Submission of Data Driven Project

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Part 1
Application Name

*S**OCR**ATES: Pondering on the Depths of OCR*

Abstract

Introducing SOCRATES, a revolutionary OCR solution for steel billet identification, leveraging a high-resolution camera and AI-driven software. This project aims to significantly improve accuracy and efficiency in harsh manufacturing environments, with potential patent opportunities in image preprocessing.

Executive Summary

Project Overview: SOCRATES, an advanced steel billet identification system, marks a significant leap in OCR (Optical Character Recognition) technology within the industrial sector. Aimed at enhancing efficiency and accuracy in challenging manufacturing environments, this project is designed to overcome the limitations of traditional OCR systems.

Technical Specifications: Central to the project is the deployment of a single high-resolution, full-frame camera, boasting 15-20 megapixels and a frame rate of roughly 60 fps. This setup ensures rapid and clear image capture, in sync with the movement of steel billets along the conveyor belt. The camera's full-frame sensor enables great low-light capabilities, crucial for capturing accurate images in variable lighting conditions typical of industrial settings. Leading brands like Cognex, or Keyence are considered for sourcing the camera, aligning with project-specific requirements.

Innovative Camera Features: A standout feature is the incorporation of the latest self-cleaning mechanisms, such as Texas Instrument’s Ultrasonic Lens Cleaning system. This technology addresses the perennial challenge of lens contamination in dusty environments, ensuring consistent image clarity.

Lighting and Image Processing: The illumination setup comprises a single broad-spectrum LED light, strategically positioned to complement the text orientation on the billets – for instance, a 45-degree angle for text angled similarly. This approach minimizes shadows and enhances contrast, facilitating easier character recognition. A diffuser is added to prevent glare and reflection. The system's height is calibrated to illuminate the entire relevant area without diminishing light intensity.

Software Preprocessing: To further bolster OCR accuracy, sophisticated software preprocessing techniques are employed. These include image sharpening, contrast adjustment, and noise reduction, all aimed at making the characters on the billets as discernible as possible.

Intellectual Property With SMS Concast AG

Current Patent Landscape and Technological Trends

a. SMS Concast AG's Patent Portfolio: What specific patents are currently held by SMS Concast AG, and what technological areas do they cover?

SMS Concast AG holds several patents, one of which is specifically relevant to pattern recognition and OCR technology. This patent (US Patent #8564656) relates to recognizing surface characteristics of metallurgical products, a method that likely incorporates OCR technology. This patent suggests that SMS Concast AG has experience in applying OCR technology to specific industrial contexts, such as identifying characteristics of metallurgical products.

b. Global OCR Patent Overview: What are the significant existing patents in the OCR domain globally, and do they focus more on hardware advancements or software algorithms?

OCR technology has been the subject of numerous patents globally, held by a variety of companies. For instance, Microsoft holds a patent (US Patent #11093740) for supervised OCR training for custom forms, indicating an emphasis on software algorithms and machine learning in OCR technology.
Another example is the patent held by First American Financial Corporation (US Patent #10896292), which improves OCR technology using artificial intelligence, focusing on software advancements to enhance accuracy in text recognition.
Moreover, Insurance Services Office Inc.'s application (US Application #20180101726) for OCR systems suitable for low-resolution documents suggests a combination of hardware (low-resolution document handling) and software (RNN and LSTM modules) components.

c. State-of-the-Art in OCR Technology: What constitutes the current state-of-the-art in OCR technology? How do existing solutions balance hardware and software components?

The current state-of-the-art OCR technology involves a blend of advanced software algorithms, including artificial intelligence and machine learning, with specialized hardware to enhance recognition accuracy, especially in challenging conditions like low-resolution documents or variable surface characteristics.
Innovations are not just limited to improvements in recognition accuracy but also encompass the efficiency of processing and the ability to integrate OCR technology into various industrial and commercial applications.

Future Patent Opportunities and Competitive Analysis

a. Identifying Patent Opportunities: Considering the existing patent landscape and SMS Concast AG's capabilities, in which areas (hardware/software) does the potential for new, innovative patents exist?

- Software Preprocessing for OCR: The preprocessing of images to enhance OCR accuracy is a critical aspect of our technology. A patent application by John Snow Labs Inc. (US Application #20210124979) describes a method for preprocessing images for OCR using character pixel height estimation and cycle generative adversarial networks. This method includes enhancing or sharpening the image, denoising, and erosion to thicken thin characters. This indicates a potential opportunity for patenting advanced image preprocessing techniques specifically tailored for OCR applications.

- AI in Patent Applications: The European Patent Office (EPO) has refined its approach to the patentability of inventions involving AI, which is a critical component of advanced pattern recognition systems. AI-based inventions are considered computer-implemented inventions (CII) and are patentable if they have a technical character and solve a technical problem. This approach is crucial for pattern recognition technology, as it often relies on AI and machine learning algorithms to analyze and recognize patterns.

b. Assessing Patentability of Proposed Technology: Given the details of SMS Concast AG's proposed technology, what are the prospects for its patentability? Does the technology present a novel approach or significant improvement over existing solutions?

Given the above findings, the technology we plan to develop with SMS Concast AG appears to have several patentable aspects. The combination of high-resolution imaging, specialized lighting, and sophisticated software preprocessing presents a novel approach to OCR, especially in challenging industrial environments. This combination could significantly improve existing OCR solutions, making it a strong candidate for patenting.
However, it's crucial to note that the technology comprises various components. It may not be beneficial to patent the entire process, as this could make the technology overly specific and potentially limit its patent relevance. We recommend focusing primarily on patenting the software processing aspect, as it embodies the key innovation and could offer a significant competitive edge.

c. Competitive Advantage through Patenting: How might patenting the new technology give SMS Concast AG a competitive edge? What are the possible strategies competitors might adopt to emulate or bypass this technology?

Patenting the new technology can give SMS Concast AG a significant competitive edge by establishing it as a unique provider of high-precision identification solutions in the industrial sector, particularly through its advanced image preprocessing and AI-based character

recognition capabilities. This move not only differentiates SMS Concast AG's offerings but also creates a barrier to entry for competitors, protecting the company's innovations. Furthermore, holding patents could open up licensing opportunities, providing additional revenue streams. In response, competitors might develop alternative technologies to circumvent SMS Concast AG's patents, seek licensing agreements, or challenge the patents' validity. Overall, patenting is a strategic tool that can strengthen SMS Concast AG's market position.

Part 2

Team

Project Manager (PM)

- **Responsibility**: Overseeing the project, managing budget and resources, coordinating team efforts.
- **Qualifications**: Experience in technical project management, preferably in industrial settings.

Software and Data Team

- **Lead Software and Machine Learning Engineer**
    - **Responsibility**: Leading software development, including OCR algorithm, and overseeing data collection and preparation.
    - **Qualifications**: Strong background in software development and machine learning, especially in computer vision.
- **Software Developer / Tester**
    - **Responsibility**: Assisting in software development and conducting software testing.
    - **Qualifications**: Skills in software development and testing, familiarity with machine learning applications.

Hardware and Integration Specialist

- **Responsibility**: Selecting and configuring the camera and lighting system, integrating the system with existing conveyor and sorting systems.
- **Qualifications**: Knowledge in industrial camera systems, lighting, and hardware-software integration.

Research and Data Analyst

- **Responsibility**: Managing data collection, processing data for model training, and collaborating with the research partner.
- **Qualifications**: Experience in data management and analysis, coordination with research entities.

Research Partner

- **Partner**: A research institution like ETH Zurich, EPFL, CSEM, or PSI.
- **Role**: Providing scientific support, expertise, and additional resources.

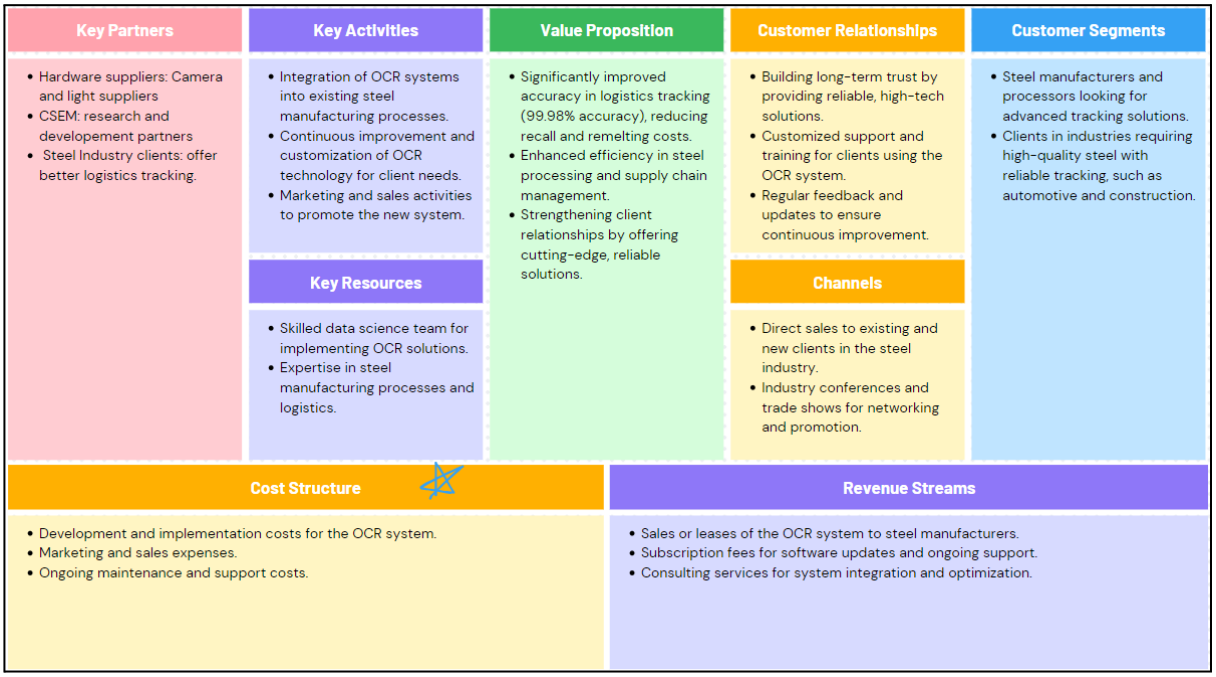
Administrative Support

- **Responsibility**: Handling administrative tasks, supporting the project manager.
- **Qualifications**: Experience in administrative roles, preferably in a technical project setting.

Part 3
Business Targets & Business Model

Business Model

The business model for SMS Concast's AI-based OCR system project, developed in partnership with CSEM, focuses on significantly enhancing the accuracy of logistics tracking in the steel industry. By reducing the error rate of misidentification from 2% to 0.02%, this advanced system addresses a critical need for precision in tracking and identification processes. We plan to market this innovative solution to its existing client base, offering them a substantial upgrade to their logistic tracking systems. This initiative not only promises to improve operational efficiency for these clients but also positions SMS Concast as a provider of cutting-edge, value-added technology solutions in the steel manufacturing sector.



Target Value Chain Position

1. **Technology Development and Innovation**: SMS Concast, in partnership with CSEM, will focus on developing advanced AI-based OCR systems. This positions the company as a leader in digital transformation within the steel industry.

2. **Supply Chain Optimization**: The OCR system will be integrated into the supply chain of steel manufacturers, enhancing the accuracy of tracking from raw material to finished product.

3. **Quality Control and Assurance**: By significantly reducing misidentification errors, the AI-based OCR system contributes to improved quality control, ensuring that only correctly identified and quality-assured steel products move through the supply chain.

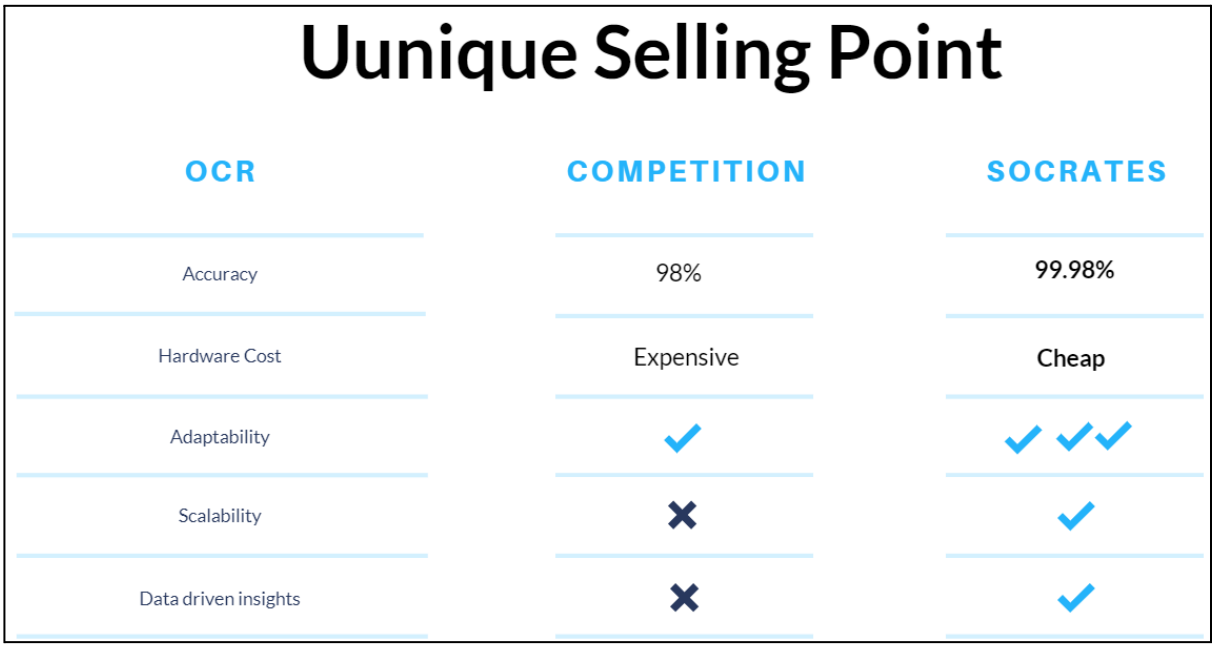
4. **Sales and Marketing**: The OCR system becomes a part of SMS Concast's product portfolio, marketed to existing and potential clients as a solution that enhances their operational efficiency and accuracy.

5. **Customer Service and Support**: Providing ongoing support and updates for the OCR system, SMS Concast enhances its customer service offerings, ensuring clients derive maximum value from their investment.

6. **Environmental Impact and Sustainability**: By reducing errors and unnecessary remelting, the system contributes to environmental sustainability, aligning with broader industry goals of reducing carbon footprint and waste.

Competitive Situation and USP

- **Competitive Edge:** Compared to existing solutions that rely heavily on complex hardware, our solution offers a more cost-effective, user-friendly, and technologically advanced alternative.
- **USP:** The key selling point is the innovative integration of simplified hardware and advanced AI-driven software, delivering high accuracy in steel billet identification with reduced complexity and maintenance needs. The table below compares our proposed solution to the existing solution of the competition including the current solution at SMS Concast.



Market Size

- **Long Products Market Share:** The market for continuous casting machines for long products, a specific segment within the broader steel industry, has an estimated total market size of €150 million per year [6]. Within this segment, SMS Concast holds a significant market share, varying between €52.5 million and €67.5 million[6]. This range highlights SMS Concast's substantial presence in the market for producing long steel products.

- **Swiss Steel Industry Market Size:** The Swiss steel industry itself represents a substantial market, with a **total market size** of approximately **8.8 billion CHF**. This sizable market indicates the extensive scope of steel manufacturing and processing activities in Switzerland, encompassing a wide range of products and services related to the steel sector.

- **Examples of Existing SMS concast clients:**
    - *Wuxi Paike*: An airplane engine manufacturer with revenues of **$810 million**, Wuxi Paike is a significant player in the aerospace industry and a potential client for SMS Concast's OCR solution, particularly for precision tracking and quality assurance in their manufacturing processes.
    - *Seversky Pipe Plant*: As an oil and gas pipe manufacturer generating **$1.92 billion** in revenues, Seversky Pipe Plant could benefit from the OCR solution in managing and tracking their large-scale pipe production, ensuring accuracy and efficiency in their supply chain.

- *Anhui Anhuang*: An automotive supplier with revenues of **$600 million**, Anhui Anhuang could utilize the OCR solution for enhanced tracking and quality control in the production of automotive components, aligning with their need for precision and reliability.

These clients represent key segments in the steel industry, each with specific needs that could be effectively addressed by SMS Concast's advanced OCR solution, demonstrating the solution's applicability and potential market reach within these sectors.

Planned revenue and profitability development and NPV:

Team Salary estimation using Salarium tool [8]

Job Title	Annual Salary Estimate (CHF)	Mean Annual Salary Estimate (CHF)	6 month project
Project Manager (PM)	120,000 - 150,000	135000	67500
Lead Software Engineer	130,000 - 160,000	145000	72500
Machine Learning Engineer	130,000 - 160,000	145000	72500
Software Developer / Tester	100,000 - 130,000	115000	57500
Hardware and Integration Specialist	110,000 - 140,000	125000	62500
Research Data Scientist	110,000 - 140,000	125000	62500
Administrative Support	70,000 - 90,000	80000	40000
		Total (CHF)	**435'000**

We estimate the hardware purchase to cost approximately CHF 20,000 and have also factored in unexpected expenses, bringing our total **initial investment to CHF 500,000**.

Assumptions for NPV calculations of the project:
Initial investment: CHF 500,000 (team salary, hardware cost and other expenses ..)
Sale Price per Unit: CHF 150,000 [6]
Gross Margin: 25% to 30% (we choose 30% due to other profits related to the products)
Units sold: We expect a slow start and then steady growth in units sold

Project Duration: 5 years (Last OCR was 10 years ago so with the fast development of technology we expect there would be a new product in 5 years.)
Discount Rate: 8%
Corporate Tax Rate in switzerland: 18% [9]

Year	0	1	2	3	4	5
Initial investment	-500'000					
Socrates price (CHF)		150'000	150'000	150'000	150'000	150'000
Units sold		3	5	7	10	15
Total sales		450'000	750'000	1'050'000	1'500'000	2'250'000
Gross margin (30%)		0,3	0,3	0,3	0,3	0,3
EBIT		135'000	225'000	315'000	450'000	675'000
Tax rate (18%)		0,18	0,18	0,18	0,18	0,18
EBIT(1-tax rate)		110'700	184'500	258'300	369'000	553'500
Discount rate (8%)		0,08	0,08	0,08	0,08	0,08
PV	-500'000	102'500	158'179	205'046	271'226	376'702
NPV (CHF)	**613'654**					

The free cash flow analysis indicates a **positive NPV** for the project, suggesting it is a financially viable investment that **we should pursue**.

Problems being solved:

In our pursuit to optimize the steel manufacturing process, we are focused on tackling two primary issues that have significant financial implications.

1. **Fixed costs:** associated with the remelting of misidentified steel billets. This not only increases energy usage and production time but also incurs considerable costs regardless of the scale of operations. We aim to reduce this cost through enhanced identification accuracy.
2. **Variable costs:** arising from the need for precise tracking of steel shipments are critical. In the event of steel defaults, identifying the exact product for recall is vital. The cost associated with recalls varies based on the risk and occurrence of faulty steel, making it a variable cost. Accurate tracking systems could mitigate these expenses significantly. Historical cases underscore the gravity of this issue:

Year	Company	Recall Reason	Tons of Steel Recalled	Estimated Recall Cost
2019	ThyssenKrupp[10]	Corrosion susceptibility	**150'000**	**€100 million**
2020	ArcelorMittal [11]	Prone to cracking	**50'000**	**€50 million**
2021	Nippon Steel [12]	More brittle than expected	**100'000**	**$88 million**

3. **Insurance Risk Premium:** It's crucial to consider the broader implications of our work with diverse manufacturers, such as airplane engine producers and car component suppliers. The risk of needing to recall these high-value products is a tangible reality in these sectors. Given the potentially enormous costs involved, many companies, including ours, resort to insurance against product recalls as a risk mitigation strategy. This insurance, while essential, adds to operational costs through the risk premiums paid to insurance companies.
   Here is an example of insurance policies from companies of a similar scale to ours:

Company	Industry	Annual Revenue (USD)	Product Recall	**Insurance Premium**
Cooper Tire & Rubber	Tire Manufacturer	$2.6 billion	(2009-2011)	**> $500 million**
Stryker Corporation	Medical Device Manufacturer	$4.5 billion	(2012)	**> $200 million**
Biomet	Medical Device Manufacturer	$3.2 billion	(2009)	**> $100 million**
Fisher-Price	Toy Manufacturer	$1.2 billion	(2007-2011)	**> $100 million**

As we can see the insurance premiums can vary **from 100$ million to more than 500$ million** which is a huge cost to consider.
However, with a more robust and accurate identification system, we not only reduce the likelihood of recalls but also positively impact our **negotiations** with insurance providers. By demonstrating a lower risk profile due to improved tracking and identification, **we can argue for reduced risk premiums**. This not only represents direct cost savings but also strengthens our risk management strategy.

Existing Actors:

Current solutions in the market tend to be more hardware-focused. Our approach differentiates by emphasizing software capabilities and simplifying hardware and gives higher identification accuracy.

Beneficiaries:

The primary beneficiaries are steel manufacturing companies, which will experience increased efficiency, accuracy, and cost savings. Indirect beneficiaries include the supply chain and end consumers who rely on the quality and reliability of steel products.

Cost-Benefit Analysis

1. **Qualitative cost-Benefit Analysis:**

Cost	Benefit
Initial Investment	Enhanced Accuracy and Reliability
Training and Adaptation	Improved Reputation
Maintenance and Updates	Customer Satisfaction
Disruption During Transition	Compliance and Standards Adherence
Dependence on Technology	Environmental Sustainability

2. **Quantitative cost-Benefit Analysis:**

   a. **Cost:** We already discussed how this project will cost us 500’000 CHF as an initial investment.

   b. **Benefit:**

      i. We begin with assessing the benefits of the variable costs related to the products recall.

         1. **Initial Risk**: With an OCR accuracy of 98%, the error rate is 2%. For every 100 steel bars, 2 are misidentified. If 1% of steel is defective, then out of 100 bars, 1 is defective, and there's a 2% chance it will be misidentified. So, the initial risk is :

            $0.01 \times 0.02 = 0.0002 =$ **0.02%**

         2. **Improved Risk**: With the improved OCR accuracy of 99.8%, the error rate is 0.2%. The risk of misidentifying a defective steel bar is now :

            $0.01 \times 0.002 = 0.00002 = 0.00002 =$ **0.002%**.

         3. **Risk Reduction**: The difference between the initial and improved risk is:

            $0.0002 - 0.00002 = 0.00018 =$ **0.018%.**

         4. **Percentage Reduction**: To find the percentage reduction, we calculate:

            $0.00018 / 0.0002 \times 100 =$ **90%**

         This would give us the **percentage reduction** in the risk of **misidentifying defective steel bars** due to the improvement in OCR accuracy.

      ii. Now Assessing the benefits on the fixed costs.The following assumptions, derived from our case study [6], will guide our yearly benefit analysis:

         1. **Number (billets/year) =** 150’000
         2. **Steel Volume (tons/year) =** 270’000

3. **Melting one billet (kwh) =** 725
4. **Energy Price (CHF/kwh) =** 0.233 (for industrial use in Switzerland) [5]
5. **Price melting one billet (CHF) =** 83
6. **Average household consumption kwh/year =** 4500

	Current OCR	Socrates
Number billets (Year)	150'000	150'000
Error rate (%)	2,00%	0,07%
Misidentified billets	3'000	105
Total energy Cost (CHF)	506'775	17'737
Remelting Cost (CHF)	249'000	8'715
Total Cost (CHF)	755'775	26'452
Cost reduction (%)	**96,50%**	
Total Energy saved (kwh)	**2'098'875**	

Potential Customers and Market Access Strategy

Customer Model

- **Model:** B2B, targeting steel manufacturing companies.
- **Market Access:** Access the market through direct sales, industry conferences, and partnerships with manufacturing technology distributors.
- **Marketing Approach:** Focus on the cost-effectiveness, technological superiority, and operational benefits of our solution by relying on all the information above about cost-benefit analysis.

Implementation Plan:

- **Customization and Integration:** Offering tailored solutions that can seamlessly integrate with the clients' existing systems, ensuring minimal disruption to their operations.
- **Pilot Programs:** Implementing pilot programs with select clients to demonstrate the system's effectiveness and to gather feedback for further refinements.
- **Training and Support:** Providing comprehensive training and ongoing support to ensure smooth adoption and maximize the utility of the system for the clients.
- **Scalability and Upgrades**: Ensuring the solution is scalable to accommodate the growth of our clients and offering periodic upgrades to keep pace with technological advancements.

Social and Ecological Relevance

The social and ecological relevance of our OCR system project is twofold, emphasizing both environmental impact and social responsibility:

Environmental Impact:

A key ecological benefit of this project is the substantial **reduction in energy consumption** linked to the remelting of misidentified steel billets. Annually, we anticipate saving approximately 2,098,875 kWh. To put this into perspective, this amount of energy **equates** to the **yearly consumption** of nearly **500 average households** in Switzerland, where the average household consumes about 4,500 kWh per year. This significant energy saving underscores our **commitment to environmental sustainability**, highlighting the project's positive impact in reducing energy usage and contributing to a **greener manufacturing process.**

Social Relevance:

From a social standpoint, the project plays a vital role in enhancing safety and quality assurance. By significantly lowering the risk of sending out products involved in recalls, we contribute to preventing potentially severe consequences. This is particularly critical in industries like automotive and aerospace, where material defects can lead to catastrophic failures and accidents. Our system ensures that only steel of the highest quality is used in products that are integral to public safety, thereby upholding stringent safety standards and protecting lives. This focus on safety and reliability not only benefits our direct clients but also resonates deeply with societal values, emphasizing our role in safeguarding community well-being.

Part 4

Innovation Solution

Current state of the art

The current state of the art in steel billet identification predominantly relies on hardware-intensive setups involving multiple cameras and complex lighting systems. These systems use optical character recognition (OCR) techniques to identify and sort steel billets in industrial settings. Typically, they are challenged by environmental factors like dust, vibration, and varying lighting conditions, which can affect accuracy and reliability.

Novelty of our solution

Our solution introduces a significant shift from hardware reliance to software-centric processing, enhancing both efficiency and accuracy. The novel aspects include:

- **Uniqueness Created:** Implementing a high-resolution full-frame camera coupled with a single, optimized LED lighting system. This approach significantly simplifies the hardware setup while maintaining or improving the image capture quality necessary for accurate OCR.

- **Mono-field/Cross-field/Cross-cluster Approach:** The solution is mono-field in its direct application to steel manufacturing but has cross-field potential, applicable in other industrial contexts requiring OCR under challenging conditions.
- **Position vs. International State of the Art:** This solution places us at the forefront of industrial OCR applications, leveraging advanced image processing algorithms and streamlined hardware to set a new standard.
- **Scientific/Technological Ambition and Risk**: The project is at a high Technology Readiness Level (TRL), with the primary risk being the transition from a hardware-focused approach to a software-centric one. The application of advanced CNNs for character recognition requires a technical team to implement, with a solid understanding of modern machine learning and data processing techniques.
- **Applicability of Research Results:** The results are immediately applicable to the steel industry but have broader implications for industrial OCR applications.
- **Data Labelling through Crowdsourcing**: A significant innovation in our approach is the use of crowdsourcing for data labelling. This method will enable us to gather a vast and diverse dataset, crucial for training our CNN models for accurate OCR in varied industrial conditions. This can be done relatively cheaply as there is no need for a specialized actor to do the labelling (like it would be with medical data).

Goals

- **Scientific Goals**: To advance the field of OCR in industrial applications by demonstrating the efficacy of a simplified hardware setup augmented with sophisticated software algorithms.
- **Economic Goals**: Reduction in setup and maintenance costs by at least 30% compared to traditional systems, with an aim to increase market adoption.
- **Technological Goals**: Achieve an OCR accuracy rate of over **99.93%** in real-world industrial conditions.

Preliminary Work Performed

- **Hardware Selection and Testing**: Identified and tested suitable camera and lighting options to ensure compatibility with industrial environments.
- **Crowdsourcing Platform Setup**: Established a platform for crowdsourcing data labeling, ensuring a rich and diverse dataset for model training.
- **Software Development**: Developed and trained a CNN model for OCR, tested under various simulated conditions to ensure robustness.
- **Integration Prototyping**: Created a prototype system integrating the camera, lighting, and software, demonstrating feasibility.

Suitability of Selected Partners

- **Value Creation**: Partners have been selected for their proven ability to foster and realize value creation in Switzerland's industrial sector.
- **Scientific/Technical Expertise**: Each partner brings specific expertise in either industrial imaging, software development for OCR, or industrial process optimization.
- **Track Record**: The partners have a strong track record of successful projects in similar industrial applications.

- **Infrastructure Availability**: Necessary infrastructure for development, testing, and implementation of the solution is readily available through the partnership.

Part 5

Project Setup

Project Dates

- Start Date: January 01, 2024
- End Date: June 30, 2024
- Project Duration: 6 months

Work Packages & Milestones

1. **WP1: Data Collection and Model Training (January - February)**

→ Milestone 1: Complete Data Collection (January 31): Gather a comprehensive dataset from the steel location, which includes various patterns and images needed for model training.
→ Milestone 2: Initial Model Training Complete (February 28): Use the collected data to train the OCR and pattern recognition model, ensuring it can accurately identify and process patterns from metal rods.

2. **WP2: Hardware Acquisition and Setup (February - March)**

→ Milestone 3: Installation at First Steel Location (March 15): Acquire and set up the required self-cleaning cameras and lighting systems, ensuring they are fully operational at the first steel location.

3. **WP3: Software Development and Integration (March - April)**

→ Milestone 4: Initial Software Development Complete (April 15): Develop the initial version of the software, including image preprocessing and OCR algorithm.
→ Milestone 5: Integration of Software with Hardware (April 30): Combine the software with the hardware setup, ensuring seamless interaction for optimal performance.

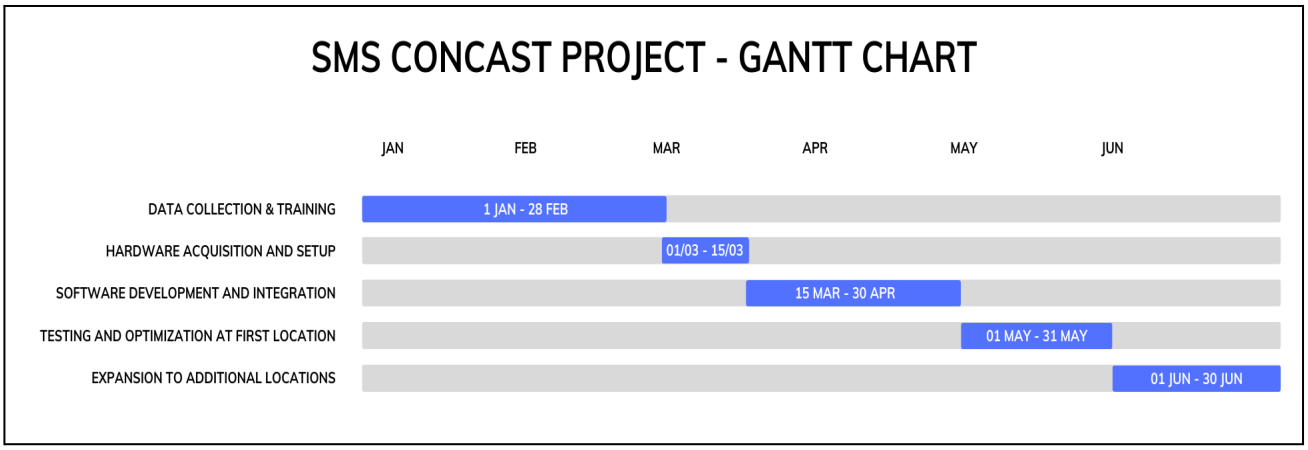
4. **WP4: Testing and Optimization at First Location (May)**

→ Milestone 6: System Testing Complete (May 15): Conduct comprehensive tests to verify the system's accuracy and functionality in the steel location environment.
→ Milestone 7: Optimization and Refinements (May 31): Refine and optimize the system based on testing feedback, focusing on enhancing accuracy and efficiency.

5. **WP5: Expansion to Additional Locations (June)**

→ Milestone 8: Deployment at Additional Locations (June 30): Extend the implementation of the system to additional steel locations, replicating the setup and ensuring consistent performance across different environments.

Gantt Chart



Part 6

Project results on Data

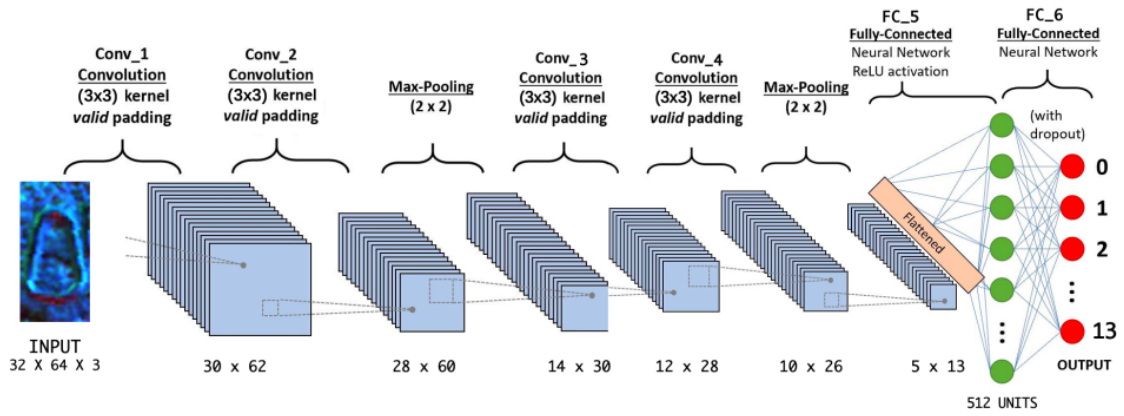
(15'000)

Methodology

- **Data collection:** The photographs obtained by the camera are eventually cropped into images of 32*64 size, each image presenting one character. Keeping the same size is important for our model. We finally have access to 74942 sample character images in total. However, for the generalization effect and stability of the model, we will subsequently augment it with data to obtain more training data.
- **Labeling:** A total of 13 unique characters appear in our sample, which are numbers 0-9 and ‘C’, ‘E’ and ‘X’. We need to label the collected data by manpower.
- **Data Structure:** Since Keras' ImageDataGenerator needs to read data from a directory structure, our image folders need to be organized by category. For example, images for each category should be stored in a subfolder named after that category.
- **Algorithm:** Our model is a deep Convolutional Neural Network (CNN) built using TensorFlow and Keras, specifically designed to process color images of size 32x64 (with 3 color channels). It contains the following main parts:
    - **Convolutional Layers**: There are four convolutional layers at the beginning of the model, each with a 3x3 convolutional kernel. These layers are responsible for extracting spatial features from the input image. The first two convolutional layers are not followed by a pooling layer, while the second and fourth convolutional layers are each followed by a maximal pooling layer with

a size of 2x2, which is used to reduce the spatial dimensions of the feature map, thus reducing the number of parameters and the computational cost.

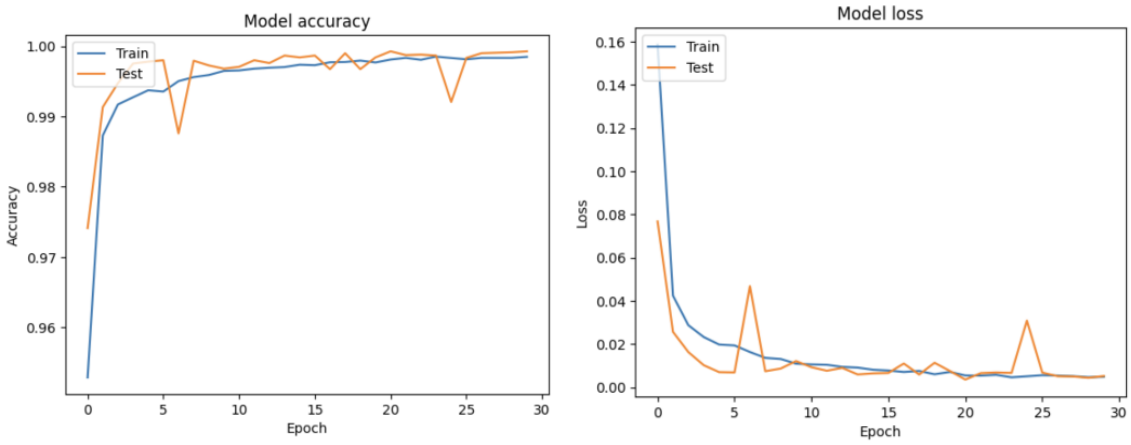
- **Batch Normalization**: Each convolutional layer is followed by a batch normalization layer, which contributes to stability during network training and accelerates learning by normalizing the inputs to the layers.
- **Activation Function**: Each convolutional layer is followed by a ReLU activation function, which introduces nonlinearity into the model, allowing the network to learn more complex patterns.
- **Flatten Layer**: After the convolutional layers, there is a Flatten layer which converts the 2D feature map to 1D so that it can be processed by the Fully Connected Layer.
- **Fully Connected Layer**: This is followed by a Fully Connected Layer with 512 neurons, again followed by a Batch Normalization and ReLU activation function. This layer is responsible for learning higher-level patterns from the features extracted by the convolutional layer.
- **Dropout**: Between the last fully connected layer and the output layer there is a dropout layer with a scale of 0.2. Dropout is a regularization technique that prevents the model from overfitting by randomly switching off a portion of the neurons during the training process.
- **Output Layer**: Finally, the model uses a fully connected layer with 13 neurons, corresponding to the 13 classification categories, as the output layer. The output layer uses a softmax activation function to generate predicted probabilities for each category.



Results

- **What did not work:**
  - We tried more sophisticated data augmentation techniques, but ultimately the results were not good. This may be because we don't need the ability to

generalize across multiple scenarios since our test data was obtained on the same hardware as the training data.
    - We tried the NFNet network [1] structure, a ResNet-based network structure that does not require Batch Normalization. But the effect is not as expected. This may be because NFNet was originally designed for large-scale image recognition, while our scenario is small-size character recognition.
- **What worked**:
    - We didn't make any augmentations to the sharpness, color, or blurriness of the image. Instead, we did some cropping, rotating, etc.
    - Good results can be achieved with the most basic 4-layer convolutional neural network. This not only saves computational overhead, but also training time.
    - We trained the model in stages for a total of 30 epochs, and at the end of each stage we evaluated when further training epochs were needed.
- **Evaluation:**
  The accuracy of the model is most important for our program, while the loss of the model can tell us to improve it. We evaluated our model performance on test set and train set based on accuracy and loss. The final accuracy we achieved on the test set is **99.93%.** The visualization of the training history is presented as follows.



Possible Future Work

- **Algorithm pipeline:**
    - There are actually many very new pre-trained models for character recognition that are pre-trained on very large datasets. We can consider further fine-tuning on the better performing and more popular pre-trained models in the future using the data we have collected and then applying it to our scenario. This may be a better solution but we are still exploring.
- **Hardware scalability**:
    - In the scope of this project we decided to simplify the hardware architecture to achieve better results with a less complicated setup. However, this setup will not scale very much if SMS concast vastly increases production, where perhaps project specifications and needs will evolve further.

Part 7

Summary

In this work, we present **SOCRATES**, a revolutionary OCR solution for billet recognition. We built on the original solution with both hardware and software improvements, ultimately achieving **99.93%** accuracy on the test set. Our solutions address industry pain points and are highly practicable, and we have also made efforts to reduce costs. At the same time, we have developed a comprehensive business management plan to ensure the possibility of landing.

Reference

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Note: We have used ChatGPT to generate some ideas for us, as well as give us a first idea of topics to follow.