Health Diagnostic Trends and Predictive Insights

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Report Submitted by

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Abstract:

Machine learning, a branch of artificial intelligence, employs statistical, probabilistic, and optimization techniques enabling computers to learn from past examples and identify intricate patterns in large, noisy datasets. This capability is particularly useful in medical applications, especially those requiring analysis of complex proteomic and genomic measurements. Consequently, machine learning is widely used in cancer diagnosis and detection, and more recently in prognosis and prediction, aligning with personalized, predictive medicine trends. In medical imaging, machine learning significantly enhances the detection of abnormalities in X-rays, MRIs, and CT scans. Advanced algorithms analyze medical images with high precision, identifying patterns and anomalies that may be difficult for human eyes to detect. This not only aids in early and accurate diagnosis but also improves our understanding of disease progression and patient outcomes, making it a vital tool in modern medical diagnostics.

Problem Statement :

Pathology, the cornerstone of medical diagnostics, involves the meticulous examination of tissue samples to diagnose diseases. However, the process is labor intensive, prone to human error, and can suffer from variability in interpretation among pathologists. As the volume of diagnostic samples increases, pathologists face mounting pressure to deliver timely and accurate diagnoses, which is critical for effective patient management and treatment planning. The primary challenges in pathology include:

1. **High Workload:** Pathologists are required to analyze a large number of samples daily, leading to fatigue and potential oversight.
2. **Interpretation Variability:** Different pathologists may interpret the same sample differently, leading to inconsistent diagnoses.
3. **Diagnostic Accuracy:** Ensuring high accuracy in detecting and diagnosing various diseases, particularly cancers, are crucial yet challenging.
4. **Time Efficiency:** The traditional diagnostic process is time-consuming, delaying critical treatment decisions.

To address these issues, there is a need for an AI-driven solution that can assist pathologists by providing accurate, consistent, and rapid analysis of pathological samples. This AI system should leverage advanced machine learning algorithms to identify and classify abnormalities in tissue samples, thereby improving diagnostic accuracy, reducing variability, and enhancing the overall efficiency of the pathology workflow.

Market/Customer Need Assessment :

Pathologists diagnose 14 million new cancer patients around the world each year. This means millions of people will face years of uncertainty. While pathologists have been performing cancer diagnoses and prognoses for decades, and most achieve a 96-98% success rate in diagnosing cancer, there is a significant problem in prognoses. According to Oslo University Hospital, the accuracy of prognoses is only 60%. Prognosis predicts the development of the disease after diagnosis and is crucial for effective treatment planning. Patients need fast and reliable service, yet pathologists often take 10 or more days to evaluate a prognosis. This delay is critical for cancer patients as cancer cells can spread rapidly. The advent of the Internet of Things (IoT) has generated vast amounts of data that humans cannot process alone. This is where machine learning (ML) can assist. Machines can work faster than humans, making accurate computations and finding patterns in data, which benefits patients and increases profitability for pathology firms. Machine learning, a branch of artificial intelligence (AI), can revolutionize the prognosis process in pathology. By analyzing data, identifying patterns, and training itself, an ML system can provide more accurate and timely prognoses. This article explores the applications of AI in pathology, offering business leaders insights into current and emerging trends. It highlights the importance of AI in improving cancer prognosis, which is vital for eradicating cancer. This information underscores the urgent need to incorporate AI into pathology to enhance diagnostic accuracy, speed up prognosis, and ultimately improve patient outcomes.

Target Market:

1. **Healthcare Providers:** Doctors and pathologists seeking to enhance diagnostic accuracy and efficiency in their practice.

2. **Medical Institutions:** Hospitals and clinics aiming to integrate advanced AI technologies to improve patient outcomes.

3.**Research Labs**: Researchers focused on developing and validating new AI models for pathology.

4.**Medical Students**: Students and trainees looking to understand the impact of AI on modern pathology and improve their diagnostic skills.

5. **Healthcare Administrators**: Professionals interested in optimizing clinical workflows and reducing operational costs with AI solutions.

6. **Patients:** Individuals looking for faster and more accurate diagnostic results to facilitate timely treatment.

7. **Insurance Companies:** Organizations aiming to improve the accuracy of claims and reduce fraudulent activities through AI-driven diagnostics.

8. **Biotech Companies:** Firms developing innovative diagnostic tools and looking to incorporate AI for enhanced functionality.

9. **Public Health Officials:** Authorities focused on improving public health surveillance and response through AI-powered diagnostic data.

External Search(Information and Data Analysis)

These are some of the sources I visited for more information and need for shopping pattern analysis of customers.

1. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9777836/#app1-healthcare-10-02493

2.https://www.grandviewresearch.com/horizon/outlook/pathology-laboratories-market-size/globl

3.https://www.linkedin.com/pulse/how-ai-improving-efficiency-accuracy-medical-reducing-mike-khan-cpa

Applicable Regulations(Government and Environmental)

1. Data collection and Privacy of Regulations of Customers.

2. Government norms for Small Businesses and Street Vendors

3. Rules against False Marketing

4. Employment Schemes and laws created by government

Applicable Constraints

1. Lack of initial data to perform algorithms.
2. Convincing Shopkeepers and vendors to use this technique of selling over traditional means.
3. Lack of technical knowledge of vendors.
4. Rarely bought items will not be detected by algorithm, so it won't be generated as an output, so shopkeepers need to note which items are rarely bought and buy them in small quantities.
5. Need to continuously update and manage the data and model.

Business Opportunity

Pathology is a critical field in medicine that involves the study of disease through the examination of tissue samples, blood, and other bodily fluids. The process traditionally relies heavily on human expertise, which can be time-consuming, subjective, and prone to error. Advances in Artificial Intelligence (AI) present a significant opportunity to enhance the accuracy, efficiency, and accessibility of pathological diagnostics.

The global market for AI in healthcare, including pathology, is rapidly growing. According to recent estimates, the AI in the healthcare market is expected to reach several billion dollars by 2027. The increasing adoption of AI technologies, coupled with a growing emphasis on precision medicine, presents a lucrative opportunity for innovation in pathology.

Key Considerations:

- **Regulatory Compliance:** Ensuring that AI solutions comply with medical device regulations and data privacy standards is crucial for market acceptance.
- **Data Quality and Diversity:** The performance of AI models depends on the quality and diversity of training data. Collaborating with medical institutions to obtain diverse and high-quality datasets is essential.
- **Integration with Existing Systems:** Developing solutions that seamlessly integrate with existing pathology workflows and EHR systems will enhance adoption and usability.

Modeling Cost Analysis for Diagnosis

Assumptions: For the analysis, the 10 years were considered, while for the starting year, the number of patients were 20 per day per hospital and the number of hospitals considered was also 20. The progression rises to 65 patients per day and the hospital count is 38 at 10 years.

Fig:1 depicts the number of patients per day in each hospital as well as the number of hospitals. It indicates that the patient count and hospitals are increasing linearly.

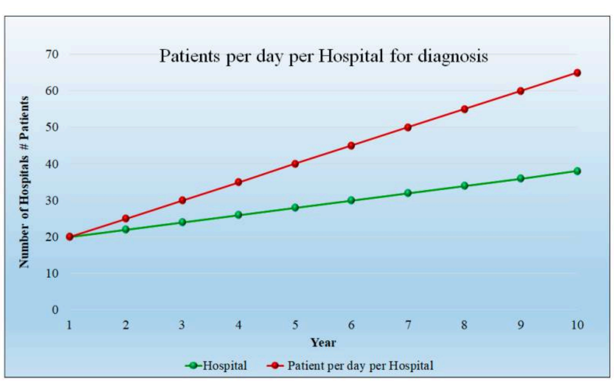


Fig2 shows the time saved (hours) during the diagnosis of the patient. In the initial year, the time savings is 3.33 h per day; in 10 years, the time saving will be 15.17 h per day. Over the course of a year, the savings in time increased even with the increase in patient quantity. The cost of diagnosis is reduced as a result of the time savings.

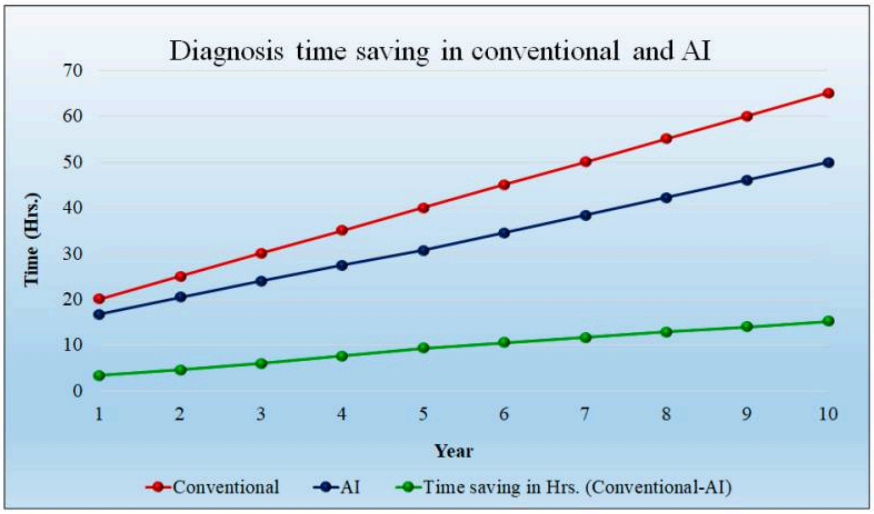


fig:2

Fig:3 shows the cost saving of the AI-based diagnosis method as compared to the conventional diagnosis method. The conventional diagnosis method requires greater time compared to the AI model. We assumed the model diagnosis price as USD 500 per hour. This observation results in cost saving in the initial year, but after 5 years the cost is saving more. The cost savings in diagnosis are USD 1666.66 per day per hospital in the first year and USD 17,881 per hospital in the tenth year.

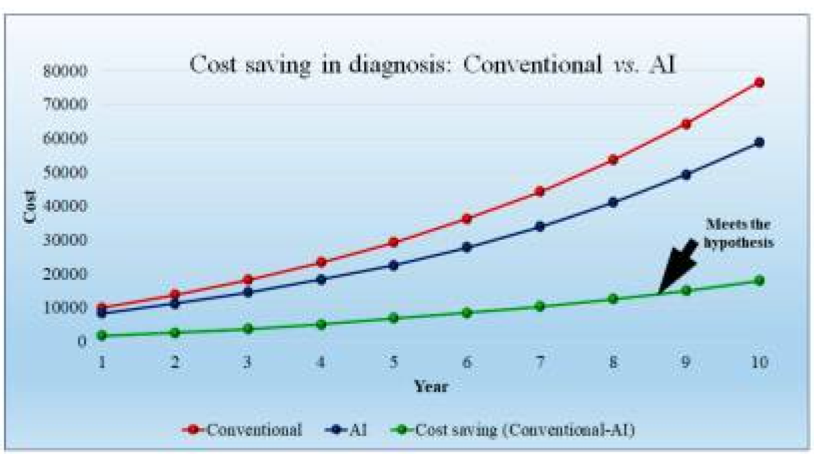


fig:3

Modeling Cost Analysis for Treatment

Treatment requires more time as compared to the diagnosis. It indicates that the patient count and hospital count are increasing linearly. For the analysis purpose, over a 10-year span, we have considered an initial year of 20 patients per day per hospital; for the initial year, 15 hospitals were considered. The progression rises to 55 patients per day and the hospital count is 21 at 10 years.

The cost associated with the treatment is higher as it requires more time for prognosis. The curve in Fig:4 shows the number of patients admitted initially to hospitals and the number of hospitals.

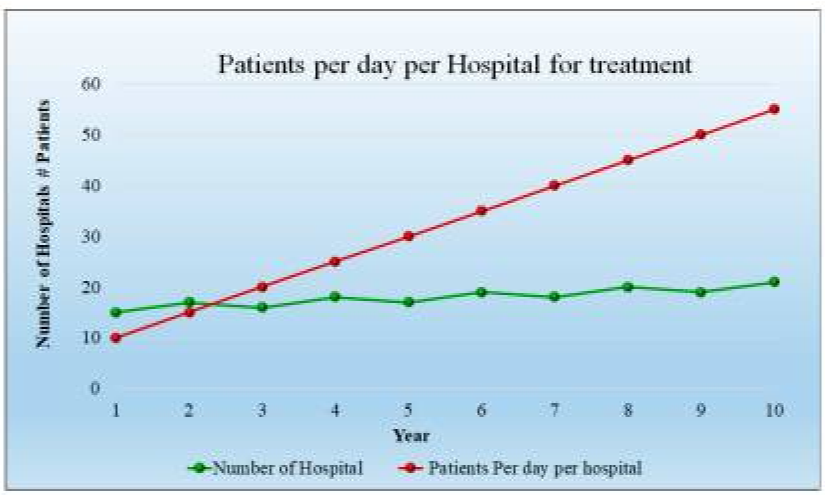


fig:4

Fig:5 shows the time saving (hours) during the treatment of the patient. Note that saving in time increases even if there is an increase in the patient sample size. The time-saving results decrease in cost. The time-saving treatment in the 1st year is 21.67 h per day per hospital, and it reaches its peak in the 10th year at 122.83 h per day per hospital.

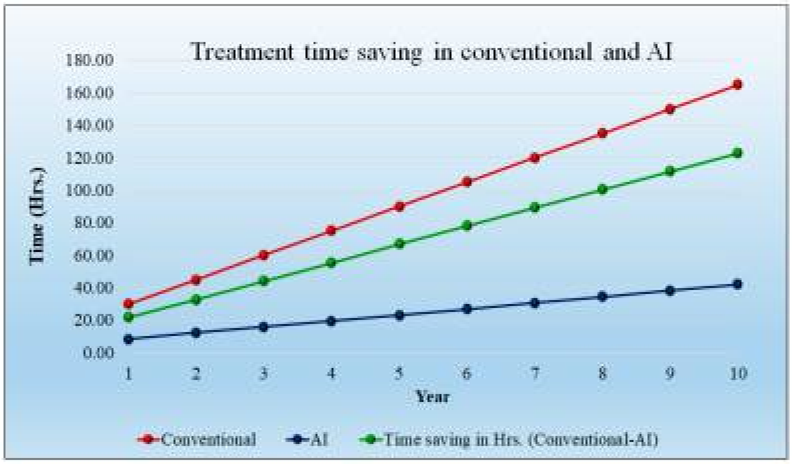


Fig:5

Cost Effective analysis for the diagnosis:

Categories	Count	Years									
		1	2	3	4	5	6	7	8	9	10
Patient Size per hospital per year	3650	7300	9125	10,950	12,775	14,600	16,425	18,250	20,075	21,900	23,725
No. of Hospital	20	20	22	24	26	28	30	32	34	36	38
Per day Patient Per hospital	20	20	25	30	35	40	45	50	55	60	65
Total patient	73,000	2,920,000	5,018,750	7,884,000	1,162,5250	1,635,2000	22,173,750	29,200,000	37,540,250	47,304,000	58,600,750
Conventional Method											
Physician charges per hour	500	500	550	605	665.5	732.05	805.255	885.7805	974.3586	1071.794	1178.974
Conventional method time (minutes) per day	60	1200	1500	1800	2100	2400	2700	3000	3300	3600	3900
Conventional method time (hours) per day	1	20	25	30	35	40	45	50	55	60	65
Physician charges per day in USD		10,000	13,750	18,150	23,292.5	29,282	36,236.48	44,289.03	53,589.72	64,307.66	76,633.3
Physician Charges per year per hospital		3,650,000	5,018,750	6,624,750	8,501,763	10,687,930	13,226,313	16,165,494	19,560,248	23,472,297	27,971,154
AI-based Method											
Physician charges per hour in USD	500	500	550	605	665.5	732.05	805.255	885.7805	974.3586	1071.794	1178.974
AI-based system time (minutes) per day	60	1000	1225	1440	1645	1840	2070	2300	2530	2760	2990
AI-based system time in (hours) per day	1	16.66667	20.41667	24	27.41667	30.66667	34.5	38.33333	42.16667	46	49.83333
Physician charges per day in USD		8333.333	11,229.17	14,520	18,245.79	22,449.53	27,781.3	33,954.92	41,085.45	49,302.54	58,752.2
Physician charges per year per hospital in USD		3,041,667	4,098,646	52,99,800	6,659,714	8,194,080	10,140,174	12,393,545	14,996,190	17,995,428	21,444,552

Cost Effective analysis for the treatment:

Categories	Count	Year									
		1	2	3	4	5	6	7	8	9	10
Patient Size per hospital per year	3650	3650	5475	7300	9125	10,950	12,775	14,600	16,425	18,250	20,075
No. of Hospital	20	15	17	16	18	17	19	18	20	19	21
Per day Patient Per hospital	20	10	15	20	25	30	35	40	45	50	55
Total patient	73,000	547,500	1,396,125	2,336,000	4,106,250	5,584,500	8,495,375	10,512,000	14,782,500	17,337,500	23,186,625
Conventional Method											
Physician charges per hour	1000	1000	1100	1210	1331	1464.1	1610.51	1771.561	1948.7171	2143.58881	2357.947691
Conventional method time (minutes) per day	180	1800	2700	3600	4500	5400	6300	7200	8100	9000	9900
Conventional method time (hours) per day	3	30	45	60	75	90	105	120	135	150	165
Physician charges per day in USD		30,000	49,500	72,600	99,825	131,769	169,103.55	212,587.32	263,076.80	321,538.32	389,061.36
Physician Charges per year per hospital		10,950,000	18,067,500	26,499,000	36,436,125	48,095,685	61,722,795.75	77,594,371.8	96,023,035.1	117,361,487.3	142,007,399.7
AI-based Method											
Physician charges per hour in USD	1000	1000	1100	1210	1331	1464.1	1610.51	1771.56	1948.71	2143.58	2357.94
AI-based system time (minutes) per day	90	500	735	960	1175	1380	1610	1840	2070	2300	2530
AI-based system time in (hours) per day	1.3	8.33	12.25	16	19.58	23	26.83	30.66666667	34.5	38.33	42.16
Physician charges per day in USD		8333.33	13,475	19,360	26,065.41	33,674.3	43,215.35	54,327.87067	67,230.73	82,170.90438	99,426.79
Physician charges per year per hospital in USD		3,041,666.66	4,918,375	7,066,400	9,513,877.08	1,229,1119.5	1,577,3603.36	19,829,672.79	24,539,220.08	29,992,380.1	36,290,779.92

Final Product Prototype/ Product Details

The final product provides service to operators about the most bought combinations of products for them to analyze customer booking patterns and helps them manage their business and also create new strategies and schemes to increase their sales. The service implements the AI Market Analysis, i.e CNN,LSTM on the dataset of transactions collected from the Pathology Center.

A) Feasibility

This project can be developed and deployed within a few years as SaaS(Software as a Service) for anyone to use.

B) Viability

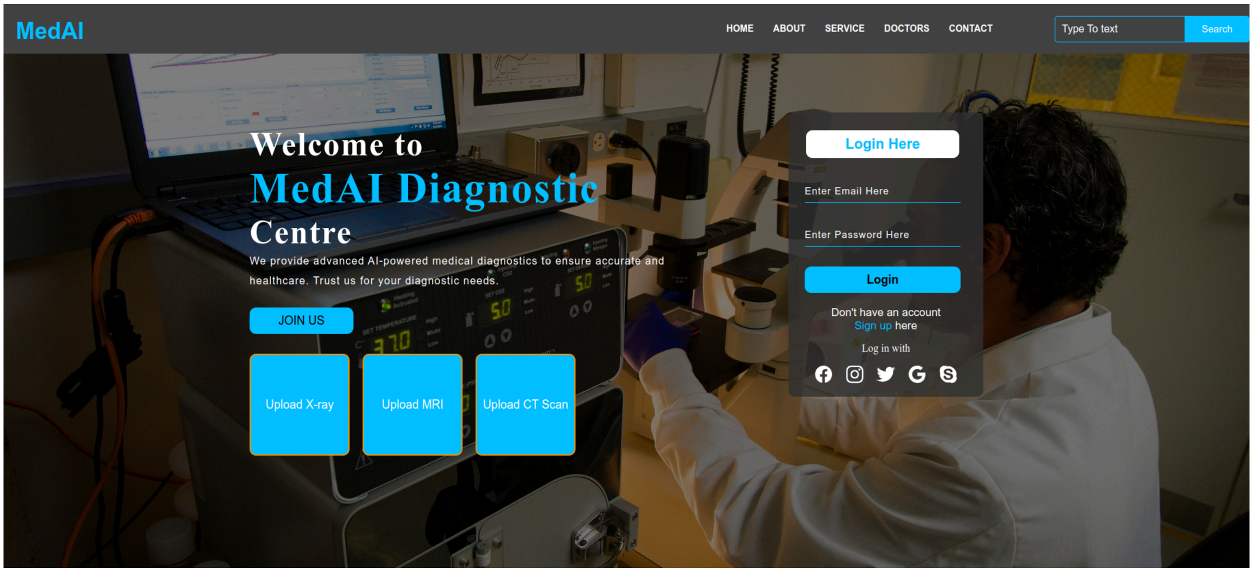
As the retail industry grows in India and the world, there will always be small businesses existing which can use this service to improvise on their sales and data warehousing techniques. So, it is viable to survive in the long-term future as well but improvements are necessary as new technologies emerge.

C) Monetization

This service is directly monetizable as it can be directly released as a service on completion which can be used by businesses.

D) Prototype Development

I have developed a prototype of my model using HTML and CSS. Link of codes are given in Github, click here for code. Here a visual of website:



Github link : [click here for website link]

E) Business Modeling

For this service, it is beneficial to use a Subscription Based Model, where initially some features will be provided for free to engage customer retention and increase our customer count. Later it will be charged a subscription fee to use the service further for their business.In the subscription business model, customers pay a fixed amount of money on fixed time intervals to get access to the product or service provided by the company. The major problem is user conversion; how to convert the users into paid users.

F) Financial Modeling

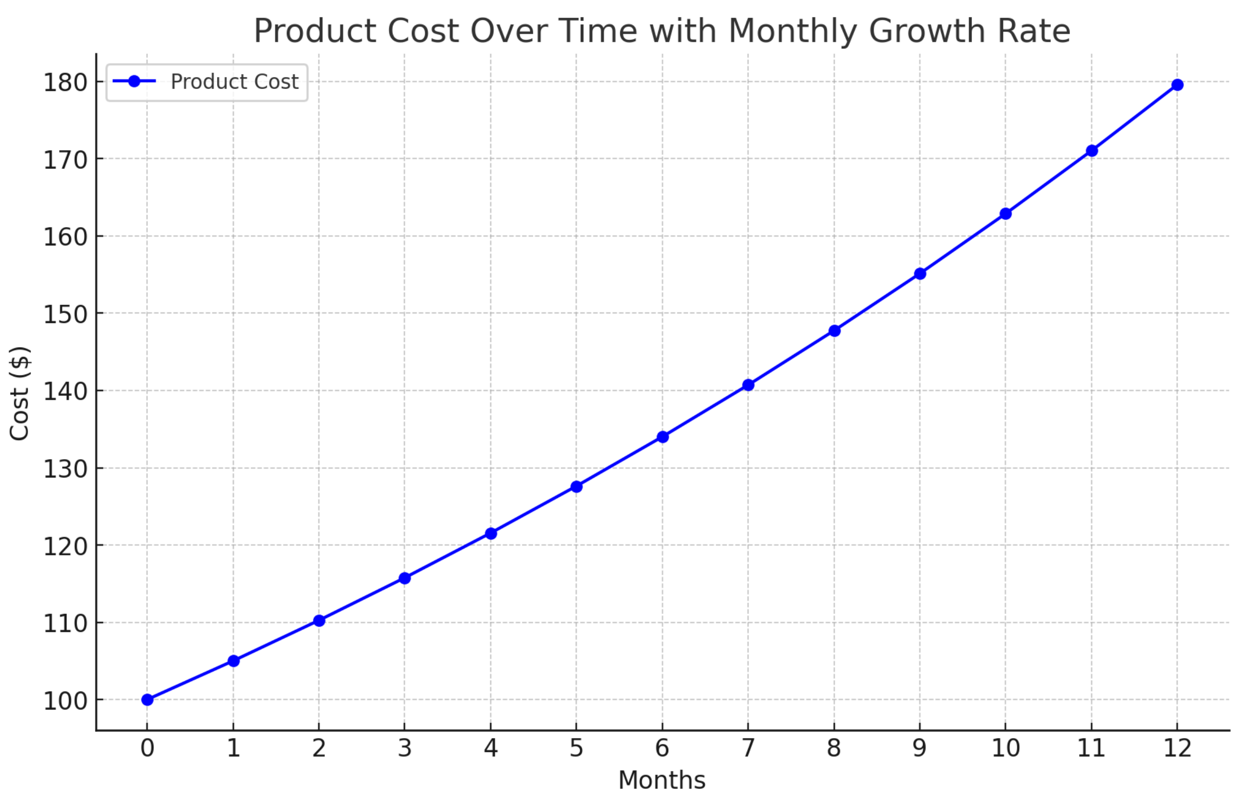
Suppose the initial cost of a product is \$100, and the monthly growth rate is 5% (i.e., r=0.05)

Financial Equation:

$$P(t) = P_0 * (1 + r)^t$$

- P_0: Initial cost of the product.
- (1+r): Growth factor per month.
- t: Number of months.
- $P(t)$: Cost of the product after t months.

Here is the graph showing the product cost over time with a monthly growth rate of 5%. The initial cost of the product is \$100, and the cost increases exponentially each month. The x-axis represents the number of months, and the y-axis represents the product cost in dollars.



Conclusion

The development of an AI-powered medical diagnostic tool, utilizing Convolutional Neural Networks (CNNs) and Random Forest algorithms, promises to revolutionize healthcare diagnostics. This tool enables rapid and accurate analysis of medical images and patient data, offering swift, reliable diagnoses and personalized treatment recommendations. Patients benefit from improved outcomes and faster access to care, while healthcare providers enhance their diagnostic accuracy and efficiency, reducing costs. The business model, featuring subscription plans, pay-per-use options, and licensing fees, ensures sustainability and scalability. By integrating this tool into healthcare systems, we can significantly improve early disease detection and treatment, particularly for conditions like cancer. Overall, this AI diagnostic tool represents a major advancement in medical technology, enhancing patient care and transforming healthcare delivery.

References :

[1]. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9777836/#app1-healthcare-10-02493

[2].https://www.grandviewresearch.com/horizon/outlook/pathology-laboratories-market-size/global

[3].https://www.linkedin.com/pulse/how-ai-improving-efficiency-accuracy-medical-reducing-mike-khan-cpa

[4].https://www.linkedin.com/pulse/how-pathology-ai-works-immuno-oncology-short-demo-video-holgerlange/