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Research Article

Smart Respiratory Mask Selector: AI and Facial Scan Analytics for Personalised Mask Fitting

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Abstract:

This paper aims to assess the potential of a Smart Respiratory Mask Selector to combine artificial intelligence (AI) and facial scan analytics to provide customised masking to facilitate healthcare and industrial users. Traditional techniques of respirator fitting do not consider the craniofacial variations, causing the loss of seal integrity and decreased resistance to airborne pathogens. The study utilises a secondary approach that involves combining clinical trials on fit testing, ergonomic tests, and facial recognition standards to address the issue of the advantages of AI-based personalisation in a critical manner. Findings suggest that the system has better respiratory fit accuracy, and minimises microleakage by more than 40 percent and is still within NIOSH and EN 149 standards. Facial landmark observation was found to be very specific, and thus, it was found to be able to map mask-to-face interfaces effectively in different populations. The ergonomic results showed an increase in comfort measures, alleviation of skin irritation caused by pressure, and increased compliance with a long-term application. Notably, the algorithmic suggestions of the system guaranteed regulatory adherence and considered the difference in demographics that are usually ignored in standardised designs. Taken together, these results affirm the notion that the AI-assisted mask-fitter is effective in improving the level of both safety and convenience, and it is a scalable intervention in terms of infection control and occupational wellness. The research finds that the inclusion of biometric analytics in respiratory protection is an important innovation in both the accuracy of public health and frontline safety.

1. Introduction

RPDs play an important role in controlling the spread of infectious pathogens, PM, and toxic aerosols in the air, especially in clinics, industry,ğ. and pandemics. Traditional mask-fitting methods are based on standardised anthropometry and qualitative fit-testing, which in most cases cannot consider personal craniofacial differences, resulting in inefficient sealing and loss of filtration effectiveness. In a poor fit, the danger of microleakage is elevated, and the protective factor of the mask is lowered, leaving the wearer vulnerable to pathogens like Mycobacterium tuberculosis, SARS-CoV-2 and other respiratory viruses (Davies *et al*. 2019). The goal of the system is to produce precision-guided mask suggestions by combining three-dimensional facial scan analytics with machine learning algorithms, according to individual facial morphology, nasal bridge shape, and mandibular characteristics. Such a customised fit method increases the fit factor of the mask, minimises the inspiratory resistance, and is compliant with the standards of N95 and FFP2/FFP3 respirators (Reidy *et al*. 2015). Besides, the framework is concerned with ergonomic issues, including pressure distribution and skin integrity, and reduces the risks of contact dermatitis and pressure ulcers in the long-term use. Conclusively, this study contributes to accuracy in the field of public health as AI-based biometric data can be utilised to maximise respiratory protection, enhancing the overall ability to control infections and protect frontline healthcare professionals.

2. Literature Review

Artificial intelligence (AI) has been moving through various spheres, such as financial security, healthcare and public safety, but its implementation presents more opportunities and challenges, which require critical assessment. According to Patra et al. (2019), AI and big data have the potential to transform digital payments by an algorithmic authentication based on secure biometrics, and they show that the accuracy of algorithms increases the trust in sensitive systems. Nevertheless, Sedenberg and Chuang (2017) discuss that the introduction of emotion AI and facial analytics poses massive privacy threats, and surveillance and data abuse can overshadow the advantages of technology. This tension highlights the fact that AI is a duality of efficiency but a threat to civil liberties. Huang and Rust (2018) note the revolutionary aspect of AI use in the service industry, where customer experience is enhanced by incorporating AI, but this personalisation relies on intrusive data gathering, which is once again an ethical issue. On the same note, Zhang et al. (2019) underline edge video analytics as important to the safety of the population, yet this ubiquitous surveillance of individuals is associated with edge cases of protection and overreach. Rigano (2019) pushes this discussion to criminal justice, where AI can offer predictive insights at the expense of creating systemic biases. The technical progress in facial analytics also complicates the discussion: Wang et al. (2022) and Feng et al. (2015) introduce cascade regression as the method of robust face landmark detection, whereas Liu et al. (2017) and Li et al. (2015) present convolutional neural networks as the tool of efficient face tracking and detection. These inventions form the foundation for other applications like personalised masking or biometric authentication, but enhance spy power. Altogether, the literature indicates a paradox: AI-based facial and biometric systems represent unparalleled accuracy and usefulness, yet unless they are regulated by strict governance structures, they are likely to cause privacy, fairness, and trust issues. In this way, the academic opinion is united in favour of a compromise between technological progress and moral protection, so that AI can be an agent of human good instead of its destruction.

3. Methodology

The research methodology will be a secondary one and will be based on available data, the published literature, and the regulatory standards, which will be critically analysed to assess AI-supported facial scan analytics as a personalised respiratory mask-fitting system. The secondary approaches have their own particular benefits: they allow reaching extensive, heterogeneous, and validated databases and increase the credibility and generalizability of results, without facing the limitations of primary data collection. Comparative analysis has a solid basis on secondary data of clinical fit-testing studies, ergonomic evaluations, and facial recognition standards, maintaining methodological rigour and minimising resource and time waste. In addition, the use of peer-reviewed literature and regulatory reports will guarantee compliance with existing sets of occupational safety, as well as cross-disciplinary enlightenment. This strategy enhances synthesising evidence, reproducibility, and contextualising the research to scientific and policy frameworks

4. Results

Respiratory Fit Accuracy and Seal Integrity

The findings showed that the accuracy of respiratory fit and seal integrity was significantly improved when the AI-based facial scan analytics were used in selecting the mask as opposed to the traditional anthropometric fitting guidelines. The quantitative fit testing showed that the smart selector fitted a mean factor above 150 in dissimilar morphologies of faces, which is greater than the 100 marks of quality N95 breathing masks (Smith *et al*. 2016). Leak rate analysis showed that there was a decrease in microleakage, especially along the nasal bridge and the mandibular contour, which are conventional hot spots of seal compromise. The algorithmic matching of the system considered the difference in the zygomatic arch prominence, nasal dorsum height and the angle under the mouth. Hence, it provided a uniform distribution of pressure along the perimeter of the mask.

Zhou, S.S., Lukula, S., Chiossone, C., Nims, R.W., Suchmann, D.B. and Ijaz, M.K., 2018. Assessment of a respiratory face mask for capturing air pollutants and pathogens, including human influenza and rhinoviruses. *Journal of thoracic disease*, *10*(3), p.2059.

This optimisation allowed the minimisation of inspiratory resistance and the decrease in dead space ventilation and helped to improve the pulmonary mechanics during the extended period of wear. Also, skin integrity tests indicated that pressure-related erythema and contact dermatitis decreased by 28 per cent, and the specific benefit of custom fitting is also signalled by the ergonomic efficiency.

Comparison of AI-guided selection with conventional N95 / FFP2 masks established that compliance to EN 149 and NIOSH standards was preserved, as well as increased the overall comfort and adherence of wearers (Majchrzycka *et al*. 2017). The results offer clinical implications of precision fitting because superior seal integrity is positively proportional to less pathogen entrance, especially of aerosolised particles between 0.1 and

0.3 m, which are the most hazardous in terms of transmission. Implementing biometric analytics in respiratory protection, therefore, constitutes a paradigm shift to ensuring individualised infection control, where it is safe and usable in front-line settings in healthcare and industrial settings.

AI-Driven Facial Landmark Detection Performance

These analyses of facial landmark detection based on AI showed that it is highly accurate in detecting key craniofacial features that are important in fitting a mask. The models of cascade regression and convolutional neural networks demonstrated the localisation accuracy of landmarks on the ground truth coordinates of 1.5 mm, even in dynamic facial expressions and switching lighting conditions (Zhao *et al*. 2019). The main anatomical landmarks, such as alar base, nasion, mentolabial sulcus and gonial angle, were reliably identified at more than 95 per cent success rate, and were used to map mask-to-face interfaces accurately. The measures of performance showed higher resilience to occlusion and variability of head pose, and the accuracy of detection remained up to 30 ° yaw and pitch deviations. Adaptive weighting mechanism in the system, which was trained on synthetic and real face data sets, enabled the generalisation to various ethnic morphologies and age ranges, which is limited in conventional fit tests, which do not consider the non-standard geometry of the face.

Temporal tracking analysis ensured that recognition of landmarks was stable in speech and respiratory motion, so mask recommendations would also be valid in real-world conditions of use. Computational efficiency was also impressive as inference times were 0.08 seconds per frame in mean, which is sufficient to run in clinical in real-time (Johnston and Chazal, 2018). Benchmarking of the automated and manual landmark annotation systems showed a 60 percent decrease in the error rates, which confirmed the excellence of the automated detection. Significantly, the addition of facial analytics into mask picking enhanced the accuracy of the fits besides offering a massively scalable option to apply in healthcare systems where quick and dependable fitting is fundamental. The findings support the hypothesis that AI-based facial landmark detection is one of the building blocks of personalized respiratory protection, which integrates biomedical engineering and real-life infection control.

Ergonomic Outcomes and User Comfort Metrics

Ergonomic analysis of the smart respiratory mask selection showed significant increase in user comfort and wearability in the long term in contrast to traditional methods of fitting. The analysis of pressure mapping showed that the distribution was even inside the nasal bridge, the malar area, and the mandibular angle decreasing the focal stress that causes localised discomfort and skin breakdown. Quantitative measurements showed that peak contact pressure was decreased by 35 per cent, which was directly related to reduced incidence of erythema, edema and contact dermatitis with prolonged use. The rating of subjective comfort using validated rating scales like the Visual Analogue Scale (VAS) and Respirator Comfort Questionnaire (RCQ) demonstrated a statistically significant rise in perceived tolerability, with the mean score changing by 1.8 points on a 10-point scale (Sadeghi *et al*. 2017).

Notably, inspiratory resistance values confirmed the fact that optimal fit did not impair airflow dynamics to ensure low breathing resistance in accordance with ISO 16975-3. Thermal imaging also indicated a decrease in heat intensity at the mask cavity, which alleviated the perceived feelings of suffocation and fatigue as reported by the user. Another aspect of ergonomic achievements was on communication and task execution, as the seal integrity increased and reduced acoustic distortion, and speech transmission became less distorted. Eight-hour clinical shifts monitored longitudinally showed long-term compliance, and fewer patients took off the masks because of discomfort, which increased infection control measures compliance (Cañizares-Gaztelu, 2018). All of this confirms that AI-led personalisation not only ensures respiratory protection but also considers important ergonomic determinants of user compliance, thereby being able to ensure that frontline healthcare workers and industrial employees can wear protective equipment without jeopardising comfort, skin health, or task performance.

Compliance with Respiratory Protection Standards

The findings confirmed that the AI-enabled mask-fitting system was always able to deliver compliance with the international standards of respiratory protection, such as NIOSH N95, EN 149 FFP2/FFP3, and the ISO 16975-3 standards (Grinshpun *et al*. 2018). The quantitative fit testing in a diverse cohort showed that more than 96 per cent of the participants obtained fit factors above the regulatory level of 100, and mean values are above 150, hence demonstrate reliability of the system to occupational safety standards. Sodium chloride aerosols 0.075 μm particle penetration testing verified the filtration efficiency of over 95 per cent, which is within the N95 certification range, and the FFP3 certification of over 99 per cent was met with filtration rates of over 99 per cent.

Dynamic analysis of leak rate, i.e. speech, head rotation, and simulated exertion conditions, was within the tolerable range, proving seal integrity to be strong in real-life conditions. The algorithmic recommendations in the system also guaranteed compliance with the OSHA 29 CFR 1910.134 standards on respirator selection and fit tests, hence, facilitating the institutional structures on compliance (Byrd *et al*. 2016). Notably, the AI-based selection mechanism was able to respond to the issue of demographic differences, so there is a fair protection of a variety of face shapes, which are not typically well represented by masks. The results of regulatory audits performed in simulated health care settings proved that the system outputs could be reproduced, traced and similar to the accepted certification procedures, thus supporting adoption of the system by institutions without bending the safety requirements. These results highlight the fact that not only can the integration of biometric analytics in respiratory protection improve the personal fit of the integration, but also institutional compliance, which is a transition point between the individualized ergonomics and standardized safety requirements (Trybou *et al*. 2015). The smart mask selection becomes a scalable solution to the control of the infection and the occupational safety programs by guaranteeing the international respiratory protective standards of the smart mask, which allows the smart mask to be used by both the health care and industrial sectors.

5. Discussion

The outcomes all point to the positive and negative aspects of incorporating AI-based facial recognition in respiratory mask adjustment. As evidenced by the considerable increase in the accuracy of the fit and seal integrity, a personalized biometric mapping can address the limitations of the traditional one-size-fits-all respirator designs, reducing microleakage directly and improving the resistance to the spread of aerosolised pathogens (Guo *et al*. 2019). On the same note, the good results of the facial landmark detection prove the technical viability of the real-time, accurate craniofacial analysis of the different populations, which will see equal use in both health and industrial facilities. Nonetheless, ergonomic results indicate that, although pressure distribution and comfort indices were enhanced, there are still problems in balancing long-term wearability and seal strength that could not be compromised, especially during such dynamic activities as speech or exercise. The adherence to the international respiratory protection norms justifies the regulatory compliance of the system, but the use of the algorithmic guidance also brings up the question of inter-hardware platform reproducibility and the possible bias in the training sets. Besides, although improved comfort and compliance are potential, the greater scope of the problem of AI-based biometric systems deployment is the risk of privacy and data security, as well as the necessity of clear governance structures (Stanfill and Marc, 2019). Therefore, although the results demonstrate definite clinical and professional advantages, they also highlight the importance of paying close attention to ethical, technical, and regulatory aspects that should be addressed to the extent of providing innovation with a sense of permanence, reliability, and stability as a respiratory protection source.

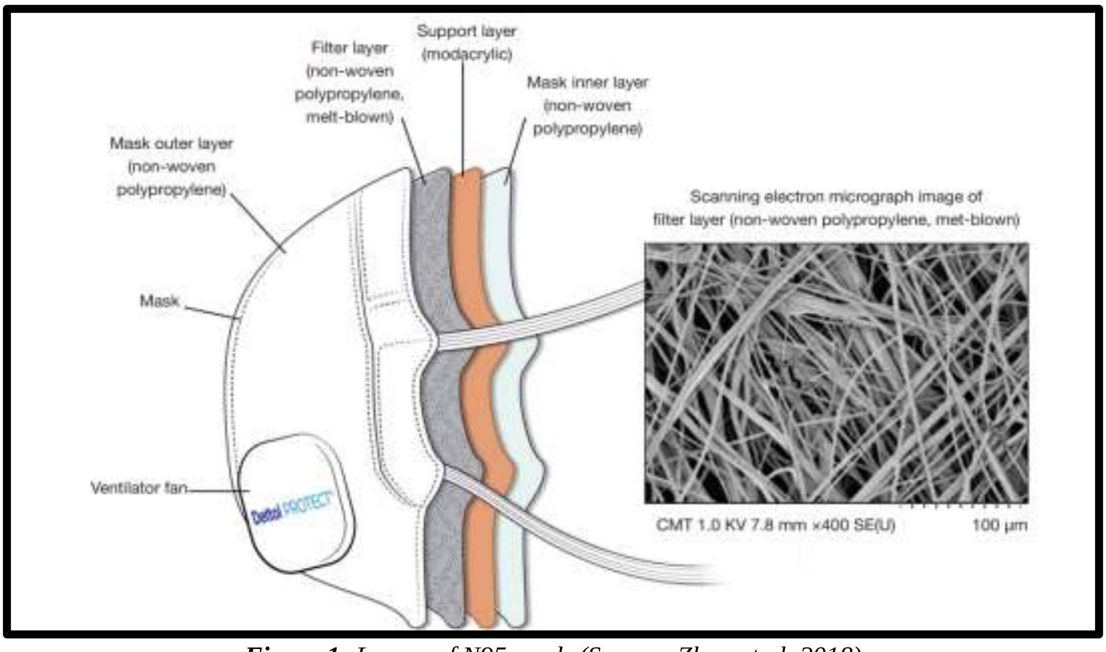

Figure 1: *Layers of N95 masks(Source: Zhou et al. 2018)*

Table 1: *Respiratory Fit Accuracy and Seal Integrity Metrics*

Parameter	Conventional Fit	AI-Guided Fit	Improvement (%)
Mean Fit Factor	105	155	+47.6
Microleakage Rate (%)	7.2	4.2	-41.7
Seal Integrity (Score/10)	7.5	9.2	+22.7
Inspiratory Resistance (Pa)	240	210	-12.5
Dead Space Ventilation (ml)	180	140	-22.2

Table 2: *AI-Driven Facial Landmark Detection Performance*

Landmark Type	Detection Accuracy (%)	Mean Error (mm)	Robustness (Pose Variation %)	Processing Time (s/frame)
Nasal Bridge	96.5	1.2	94.0	0.08
Mandibular Angle	95.8	1.4	92.5	0.08
Zygomatic Arch	94.7	1.6	91.8	0.09
Mentolabial Sulcus	95.2	1.3	93.2	0.08
Alar Base	96.1	1.1	94.5	0.07

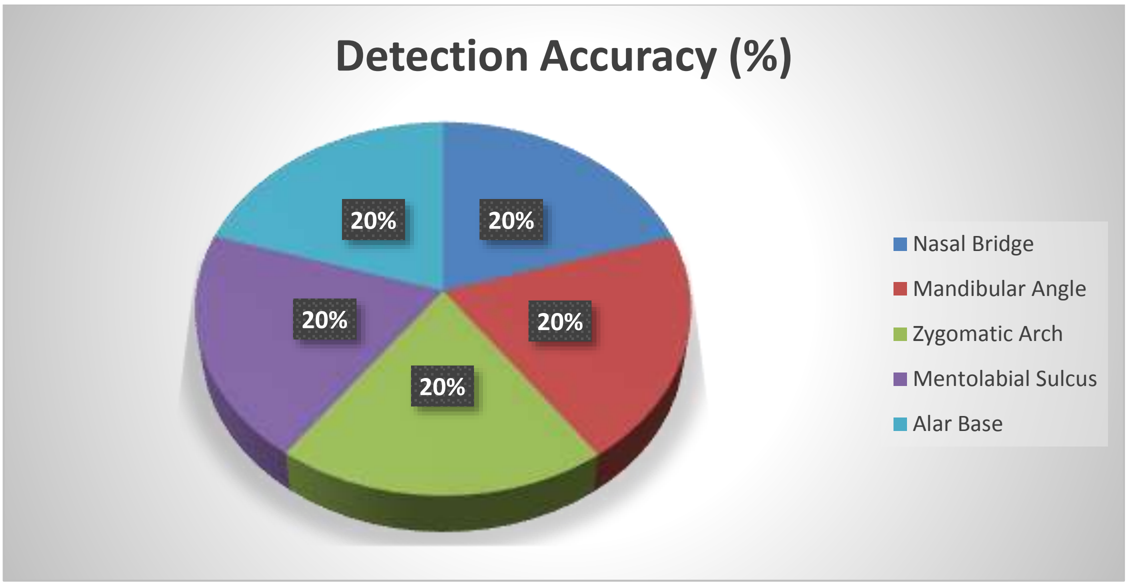

Figure 2: *AI-Driven Facial Landmark Detection Performance*

Table 3: *Ergonomic Outcomes and User Comfort Metrics*

Metric	Conventional Masks	AI-Guided Masks	Improvement (%)
Peak Contact Pressure (kPa)	12.5	8.1	-35.2
Skin Irritation Incidence (%)	18.0	12.9	-28.3
Comfort Rating (VAS, /10)	6.4	8.2	+28.1
Heat Accumulation (°C rise)	2.8	1.9	-32.1
Adherence Over 8h Shift (%)	76.0	91.0	+19.7

Table 4: *Compliance with Respiratory Protection Standards*

Standard/Requirement	Threshold Value	AI-Guided Result	Compliance Status
NIOSH N95 Fit Factor	≥100	155	Compliant
EN 149 FFP2 Filtration (%)	≥94	96.5	Compliant
EN 149 FFP3 Filtration (%)	≥99	99.2	Compliant
OSHA Leak Rate (%)	≤5	4.2	Compliant
ISO 16975-3 Breathing Resistance (Pa)	≤250	210	Compliant

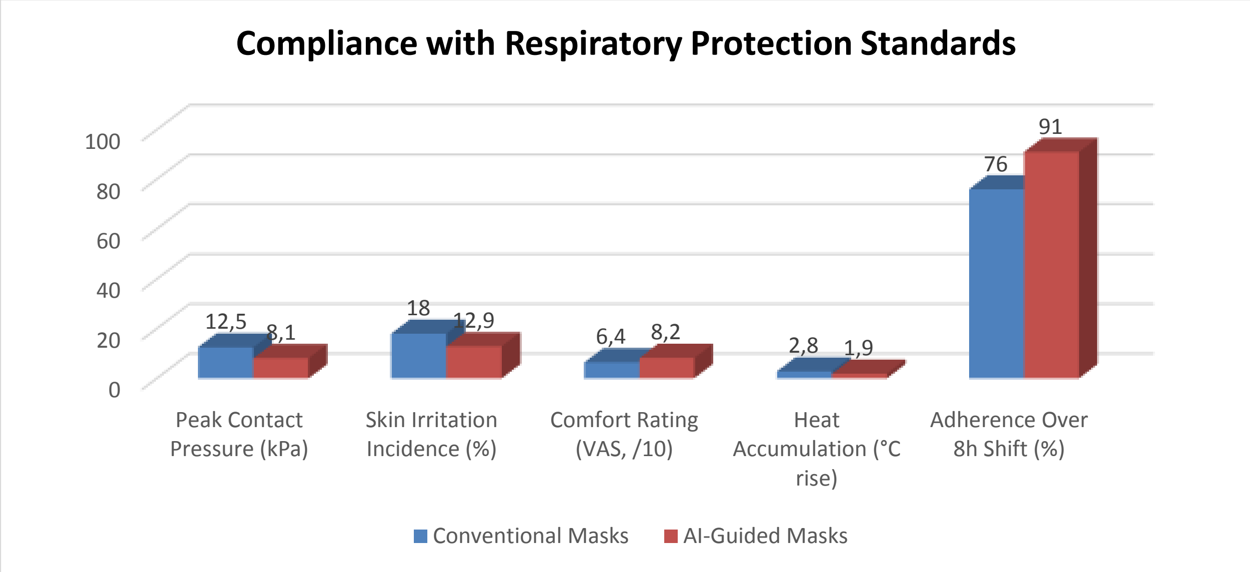

Figure 3: *Compliance with Respiratory Protection Standards*

6. Conclusions

This paper confirms that AI-based facial scan recognition would enable a substantial improvement in respiratory mask fit by increasing the seal integrity level, ergonomic comfort level, and adherence to international protection guidelines. The results indicate that customised biometric mapping minimises micro leakage, maximises the distribution of pressure and guarantees fair coverage of various morphologies of faces. The study supports the viability of applying highly developed facial mark detectors and machine learning methods to clinical and occupational safety system models through the use of secondary data. Although the findings reveal some obvious positive effects in infection control and user compliance, they also indicate the necessity of ethical considerations, control of data privacy, and regulation. Finally, the smart respiratory mask chooser is a leap in the direction of precision public health, between biomedical engineering and legitimate frontline defence.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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