic approach to decision-making, placing significant weight on the team's perspectives. Among this group, 60% engaged in a highly participatory decision-making process that involved brainstorming sessions, and actively seeking diverse opinions before finalizing a decision, whereas 7% inclined to develop a set of personal final preferences and then involve the team for input. A considerable number of participants, more exactly 32.2% indicated that they prefer consulting with a more experienced team member before making a decision, with the majority of this subset having led three or more teams in their capacity as project managers.

The survey further investigated the role of feedback in decision-making, particularly focusing on how the receipt of feedback influences the decisions of project managers. An overwhelming majority of 96.5% expressed that they typically incorporate all feedback received to refine their future decisions. In contrast, a small fraction of 2.7% specified that they only take into account feedback from their superiors.

The study also aimed to uncover how frequently project managers solicit feedback and its subsequent consideration in decision-making. Responses to this query were somewhat evenly split between those who seek feedback only when they deem it necessary, 58.8% and those who consistently gather feedback and review it periodically - 40.4%.

The research has proven that feedback obtained by project managers carries the biggest influence on decision-making, and it is also the aspect that is most usually considered in this process.

Following feedback, the most impactful factors are categorized under contextual variables, namely, team members and stakeholders. The study revealed that project managers often assign nearly equal weight to the input of stakeholders and team members when making decisions.

On the other hand, the category of factors that bears the least weight over the decision-making process comprises previous experiences and managing risks. While the majority of project managers regard past experiences to be helpful, they do not view them as a critical aspect in decision-making. A considerable number of project managers even make their

decisions regardless of past events. As for risk administration, the study found that most project managers are eager to take on risks, suggesting that risk management as a factor does not heavily impact their decision-making process.

The research outlined doesn't provide recommendations on how to decrease the harmful effects that decision-influencing factors can impose on the results. Methodologies such as case studies, grounded theory, and protocol studies, all of which are qualitative in nature, are appropriate for researching strategies to reduce such harmful consequences. It would be beneficial to delve into new perspectives on this topic, as well as adapt existing approaches to software-specific contexts. Any models unearthed through this exploration could subsequently be assessed using controlled experiments or action research, marking a necessary and valuable direction for future studies.

5.2.2 Good practices: Impact of the sleep on the developers

The performance of the teams is based not only on skills of the team, the capacity and effective teamwork. The wellbeing of the developers impacts direct the work and this implies in the quality of the end product. We believe that sleep is more than a good practice, is a habit that resets your limits and restores your internal processes. Is the meta habit that keeps you away from bad stuff happening. With this in mind, we tried to explore how sleep impacts the work of the developers.

The escalating issue of insomnia and inadequate sleep constitutes a significant challenge in contemporary society. This prevalent problem results in individuals suffering from persistent fatigue, increased stress levels, decreased workplace performance, and reduced efficacy in daily tasks. This present research undertakes an investigation into the effect of sleep on a group of 30 software developers, employing a variety of programming and attention-based tasks to ascertain parameters that may contribute to a comprehensive understanding of how sleep influences this profession. The findings corroborate the detrimental impact of sleep deprivation on programming productivity, while also indicating distinct gender-related differences.

For the last century, research of the sleep impact has been ongoing, shedding light on the fact that healthy sleep is paramount for effective cognitive function during wakefulness, encompassing clarity of thought, alertness, and attention. Moreover, sleep has been established as an integral component for memory consolidation, allowing newly acquired information to embed securely within our neural networks [46][47].

The recommendation for the optimal sleep duration for adults is typically between seven and nine hours[48]. Deviations from this range, either fewer or more hours, have been linked with adverse health outcomes such as weight gain, obesity, diabetes, depression, hypertension, heightened risk of injury, and decreased physical and cognitive performance [49].

The participant pool for the study comprised 30 individuals working in full-time or intern positions as software developers, DevOps, or verification engineers. The gender distribu-

tion was balanced, with 15 male and 15 female participants. Participants were required to be in their usual work environment, preferably a home office, and alone in the room to facilitate enhanced concentration and focus on the tasks at hand. The testing was conducted during the early morning hours.

Two psychological tests were administered to assess the participants' distributive attention. The first test required participants to identify ascending numerical sequences within a matrix populated with various shapes and numbers and then discern the number placement algorithm. The second test, known as the Prague test, also involved numerical assessment and aimed to gauge the participants' distributive attention.

Given that the focus of the study was on software developers, the third test featured programming tasks. Participants were presented with challenges related to coding, algorithmic thinking, and optimization tasks.

We investigated how sleep affects the productivity of software developers. The experiment involved 30 participants, an equal mix of men and women, ranging in age from 20 to 30 years. All participants were full-time professionals in the software development industry. We employed two attention distribution tests and six programming tasks, encompassing algorithms, debugging, code optimization, and coding, to evaluate our participants. From the analysis above, we distilled several key findings.

Participants aged 23-25 maintained the most regular and organized sleep schedules, with the least efficient schedules observed among the 20-22 age group. We also found that the order of testing influenced results; those who took the programming test before the Attention and Prague tests scored lower than those who tackled the attention tests first. This suggests the value of mental exercise or rejuvenation before embarking on coding tasks to mitigate potential errors or issues.

While our study provides valuable insights, its scope was limited to 30 Romanian participants. In future research, we aim to expand the sample size to include individuals from different countries, covering a wider age range, from 20 to 70 years. Limitations of our current study include the inability to verify participants' problem-solving methods in person. Future research will also consider additional variables such as the psychosocial state of participants, meal patterns and content, and physical activity levels. The next logical step would be to explore potential solutions for sleep-deprived software developers.

5.3 On the business side

A product without the business side is failed from day 0. We expand on how ideas come into startups and tech transfers and how can we compare these two types and we explore the Romanian tech startup ecosystem with the flavor of diversity.

5.3.1 Startups and tech transfers

The purpose of this study is to guide in selecting an appropriate approach for idea development based on individual needs. While start-up companies may experience disordered and slow development processes, potential benefits may outweigh the efforts if the start-up is successful. In contrast, tech transfer programs can allow for a more focused approach to tech development by providing access to marketing and management experts. The study will utilize metrics that reflect business success rates, the impact of external factors, and risk management. The results of the study demonstrate varying outcomes for individuals with diverse interests and objectives. Overall, the findings suggest that a tech transfer program may be a more favorable option for most individuals due to its relatively lower risk.

Despite the proliferation of blog posts, news articles, and other forms of literature [50][51] [52] discussing the emergence and potential of tech transfer, there is a dearth of studies comparing this business model with the more traditional Startup approach. Although these two models may appear similar on the surface, closer examination reveals a number of significant differences that can impact the process of idea development. Most existing studies emphasize the benefits of tech transfer in driving technological innovation, but they often neglect the perspectives of students and developers who participate in this process regarding their autonomy in the development and management of risk. To address these gaps, we conducted a comprehensive study that examines all the aforementioned aspects.

Startups are defined by Mitchel Grant [53] as companies that are in the initial stages of operation. Typically, one or more individuals who have identified a problem they believe can be solved through a new product or service can decide to put their effort together and find a startup. These companies often have significant expenses and limited revenue, necessitating funding from various sources, such as venture capital, grants [54], or bootstrapping [55].

Twi Global defines technology transfer as the transfer of data, designs, inventions, materials, software, technical knowledge, or trade secrets between organizations or purposes. This process hinges on internal policies, company procedures, and the organization's culture and values. Comparing startups and technology transfers reveals that startups face slower growth due to the need to build from scratch with limited funding. Nevertheless, startups offer greater flexibility in idea development. Conversely, technology transfers offer a stronger foundation in business, marketing, or management, backed by the transferring company's support and potentially superior financial resources. Idea development in technology transfer encompasses Vertical and Horizontal Transfers. The former comprises four stages, progressing from basic research to production, while the latter involves transferring established technology within an organization to a different location[56].

To examine the available tech transfer data, we used the `spinout.fyi` database[57], which provided comprehensive information on tech transfer projects conducted by universities or other TTOs. We used data such as total profit made and profit until the last financing round to calculate the return on investment metric, the requirement of a board seat for risk man-

	Success Rate	Risk Management	External Factor Influence
Startups	52.86% Unicorns	Higher	Complete autonomy IP owned
TTOs	62.77% Unicorns	Lower 24.65% requires a board	IP shared with other companies

Table 5.1: Comparison between startups and TTOs on success rate, risk management, external factor influence

agement, and the contribution of the founding team for the IP, along with the percentage of the University/TTO owned before any investment was raised to analyze the influence of external factors[57]. For startups data, we employed the LaunchVic database[58], which provided information on more than 2500 companies from all over the world.

After analyzing the data and comparisons, several conclusions can be drawn that will help individuals make informed decisions about which approach best suits their needs.

For investors seeking to support new ideas through Startups and tech transfers, the data suggests that investing in a tech transfer would be a safer option, while a Startup may offer greater profit potential, especially for those willing to take on higher risk. However, ROI alone does not guarantee business success, and the time required to reach the seed growth stage should also be considered. Based on these factors, tech transfers may be the better alternative, as they showed better stability even during economic crises.

For students with little experience in the business/management area who wish to focus only on the technical development of their idea, tech transfers may be a better fit, as approximately 25% of TTOs require a board seat in the spinout, resulting in expert management to provide the best development environment possible. However, for students passionate about management and business and seeking to learn to become experts in these areas, a Startup may be a better choice. Even if the Startup fails, valuable lessons can be learned that can be applied to future ventures.

Finally, for individuals who wish to retain full control over their intellectual property (IP) or do not want to be influenced by others, a Startup may seem like the obvious choice. However, the data suggests that tech transfers do not typically take a significant percentage of IP, and the tradeoff of some independence may provide additional support and guidance when difficult decisions arise or when facing obstacles.

5.3.2 Impact of the diversity on tech startups

In recent years, Romania has emerged as a vibrant hub for start-ups and tech innovation, thanks to its growing pool of skilled engineers, affordable living costs, and supportive government policies conformed by [59]. This growth has led to a surge in the number of successful tech startups, attracting significant investment from both domestic and interna-

tional investors.

During the past few years, a variety of events, accelerators, and incubators have supported founders in the development of new technologies through startups [60]. These programs cater to startups in different stages, verticals, or team compositions. StepFWD, a pre-accelerator program, has taken a unique approach by focusing on supporting women-led startups. Initially targeting mixed teams, StepFWD shifted its focus in 2022 to promote gender diversity within the national startup ecosystem [61]. This work presents an analysis of the Romanian tech startup ecosystem, emphasizing diversity based on a survey conducted by StepFWD.

The survey was completed by 118 founders from 113 startups based in Romania. There were some cases where the survey had multiple submissions from different members of the same startup. To make the data relevant, the study only evaluated teams with two or more members in many specific circumstances, even when there were firms with a single founder and a diversity score.

The scope of this work was to analyze the implication of diversity on the maturity, verticals, growth of the startups and see how diversity is looked in the ecosystem. Also, what are the dimensions which contribute to a better diverse team.

Below, we list the main contributions of this chapter.

- We added an extensive analysis of modern teaching with the approach of cooperative and competitive models and results based on combining them.
- We developed an analysis of how managers are making decisions in their teams on software projects.
- We provided a study on how sleep is influencing the work of the developer.
- We presented a comparative analysis between startup and tech transfer using the following metrics: Success Rate, Risk Management, and External Factor Influence.
- We introduce a study on how diverse are the tech startups in the Romanian local ecosystem. Using this work, we proposed a metric to evaluate the diversity of a team.

Chapter 6

Conclusions

The thesis at hand is an interdisciplinary exploration that delves into multiple facets of Human-Computer Interaction (HCI). It comfortably resides at the crossroads of Computer-Supported Collaborative Learning/Working (CSCL/CSLW), Image Processing, and Teaching Engineering.

This thesis addresses contemporary educational demands through the lens of technological integration in learning and working environments. It not only champions the engagement of students in research initiatives to foster hard and soft skill development but also scrutinizes the team's involvement throughout the development process. The thesis provides a holistic view of these intersecting elements, crafting a comprehensive landscape of their synergies.

6.1 List of Publications

6.1.1 Journals

1. **Giorgiana Violeta Vlăsceanu**, Nicolae Tarbă, "*Harnessing Neural Networks for enhancing Image Binarization through threshold combination*", BRAIN. Broad Research in Artificial Intelligence and Neuroscience, 14(2), 59-75, 2023
2. **Giorgiana Violeta Vlăsceanu**, Cristian Avatavului, Costin-Anton Boiangiu, "*An extensive review of metrics for evaluating image binarization*", Journal of Information Systems & Operations Management Vol 17 No. 1, 2023, ISSN: 1843-4711, pp: 200-222
3. Marcel Prodan, **Giorgiana Violeta Vlăsceanu**, Costin-Anton Boiangiu, "*Comprehensive evaluation of metrics for image resemblance*", Journal of Information Systems & Operations Management Vol 17 No. 1, 2023, ISSN: 1843-4711, pp: 161-185
4. **Giorgiana Violeta Vlăsceanu**, Alin Drăguț, Gabriel Sandu, Nicolae Tarbă, Mihai-Lucian Voncilă, Costin-Anton Boiangiu, Nicolae Goga, "*ARchitect: Extracting Building Related Informations and Changing Architectural Style in AR*", UPB Scientific Bulletin, Series C: Electrical Engineering and Computer Science, Series C, Vol. 85, Iss. 3, 2023, ISSN 2286-354
5. **Giorgiana Violeta Vlăsceanu**, Tiberiu-Mihai Iordache, Alin-Călin Duțu, Alexandru Cîrlomăneanu, Mihail Ungureanu, Costin-Anton Boiangiu, Răzvan Deaconescu,

"*Startups vs Tech Transfers: A Fair Comparison*", UPB Scientific Bulletin, Series C: Electrical Engineering and Computer Science (`Accepted for publication in Vol. 85, Iss. 4, 2023`)

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6.1.2 Conferences

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6.1.4 Posters

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