The kaobook class

PhD Thesis

# Towards optimal resource management in solar thermal applications: desalination and CSP

Juan Miguel Serrano Rodríguez

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University of Almería

The kaobook class

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Colophon
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The harmony of the world is made manifest in Form and Number, and the heart and soul and all the poetry of Natural Philosophy are embodied in the concept of mathematical beauty.

– D’Arcy Wentworth Thompson

# Acknowledgements

Test test test

*Federico Marotta*

# Summary

I am of the opinion that every LaTeX geek, at least once during his life, feels the need to create his or her own class: this is what happened to me and here is the result, which, however, should be seen as a work still in progress. Actually, this class is not completely original, but it is a blend of all the best ideas that I have found in a number of guides, tutorials, blogs and tex.stackexchange.com posts. In particular, the main ideas come from two sources:

- Ken Arroyo Ohori's Doctoral Thesis, which served, with the author's permission, as a backbone for the implementation of this class;
- The Tufte-Latex Class, which was a model for the style.

The first chapter of this book is introductory and covers the most essential features of the class. Next, there is a bunch of chapters devoted to all the commands and environments that you may use in writing a book; in particular, it will be explained how to add notes, figures and tables, and references. The second part deals with the page layout and design, as well as additional features like coloured boxes and theorem environments.

I started writing this class as an experiment, and as such it should be regarded. Since it has always been intended for my personal use, it may not be perfect but I find it quite satisfactory for the use I want to make of it. I share this work in the hope that someone might find here the inspiration for writing his or her own class.

Resumen

# Contents

# List of Figures



# List of Tables



# List of Listings

# Introduction

# 1 Context and motivation

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# Thermal desalination overview 2



Desalination is increasingly recognized as a key strategy to address global freshwater scarcity, driven by the combined pressures of climate change and population growth. Regions already facing drought and water stress, such as parts of Spain, are expected to see growing dependence on desalinated water to meet rising demand. While desalination technologies—particularly membrane-based systems like Reverse Osmosis (RO)—have seen rapid expansion, the energy intensity of the process remains a major challenge. To mitigate this, efforts have focused on improving energy efficiency and integrating renewable energy sources such as solar or geothermal heat. In particular, thermal desalination technologies like Multi-Effect Distillation (MED) are gaining renewed interest due to their compatibility with low-exergy heat sources (*e.g.* waste heat) and the ability to treat high-salinity brines. These thermal processes also align better with circular economy approaches, allowing the concentration of brine and the recovery of valuable minerals such as lithium or magnesium, an emerging field known as brine mining.

## 2.1 (Pendiente mover) SolarMED pilot plant description

The SolarMED system is an MED plant that receives its thermal energy from a solar field + thermal storage system as depicted in Figure 2.1: a flat plate collector solar field which is the heat source, a pressurized hot water two-tank thermal storage system, and an MED plant which uses this heat to separate seawater into fresh water and brine. The solar field and thermal storage circuits are separated by a heat exchanger.

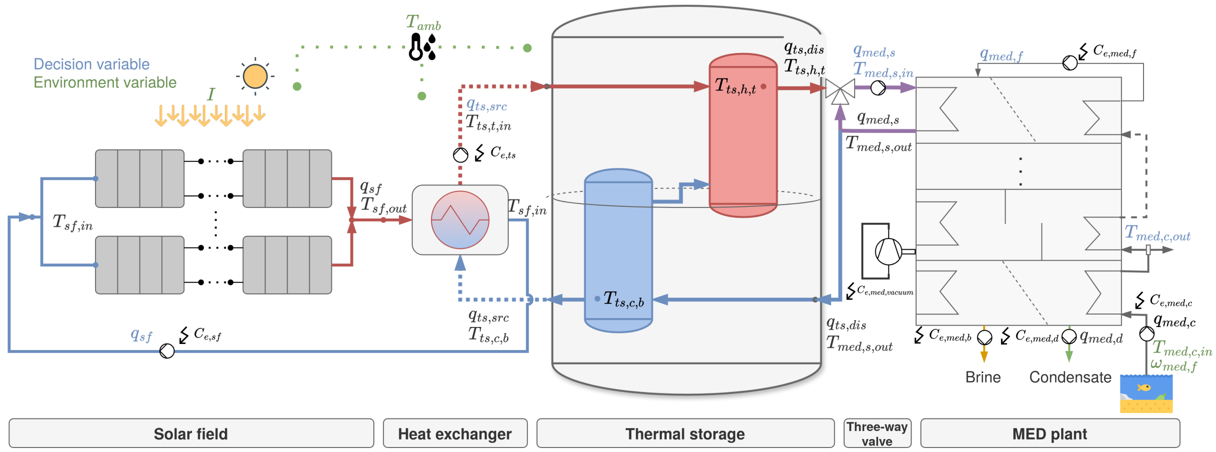



**Figure 2.1:** SolarMED process diagram

# CSP overview | 3



In the pursuit of eliminating reliance on fossil fuels sources for energy generation and replacing them by renewable sources, Concentrated Solar Power (CSP) has proven to be a reliable contributor. In particular, in providing much needed energy storage, dispatchability and ensuring grid stability.

CSP plants use mirrors to concentrate the sun's energy to finally drive a turbine that generates electricity. This technology currently represents a minor part of renewable energy generation in Europe. Only approximately 5 GW are installed globally (of which 2.3 GW in Europe are concentrated in Spain). However, the potential for growth is significant given the capability of CSP to provide renewable electricity when needed thanks to in-built energy storage continuing the production even in the absence of sunlight, unlike other renewable technologies that are dependent on the availability of the energy source. Of increasing importance is also their potential application in improving the manageability of the grid, replacing fossil fuel alternatives. Their dispatchability enables plants to respond to peaks in demand, and provide ancillary services to the grid. According to the International Energy Agency forecasts, CSP has a huge potential in the long term, ranging from the 986 TWh by 2030 up to 4186 TWh by 2050 [1], which means that CSP will account for 11% of the electricity generated worldwide and for 4% in the case of Europe.

[1]: IEA (2014), *Energy Technology Perspectives*

## 3.1 Water use

The cooling of the power block in this technology plays a crucial role in its feasibility. The cheapest and most efficiency cooling technology is evaporative cooling, and that is why most plants, specially in Spain where built using this alternative (XX % [2]), however, the high-radiation areas in which they are located are usually regions with rapidly-degrading water availability due to climate change, so water has become a scarce resource. Nowadays most likely those plants would have been built with dry cooling technologies, significantly increasing the cost (up to 8% during periods of high ambient temperatures when energy demand and prices peak [**<empty citation>**]).

[2]: Thonig et al. (2023), *CSP.Guru 2023-07-01*

<empty citation>

# 4 Cooling overview



CSP plants are, in general, located in arid areas, where sun irradiance is high but water is scarce. The efficiency of these plants is highly dependent on the temperature at which the steam is condensed. To date, the conventional systems used to remove excess heat from CSP plants are either wet (water-cooled) or dry (air-cooled). The lowest attainable condensing temperature is achieved in wet cooling systems that depend on the wet-bulb temperature, allowing CSP plants to achieve higher efficiencies. However, this efficiency increase is at the expense of a high cost: excessive water use. Dry cooling systems eliminate the water use but they lead to lower plant efficiencies when the ambient air temperature is high. Those hot periods are often the periods of peak system demand and higher electricity sale price. The combination of the advantages of each of them into an innovative cooling system is thus of great interest. There are different types of innovative cooling systems: those that integrate the dry and wet cooling systems into the same cooling device, which are called hybrid cooling systems [3–5] and those that combine separate dry and wet cooling systems, which are called combined cooling systems. In the case of hybrid cooling systems, the dry section are composed of compact heat exchangers included in a wet cooling tower [3]. This kind of cooling systems can be considered as an efficient cooling solution for CSP plants [6] due to the energy conservation and water and greenhouse gas emissions savings. In the case of combined cooling systems, different configurations can be found. The most commonly proposed in the literature is the one that considers an Air-Cooled Condenser (ACC) in parallel with a Wet Cooling Tower (WCT), as can be seen in [7, 8]. In this kind of configuration, the exhaust steam from the turbine is condensed either through the ACC or through a Surface Condenser (SC) coupled with the WCT. Another configuration, recently proposed in [9] is a wet cooling tower and a Dry Cooler (DC) (type Air-Cooled Heat Exchanger (ACHE)) sharing a surface condenser. In this case, the exhaust steam from the turbine is condensed through the surface condenser and the heated cooling water is cooled either through the WCT or through the dry cooler. This kind of combined cooling systems are proposed as the most suitable option for a flexible operation as a function of the ambient conditions, since they allow to select the best operation strategies to achieve an optimum water and electricity consumption compromise [10]. In addition, if the optimization is combined with energy demand forecasting as described in [11], the expected results can be even better.

[3]: Rezaei et al. (2010), "Reducing Water Consumption of an Industrial Plant Cooling Unit Using Hybrid Cooling Tower"

[4]: Asvapoositkul et al. (2014), "Comparative Evaluation of Hybrid (Dry/Wet) Cooling Tower Performance"

[5]: Hu et al. (2018), "Thermodynamic Characteristics of Thermal Power Plant with Hybrid (Dry/Wet) Cooling System"

[6]: El Marazgioui et al. (2022), "Impact of Cooling Tower Technology on Performance and Cost-Effectiveness of CSP Plants"

[7]: Barigozzi et al. (2011), "Wet and Dry Cooling Systems Optimization Applied to a Modern Waste-to-Energy Cogeneration Heat and Power Plant"

[8]: Barigozzi et al. (2014), "Performance Prediction and Optimization of a Waste-to-Energy Cogeneration Plant with Combined Wet and Dry Cooling System"

[9]: Palenzuela et al. (2022), "Experimental Assessment of a Pilot Scale Hybrid Cooling System for Water Consumption Reduction in CSP Plants"

[10]: Asfand et al. (2020), "Thermodynamic Performance and Water Consumption of Hybrid Cooling System Configurations for Concentrated Solar Power Plants"

[11]: Wazirali et al. (2023), "State-of-the-Art Review on Energy and Load Forecasting in Microgrids Using Artificial Neural Networks, Machine Learning, and Deep Learning Techniques"

## 4.1 (Pendiente mover) Combined cooling pilot plant description

The combined cooling pilot plant at the Plataforma Solar de Almería (shown in Figure Figure 4.1) consists of three circuits: cooling circuit, exchange circuit and heating circuit. In the cooling circuit, water circulating inside the tube bundle of a surface condenser is cooled through a WCT and/or a DC of the ACHE type. Valves 1 and 2 ($R_p$, $R_s$, respectively) allow operation in different configurations: DC only, WCT only, in series, in parallel with different opening percentages, or parallel-series. In the exchange circuit, a saturated steam generator generates steam at different pressures, which is in turn condensed through the Surface Condenser, transferring its latent heat to the cooling water that is thus heated. Finally, in the heating circuit, a static solar field provides the thermal energy required by the steam generator using hot water as heat transfer fluid. A more detailed description of this installation can be found in Palenzuela et al. [9].

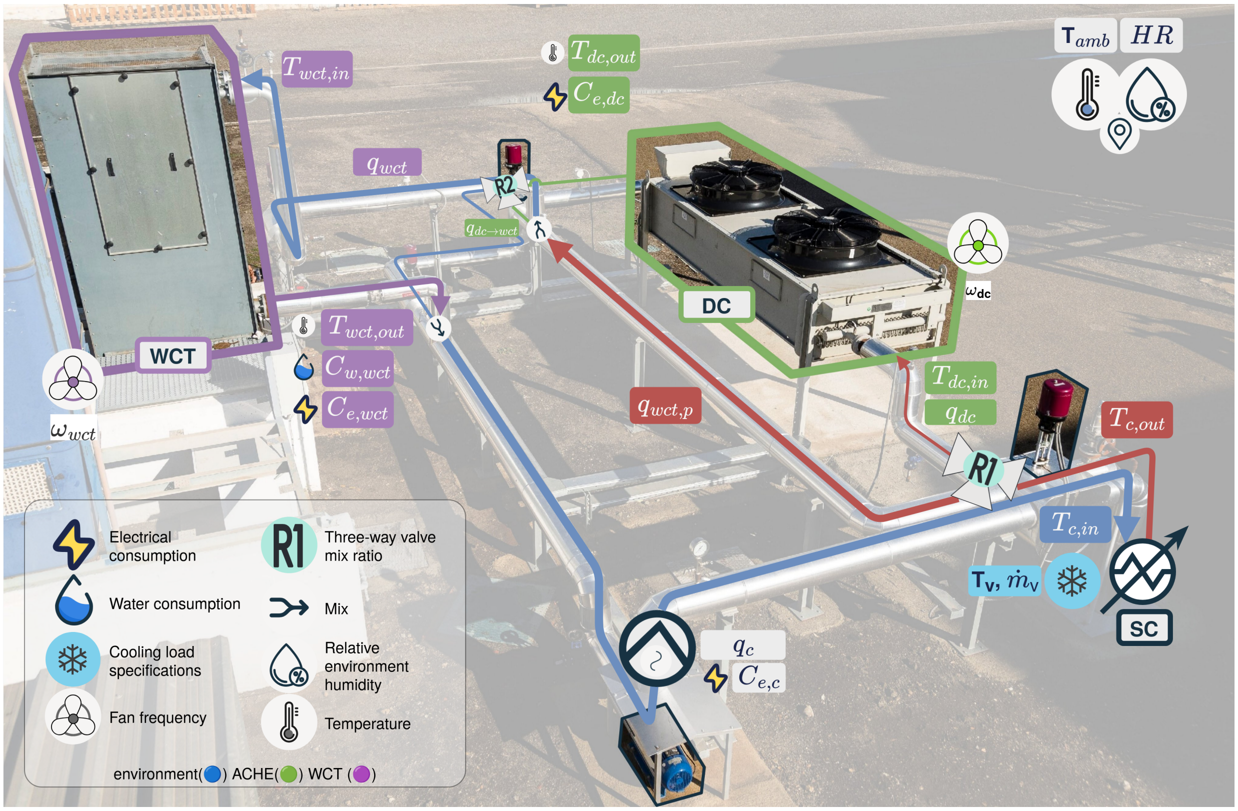



**Figure 4.1:** PSA combined cooling system facility

**Figure 4.2:** Back view of the WCT.

The pilot plant of combined cooling systems located at PSA (see the layout in Figure 4.3) consists of three circuits: cooling, exchange and heating. In the cooling circuit (see a picture in Figure 4.2), water circulating inside the tube bundle of a Surface Condenser (SC) can be cooled through a Wet Cooling Tower and/or a Dry Cooling Tower (type Air Cooled Heat Exchanger, ACHE), both with a designed thermal power of 204 kW$_{th}$. In the exchange circuit, a saturated steam generator of 80 kW$_{th}$ (on the design point), generates steam at different pressures (in the range between 82 mbar and 200 mbar), which is in turn condensed in the surface condenser. In this way, the steam transfers its latent heat of condensation to the refrigeration water, that is heated. Finally, in the heating circuit, a solar field with a thermal power of 300 kW$_{th}$ at the design point, provides the energy required by the steam generator, in the form of hot water. It is a unique, very flexible, fully instrumented and versatile facility, able to operate in different operation modes: series and parallel mode, conventional dry-only mode (all water flow is cooled through the dry cooling tower) and wet-only mode (all water flow is cooled through the wet cooling tower). The instrumentation related to the WCT is described in Table Table 4.1. Note that the sensors measuring the air velocity and temperature and relative humidity at the outlet area of the wet cooling tower have not been installed in the plant. Portable sensors were used instead in some experiments, as described in Section ??.

In regards to operational aspects of the system, note that the cooling water and air flow rates at the experimental facility ($\dot{m}_w$, and air, $\dot{m}_a$, respectively), are modified with the *Pump 1* and the fan frequency percentage `SC-001`, respectively (see Figure 4.3).

| Measured variable | Instrument | Range | Measurement uncertainty |
|---|---|---|---|
| Water temperature (TT-001, TT-006) | Pt100 | 0 - 100 °C | 0.03 + 0.005·$T^a$ |
| Cooling water flow rate (FT-001) | Vortex flow meter | 9.8 - 25 $m^3$/h | ± 0.65 % o.r.[b] |
| Water flow rate (FT-004) | Paddle wheel flow meter | 0.05 - 2 $m^3$/h | ± 0.5 % of F.S[c] + 2.5 % o.r |
| Ambient temperature | Pt1000 | -40 - 60 °C | ± 0.4 @20 °C |
| Relative humidity | Capacitive sensor | 0 - 98% | ± 3 % o.r @20 °C |
| Air velocity | Impeller anemometer | 0.1-15 m $s^{-1}$ | ± 0.1 m $s^{-1}$ + 1.5 % o.r |
| Outlet air temperature | Pt100 | -20-70°C | ±0.5°C |
| Outlet air humidity | Capacitive sensor | 0-100% | ± 2% |

**Table 4.1:** Characteristics of instrumentation ([a] value of the temperature in °C, [b] of reading, [c] full scale, [d] mean value).

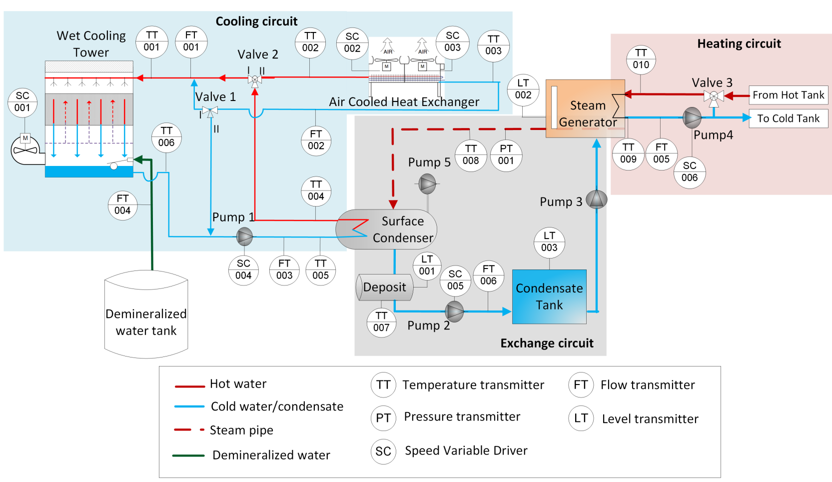



**Figure 4.3:** Layout of combined cooling systems pilot plant at PSA.

# 5 Modelling overview



## 5.1 Performance metrics

To evaluate the quality of the models fit to the experimental data, four performance metrics were evaluated: coefficient of determination ($R^2$), Root Mean Squared Error (RMSE), Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE). These metrics are described below.

**Coefficient of determination**. $R^2$ measures the proportion of the variance in the predicted variable that can be attributed to the independent variable(s), in this case the considered system inputs. Values close to one indicate a better prediction accuracy. It is calculated as follows:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2},$$

where $y_i$ is the measured or observed value for the output variable, in the $i-th$ observation, $\hat{y}_i$ is the estimated value of the same variable and $n$ is the total number of observations. Finally, $\bar{y}$ is the mean value of the experimental values.

**Root Mean Square Error**. RMSE is a statistical measure of the difference between the values predicted by a model and the observed values. It is calculated as the square root of the mean of the squared differences between the predicted and observed values and it has its units.

$$\text{RMean Squared Error (MSE)} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}$$

**Mean Absolute Error**. It represents the average absolute difference between predicted and actual values.

$$\text{MAE} = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i|$$

**Mean Absolute Percentage Error**. As the MAE, it calculates the difference between the predicted and the actual values, but in this case it does so in relative terms:

$$\text{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{y_i - \hat{y}_i}{y_i}\right| \times 100\%$$

## 5.2 First principle modelling

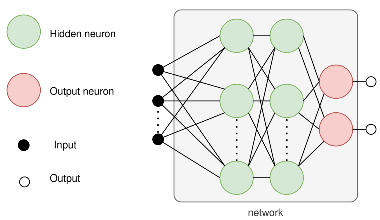
## 5.3 Data-driven modelling

Machine learning algorithms are unique in their ability to obtain models and extract patterns from data, without being explicitly programmed to do so. They are more effective with large volumes of data but can also be applied to build steady state regression models with less information of a process.

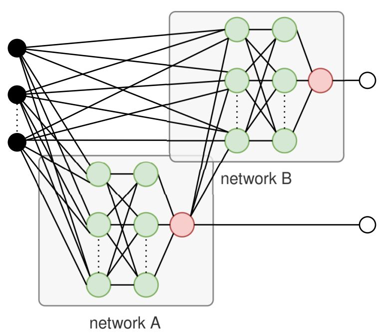
### 5.3.1 Gaussian Process Regression

### 5.3.2 Artificial Neural networks

Artificial Neural Networks (ANNs), as the name suggests, have a behavior similar to biological neurons. Their structure is formed by a succession of layers, each one composed by nodes (or neurons) and they receive as input the output of the previous layer. This process is subsequently repeated until the final layer which has a number of neurons equal to the number of outputs.




(a) MIMO configuration




(b) Cascade configuration

**Figure 5.1:** ANN model configurations

There are important aspects to be considered in the ANN model design, such as the model configuration, the network architecture and the network topology. They are discussed below.

**Model configuration**. If the model has more than one output, several configurations are available for the implementation of the model as shown in Figure 5.1. The first one is a Multiple Inputs Multiple Outputs (MIMO) configuration, where a single network receives all the inputs and directly produces all predicted outputs. The second one is a cascade structure. This cascading approach involves training a network (*network A* in Figure 5.1 (b)) to predict one output using the available inputs. Subsequently, these inputs, along with the output from the first-output-predicting network, are fed into a second network (*network B* in Figure 5.1 (b)) that is in charge of forecasting the second output. This procedure can be repeated as many times as desired. A potential advantage of this configuration is that it may reduce the experimental data requirements to obtain satisfactory results. A third option is the combination of both configurations, where some networks may predict several outputs, while others are fed some of these outputs as subsequently use them as inputs.

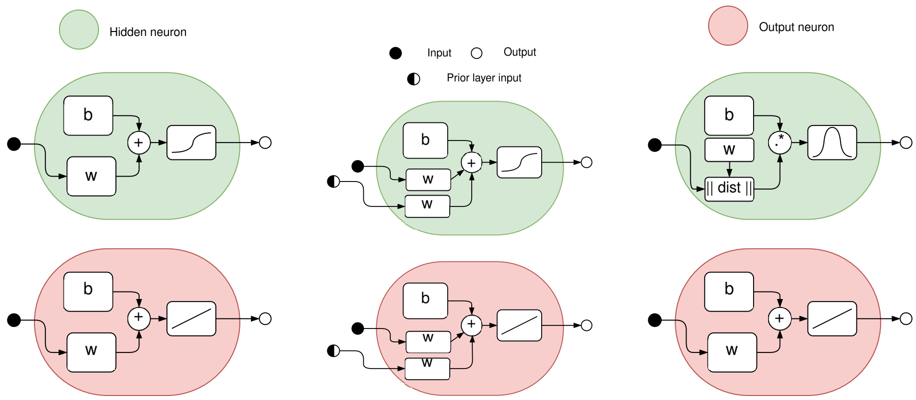
**Network architectures**. Three network architectures have been implemented and tested:

1. Feed Forward (FF) network - Figure 5.2 (a). This is the base network architecture, where different layers are added sequentially and the flow of information is unidirectional. The transfer function adopted in the hidden layers is the differentiable *Log-Sigmoid*[1], whereas the one employed in the output layer is a linear one with no saturations.
2. Cascade-forward (CF) network - Figure 5.2 (b). It is a variation on the feedforward network since it adds direct connections from the input and hidden layers to the output layer.
3. Radial Basis Function (RBF) network - Figure 5.2 (c). The transfer functions used in the first layer of the RBF network are different, they are local Gaussian like functions. Also, instead of multiplying by the weights, the distance between inputs and weights is computed and the bias is multiplied instead of added [12].

1: Defined as $logsig(x) = 1/(1+e^{-x})$, mapping any real input to a value between 0 and 1.

[12]: Hagan et al. (2014), *Neural Network Design*

**Network topology**. Two-layer networks (one hidden and one output layer) can learn almost any input-output relationship, including non-linear ones. Adding more layers can improve the learning for more complex problems. However, increasing the number of layers or neurons per layer increases the training computational requirements, requires more data for a satisfactory model and can lead to overfitting. Therefore, the process is usually started with two layers and then the number of layers is increased if they do not perform satisfactorily [12]. In this study, for the feedforward and cascade-forward architectures, one and two hidden layers have been tested with the following configurations: 5, 10, 20, 5-5, 5-10, 10-5, 10-10. For the case of the RBF, it only has one hidden layer and




**(a)** Feedforward **(b)** Cascade-forward **(c)** Radial-basis

**Figure 5.2:** Considered ANN architectures

neurons are added sequentially during the training process up to a maximum which is set to 120 neurons.

**Training process**. The next important aspect to consider is the training process. For the FF and CF networks many Gradient- or Jacobian-based algorithms can be utilized. In this case, the Levenberg-Marquardt backpropagation algorithm [13] has been used. It is a fast algorithm, ideal for multilayer networks with up to a few hundred weights and biases enabling efficient training. The training in this case is done in batches since sequential training is slower and does not produce better results. All data have been normalized applying the z-score normalization method. The criteria established for deciding when to stop the training is the following one: when the performance on the validation set increases (worsens) or when the gradient is below a minimum ($1 \times 10^{-7}$) for a number of iterations or epochs, or when a maximum number of 1000 epochs is reached. The number of iterations to wait, often refereed as patience, is set to 6. Finally, the selected network parameters will be those of the best epoch.

[13]: Beale et al. (2010), "Neural Network Toolbox"

For each network architecture, the training process was repeated a total of ten times (this is the recommended practice if the computational requirements allow it, since it guarantees reaching a global optimum with a high degree of confidence [14]). The optimal architecture and training was selected according to a performance function, which in this case has been the MSE with the values normalized.

[14]: Hamm et al. (2007), "Comparison of Stochastic Global Optimization Methods to Estimate Neural Network Weights"

In the case of the RBF network, the chosen training method consists in two stages which treats the two layers of the RBF network separately. The first layer weights and biases are tuned based on the orthogonal least squares method [12], while for the second layer are computed in one step using a linear least-squares algorithm. During training, neurons are added to the first layer (in increments of 20) trying to minimize the MSE to some goal, which in this case is set depending on the case study: 10 for the MIMO configuration and 0 ($°C^2$) and 20 ($l^2/h^2$) for temperature and water lost networks, respectively, for the cascade configuration. Finally, a parameter called spread is used to set the first layer biases. Larger values of this parameter promote a smoother approximation of the training data (more generalization), conversely, lower values provide a more exact fit to the training data. Values from 0.1 to 30 have been tested for this parameter.

[12]: Hagan et al. (2014), *Neural Network Design*

#### 5.3.3 Random Forest

#### 5.3.4 Gradient Boosting

### 5.4 Hybrid modelling

### 5.5 Data-driven from first-principles models. Sample generation

# 6 Sensitivity analysis



It involves systematically assessing how variations in input parameters impact the model's outputs. In this case, the Sobol method [15], which is a variance-based approach, has been used. This method decomposes the total variance of the model output into contributions from individual input parameters and their interactions. By quantifying the relative importance of each parameter, Sobol analysis facilitates the identification of influential factors, enabling a more nuanced understanding of complex systems characterized by numerous interacting variables.

[15]: Nossent et al. (2011), "Sobol'sensitivity Analysis of a Complex Environmental Model"

## 6.1 Sensitivity analysis as a model analysis tool

Sobol sensitivity analysis provides a quantitative basis for assessing the consistency and validity of results when different approaches to model a system are compared. ANNs models with similar sensitivity analysis outcomes to those of the physical model, are likely to capture the essential features of the system, offering a means to verify their credibility and ensuring that the proposed solutions align with the underlying physical principles. Therefore, Sobol sensitivity analysis emerges as a powerful tool not only for understanding the system input-outputs relationships, but also as a way to validate and compare various modelling approaches. The sensitivity analysis has been performed using *SAlib*, an open source sensitivity analysis tool for the *Python* programming language [16, 17].

[16]: Herman et al. (2017), "SALib: An Open-Source Python Library for Sensitivity Analysis"

[17]: Iwanaga et al. (2022), "Toward SALib 2.0: Advancing the Accessibility and Interpretability of Global Sensitivity Analyses"

## 6.2 Sensitivity analysis as a measurement influence quantification tool

Sensitivity analysis can also be used to quantify the influence of measurement...

# 7 Control overview



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## 7.1 PID controllers

## 7.2 Hierarchical control

# 8 Optimization overview



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## 8.1 NLP problems

Non-Linear Programming (NLP)

## 8.2 MINLP problems

Mixed Integer Non-Linear Programming (MINLP)

## 8.3 Multi-objective optimization

## 8.4 Optimization algorithms

# 9 Research plan



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## 9.1 Hypothesis

## 9.2 Objectives

# 10 Contributions

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# Optimal water and electricity management in a combined cooling system

Introduction

TL;DR

Derived scientific contributions

# Modelling of a combined cooling system 11



Decripción del modelo completo, cómo se integran los componentes, y después se describe cada component.

In order to study the potential advantages of making use of a combined cooling system, it is first necessary to develop the modelling of its components. Since the objective is performance prediction, this chapter focuses on the steady state modelling of the combined cooler main components, *i.e.* the WCT and the DC. More specifically, the aim is to compare two modelling strategies: that based on physical equations (Section 5.2) and that based on black box models (Section 5.3) such as ANNs, in order to see which one is more suitable for its integration in the optimization of the complete process.

This chapter presents a comparison between the two modelling approaches, at steady state and with a focus on optimization applications, in terms of predictive capabilities, experimental and instrumentation requirements, execution time, implementation and scalability. A sensitivity analysis is performed to further analyze and compare each case study. It also presents and evaluates all relevant aspects of interest in the development of such models, specifically for ANNs, model configuration, architecture and topology are discussed.

Other system components are also described in Section 11.3 (Other components) and finally their integration is discussed in Section 11.4 (Complete system).

## 11.1 Wet cooler

In the case of the models based on physical equations, the analysis of wet cooling towers has its origin in [18], in which the theory for their performance evaluation was developed. Merkel proposed a model based on several assumptions to simplify the heat and mass transfer equations to a simple hand calculation. However, these assumptions mean that Merkel's method does not reliably represent the physics of the heat and mass transfer process in a cooling tower. This was already stated by Bourillot [19] who concluded that the Merkel method is simple to use and can correctly predict cold water temperature when an appropriate value of the coefficient of evaporation is used. However, it is insufficient for the estimation of the characteristics of the warm air leaving the fill and for the calculation of changes in the water flow rate due to evaporation. Jaber and Webb [20] developed the equations necessary to apply the effectiveness-NTU[1] method directly to counterflow or crossflow cooling towers. This approach is particularly useful in the latter case and simpler compared to a more conventional numerical procedure. Notice that the effectiveness-NTU method is based on the same simplifying assumptions as the Merkel method. On the other hand, Poppe and Rögener [21] developed the Poppe method. They derived the governing equations for heat and mass transfer in a wet cooling tower and did not make any simplifying assumptions as in the Merkel theory, which makes it a very precise model. As a matter of fact, predictions from the Poppe formulation have resulted in values of evaporated water flow rate that are in good agreement with full scale cooling tower test results [22]. This model has already been used for the evaluation of the thermal performance of solar power plants using different condensation systems (wet, dry and hybrid system), as can be found in Cutillas et al. [23].

In the case of black box models, numerous authors in the literature have designed ANN models for WCT with different objectives, such as performance

[18]: Merkel (1925), "Verdunstungskühlung"

[19]: Bourillot (1983), "Hypotheses of Calculation of the Water Flow Rate Evaporated in a Wet Cooling Tower"

[20]: Jaber et al. (1989), "Design of Cooling Towers by the Effectiveness-NTU Method"

1: The effectiveness-NTU method estimates how well a heat exchanger transfers heat by comparing the actual heat transfer to the maximum possible, using a parameter, Number of Transfer Units (NTU), that reflects its size and flow characteristics.

[21]: Poppe et al. (1991), "Berechnung von Rückkühlwerken"

[22]: Kloppers et al. (2005), "A Critical Investigation into the Heat and Mass Transfer Analysis of Counterflow Wet-Cooling Towers"

[23]: Cutillas et al. (2021), "Energetic, Exergetic and Environmental (3E) Analyses of Different Cooling Technologies (Wet, Dry and Hybrid) in a CSP Thermal Power Plant"

prediction, simulation and optimization. One of the first works in this area is the one described in [24] where an ANN model was developed to predict the performance of a forced-counter flow cooling tower at lab scale. In this case, the input variables were the dry bulb temperature, the relative humidity of the air stream entering the tower, the temperature of the water entering the tower, the air volume flow rate and the cooling water mass flow rate. The outputs of this model were the heat rejection rate at the tower, the mass flow rate of water evaporated, the temperature of the cooling water at the tower outlet, the dry bulb temperature and the relative humidity of the air at the outlet of the tower. The results obtained with a 5-5-5[2] ANN demonstrated that wet cooling towers at lab-scale can be modelled using ANNs with a high degree of accuracy. There are also ANN models for Natural Draft Counter-flow Wet Cooling Towers (NDWCT) at lab-scale, such as the one proposed by [25]. In this case, the authors used a 4-8-6 ANN structure and considered some additional variables, such as air gravity, wind velocity, heat transfer coefficients and efficiency as outputs. All these works can be useful to validate the model development methodology but may fail predicting the performance of WCT at larger scale. In this sense, special attention deserves the study carried out by [26] where an 8-14-2 ANN model was proposed to predict the performance (the cooling number and the evaporative loss proportion) of NDWCTs at commercial scale. The model is based on 638 sets of field experimental data collected from 36 diverse NDWCTs used in power plants. It is a very challenging work since it covers samples from a wide range of tower sizes and capacities being the Mean Relative Error (MRE) below 5 %.

[24]: Hosoz et al. (2007), "Performance Prediction of a Cooling Tower Using Artificial Neural Network"

2: The notation $n_1$-...-$n_l$ represents the architecture of the ANN model, where $l$ is the number of layers and $n_i$ are the nodes in each one of the layers.

[25]: Gao et al. (2013), "Artificial Neural Network Model Research on Effects of Cross-Wind to Performance Parameters of Wet Cooling Tower Based on Level Froude Number"

[26]: Song et al. (2021), "A Novel Approach for Energy Efficiency Prediction of Various Natural Draft Wet Cooling Towers Using ANN"

From the literature review, it can be stated that there are works based on Poppe and ANN models that evaluate the main output variables of WCTs. Nevertheless, to the author knowledge, there are no studies focused on the comparison between both modelling strategies. Also lacking is a comprehensive analysis of the different aspects that affect the models development and performance.

The static models presented in this section have been developed to predict two main outputs, the water temperature at the outlet of the WCT, $T_{w,o}$, and the water consumed due to evaporation losses, $\dot{m}_{w,lost}$. The inputs variables required by both modelling approaches, Poppe model and ANN models, are: the cooling water flow rate ($\dot{m}_w$), the water temperature at the inlet of the WCT ($T_{w,i}$), the ambient temperature ($T_\infty$), the ambient relative humidity ($\phi_\infty$) and the frequency percentage of the fan ($f_{fan}$) (or its equivalence in air mass flow rate[3], $\dot{m}_a$).

3: ANN uses as input $f_{fan}$ whereas Poppe's model uses $\dot{m}_a$.

### 11.1.1 Poppe model

The well-known Merkel number is accepted as the performance coefficient of a wet cooling tower [27]. This dimensionless number is defined in Equation 11.1, and it measures the degree of difficulty of the mass transfer processes occurring in the exchange area of a wet cooling tower.

[27]: Navarro et al. (2022), "Critical Evaluation of the Thermal Performance Analysis of a New Cooling Tower Prototype"

$$Me = \frac{h_D a_v V}{\dot{m}_w}, \tag{11.1}$$

where $h_D$ is the mass transfer coefficient, $a_V$ is the surface area of exchange per unit of volume and $V$ is the volume of the transfer region.

The Merkel number can be calculated using the Merkel and Poppe theories for the performance evaluation of cooling towers. On the one hand, the Merkel theory [18] relies on several critical assumptions, such as the Lewis factor (Le) being equal to 1, the air exiting the tower being saturated with water vapour and it neglects the reduction of water flow rate by evaporation in the energy balance. On the other hand, the Poppe theory [21], which is the one used in this work, do not consider simplifying assumptions, thus being the one most usually preferred. In this theory, the authors derived the governing equations for heat and mass

[18]: Merkel (1925), "Verdunstungskühlung"

[21]: Poppe et al. (1991), "Berechnung von Rückkühlwerken"

transfer in the transfer region of the wet cooling tower (control volume shown in Figure 11.1) assuming a one dimensional problem. In this figure, the red and green dashed lines indicate the fill and air-side control volumes, respectively.

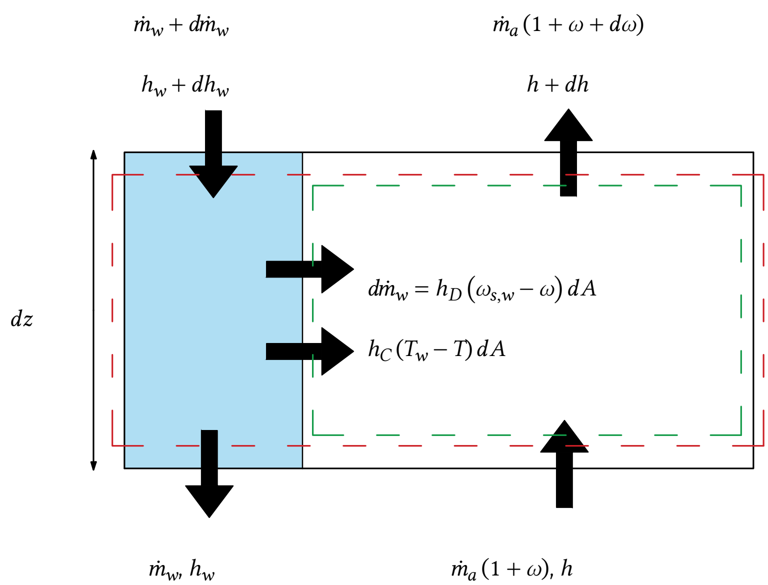


**Figure 11.1:** Control volume in the exchange area of a wet cooling tower arrangement.

Following the detailed derivation process and simplification of the previously-mentioned governing equations described in [27], the major following equations for the heat and mass transfer obtained, according to the Poppe theory, are:

$$\frac{d\omega}{dT_w} = \frac{c_{p_w}\frac{\dot{m}_w}{\dot{m}_a}\left(\omega_{s,w}-\omega\right)}{\left(h_{s,w}-h\right)+(\mathrm{Le}-1)\left[\left(h_{s,w}-h\right)-\left(\omega_{s,w}-\omega\right)h_v\right]-\left(\omega_{s,w}-\omega\right)h_w} \tag{11.2}$$

$$\frac{dh}{dT_w} = c_{p_w}\frac{\dot{m}_w}{\dot{m}_a}\left[1+\frac{\left(\omega_{s,w}-\omega\right)c_{p_w}T_w}{\left(h_{s,w}-h\right)+(\mathrm{Le}-1)\left[\left(h_{s,w}-h\right)-\left(\omega_{s,w}-\omega\right)h_v\right]-\left(\omega_{s,w}-\omega\right)h_w}\right] \tag{11.3}$$

$$\frac{d\mathrm{Me}}{dT_w} = \frac{c_{p_w}}{\left(h_{s,w}-h\right)+(\mathrm{Le}-1)\left[\left(h_{s,w}-h\right)-\left(\omega_{s,w}-\omega\right)h_v\right]-\left(\omega_{s,w}-\omega\right)h_w}, \tag{11.4}$$

where the quantity referred to as $\mathrm{Me}$ in Eq. 11.4, is the Merkel number calculated according to the Poppe theory. The above described governing equations can be solved by the fourth order Runge-Kutta method to provide the evolution of the air humidity ratio, air enthalpy and Merkel number inside the transfer area of the cooling tower (fill). Once these profiles are known, the amount of water lost due evaporation can be calculated as per Eq. Equation 11.6. Refer to [27] for additional information concerning the calculation procedure.

[27]: Navarro et al. (2022), "Critical Evaluation of the Thermal Performance Analysis of a New Cooling Tower Prototype"

$$Me = \frac{h_D a_v V}{\dot{m}_w}, \tag{11.5}$$

$$\dot{m}_{w,lost} = \dot{m}_a(\omega_{a,o} - \omega_{a,i}) \tag{11.6}$$

It is important to mention that the Merkel number varies with the operation conditions and its value can be obtained using a correlation with the water-to-air mass flow ratio as an independent variable. One of the proposed correlations in ASHRAE [28] is: $\mathrm{Me} = c\,(\dot{m}_w/\dot{m}_a)^{-n}$, where the constants $c$ and $n$ can be obtained from the fitting of experimental data[4].

[28]: Ashrae (2004), "HVAC Systems and Equipment"

4: See Section ?? (??)

#### 11.1.2 Samples generation for FP to data-driven model

### 11.2 Dry cooler

#### 11.2.1 Samples generation for FP to data-driven model

### 11.3 Other components

### 11.4 Complete system

# 12 Optimization of a combined cooling system



## 12.1 Static optimization

## 12.2 Shrinking horizon optimization

# Validation 13



## 13.1 Modelling

### 13.1.1 Wet cooler

With the aim of comparing two modelling strategies established to predict the outlet water temperature and the water consumption of WCT (physical equation-based and ANN-based models), three different experimental campaigns have been carried out at the pilot plant of combined cooling systems located at PSA (see a detailed description in Section **??**): the first one for the calibration of the physical equation-based model, the second one for tuning the ANN-based model and the last one for the validation and comparison of the two modelling strategies. These strategies and the experimental campaigns are exhaustively detailed in Sections **??** and **??**, respectively.

Fig. Figure 13.1 schematically shows the procedure followed for the calibration, tuning and validation of the two modelling strategies established as well as for the comparison between them.

As previously mentioned, three experimental campaigns have been performed, shown in Fig. Figure 13.1 as *Exp 1*, *Exp 2*, and *Exp 3*. *Exp 1* corresponds to the Poppe model calibration campaign and it was designed for the calibration of the first principles model. The aims of such campaign was to fit a function (mapping) that relates the air mass flow rate at the outlet of the tower, $\dot{m}_a$, with the frequency of the fan, $f_{fan}$, and to calibrate a WCT performance coefficient: the Merkel number, $\mathrm{Me}$. Exp 2, which corresponds to the ANN tuning experimental campaign, is a set of data obtained over several years of operation in a wide range of operating and ambient conditions that has been used for tuning the ANN model. Finally, in the validation and comparison experimental campaign (Exp 3), new data, not included in the other two campaigns, has been collected by applying a design of experiments in order to validate and compare the proposed modelling strategies.

1. FP model
2. DB from experimental campaign

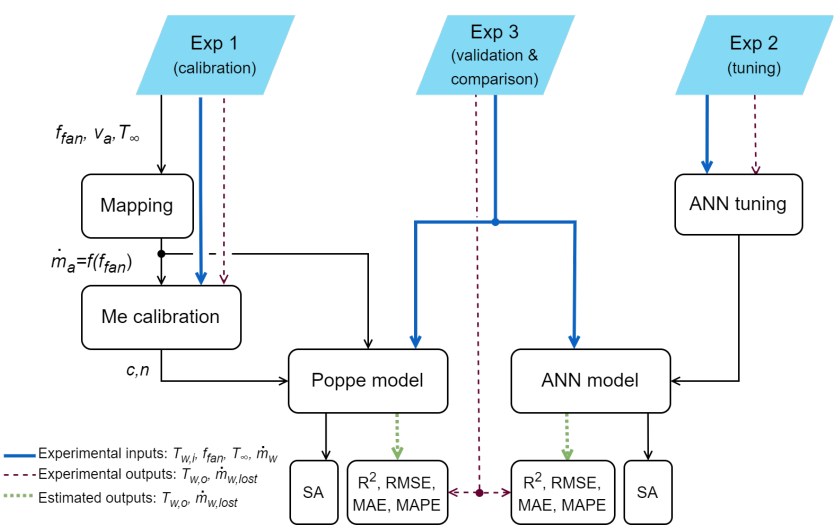


**Figure 13.1:** Calibration, tuning, validation and comparison procedure

3. DB from FP
4. Comparison

Tabla tocha añadiendo casos (GPR, DB from FP)

On the other hand, the robustness and reliability of the models have been evaluated by a sensitivity analysis.

### 13.1.2 Dry cooler

1. FP model
2. DB from experimental campaign
3. DB from FP
4. Comparison

Tabla tocha añadiendo casos (GPR, DB from FP)

### 13.1.3 Complete system

1. solo DB from FP

## 13.2 Control and optimization results

### 13.2.1 Regular operation

### 13.2.2 Planned changes in operation

### 13.2.3 Unanticipated operational changes

# 14 Annual analysis: CSP and inland-MED



## 14.1 ANDASOL-II CSP plant

### 14.1.1 WCT static

### 14.1.2 DC static

### 14.1.3 CC static

### 14.1.4 CC horizon

# Conclusions and outlook

## Conclusions

## Outlook

### MED

1. Configuraciones alternativas para procesos MED para aplicaciones de concentración de salmueras: geometría variable de efectos fuentes externas en efectos distintos al primero
2. Configuraciones alternativas para el proceso solar MED (almacenamiento con distintos puntos de carga y descarga, MED con distintos puntos de fuente externa, etc. Incluir diagrama de draw.io con las distintas configuraciones)
3. Configuraciones híbridas MED-MSF para aplicaciones de concentración de salmueras

## Derived scientific contributions

1. Publicaciones en revista
2. Contribuciones a congreso
3. Coloquios doctorales
4. Colaboraciones en proyectos de investigación
5. Estancias de investigación
6. Repositorios de código
7. Repositorios de datos
8. Herramientas interactivas
9. Contribuciones a librerías de código abierto?

# Template content

# 15 Introduction



## 15.1 The Main Ideas

Many modern printed textbooks have adopted a layout with prominent margins where small figures, tables, remarks and just about everything else can be displayed. Arguably, this layout helps to organise the discussion by separating the main text from the ancillary material, which at the same time is very close to the point in the text where it is referenced.

This document does not aim to be an apology of wide margins, for there are many better suited authors for this task; the purpose of all these words is just to fill the space so that the reader can see how a book written with the kaobook class looks like. Meanwhile, I shall also try to illustrate the features of the class.

The main ideas behind kaobook come from this blog post, and actually the name of the class is dedicated to the author of the post, Ken Arroyo Ohori, which has kindly allowed me to create a class based on his thesis. Therefore, if you want to know more reasons to prefer a 1.5-column layout for your books, be sure to read his blog post.

Another source of inspiration, as you may have noticed, is the Tufte-Latex Class. The fact that the design is similar is due to the fact that it is very difficult to improve something which is already so good. However, I like to think that this class is more flexible than Tufte-Latex. For instance, I have tried to use only standard packages and to implement as little as possible from scratch;[1] therefore, it should be pretty easy to customise anything, provided that you read the documentation of the package that provides that feature.

1: This also means that understanding and contributing to the class development is made easier. Indeed, many things still need to be improved, so if you are interested, check out the repository on github!

In this book I shall illustrate the main features of the class and provide information about how to use and change things. Let us get started.

## 15.2 What This Class Does

The kaobook class focuses more about the document structure than about the style. Indeed, it is a well-known LaTeX principle that structure and style should be separated as much as possible (see also Section Section 15.3 on the following page). This means that this class will only provide commands, environments and in general, the opportunity to do things, which the user may or may not use. Actually, some stylistic matters are embedded in the class, but the user is able to customise them with ease.

The main features are the following:

**Page Layout** The text width is reduced to improve readability and make space for the margins, where any sort of elements can be displayed.

**Chapter Headings** As opposed to Tufte-Latex, we provide a variety of chapter headings among which to choose; examples will be seen in later chapters.

**Page Headers** They span the whole page, margins included, and, in twoside mode, display alternatively the chapter and the section name.[2]

2: This is another departure from Tufte's design.

**Matters** The commands `\frontmatter`, `\mainmatter` and `\backmatter` have been redefined in order to have automatically wide margins in the main matter, and narrow margins in the front and back matters. However, the page style can be changed at any moment, even in the middle of the document.

**Margin text** We provide commands `\sidenote` and `\marginnote` to put text in the margins.[3]

**Margin figs/tabs** A couple of useful environments is `marginfigure` and `margintable`, which, not surprisingly, allow you to put figures and tables in the margins (*cfr.* Figure 15.1).

**Figure 15.1:** The Mona Lisa. https://commons.wikimedia.org/wiki/File:Mona_Lisa,_by_Leonardo_da_Vinci,_from_C2RMF_retouched.jpg

**Margin toc** Finally, since we have wide margins, why don't add a little table of contents in them? See `\margintoc` for that.

**Hyperref** `hyperref` is loaded and by default we try to add bookmarks in a sensible way; in particular, the bookmarks levels are automatically reset at `\appendix` and `\backmatter`. Moreover, we also provide a small package to ease the hyperreferencing of other parts of the text.

**Bibliography** We want the reader to be able to know what has been cited without having to go to the end of the document every time, so citations go in the margins as well as at the end, as in Tufte-Latex. Unlike that class, however, you are free to customise the citations as you wish.

The order of the title pages, table of contents and preface can be easily changed, as in any LaTeX document. In addition, the class is based on KOMA-Script's `scrbook`, therefore it inherits all the goodies of that.

## 15.3 What This Class Does Not Do

As anticipated, further customisation of the book is left to the user. Indeed, every book may have sidenotes, margin figures and so on, but each book will have its own fonts, toc style, special environments and so on. For this reason, in addition to the class, we provide only sensible defaults, but if these features are not needed, they can be left out. These special packages are located in the `style` directory, which is organised as follows:

**kao.sty** This package contains the most important definitions of macros and specifications of page layout. It is the heart of the `kaobook`. Special features include: most commonly used LaTeX packages are already loaded; there is some flexibility to change the default layout; some fancy environments (with coloured boxes around them, floating, and/or with a counter) are predefined.

**kaobiblio.sty** Where commands to print citations in the margins are defined.[4] It is the `kao-` analog of `biblatex`.

4: See Chapter 19.

**kaorefs.sty** It contains some useful commands to manage labeling and referencing, again to ensure that the same elements are referenced always in a consistent way.

**kaotheorems.sty** For the style of mathematical environments, which can be optionally wrapped in a colourful `mdframed` environment, like in this document, or not.

The audacious users might feel tempted to edit some of these packages. I'd be immensely happy if they sent me examples of what they have been able to do!

In the rest of the book, I shall assume that the reader is not a novice in the use of LaTeX, and refer to the documentation of the packages used in this class for things that are already explained there. Moreover, I assume that the reader is willing to make minor edits to the provided packages for styles, environments and commands, if he or she does not like the default settings.

## 15.4 How to Use This Class

Either if you are using the template from latextemplates, or if you cloned the GitHub repository, there are infinite ways to use the `kaobook` class in practice, but we will discuss only two of them. The first is to find the `main.tex` file which I used to write this book, and edit it; this will probably involve a lot of text-deleting, copying-and-pasting, and rewriting. The second way is to start almost from scratch and use the `./examples/minimal_book/main.tex` file, which is a cleaned-up version of the `./examples/documentation/main.tex`; even if you choose the second way, you may find it useful to draw inspiration from the `./examples/documentation/main.tex` file.

To compile the document, assuming that its name is `main.tex`, you will have to run the following sequence of commands:

```
pdflatex main # Compile template
makeindex main.nlo -s nomencl.ist -o main.nls # Compile nomenclature
makeindex main # Compile index
biber main # Compile bibliography
makeglossaries main # Compile glossary
pdflatex main # Compile template again
pdflatex main # Compile template again
```

You may need to compile the template some more times in order for some errors to disappear. For any support requests, please ask a question on `tex.stackexchange.org` with the tag “kaobook”, open an issue on GitHub, or contact the author via e-mail.

# Class Options, Commands and Environments

# Class Options 16

In this chapter I will describe the most common options used, both the ones inherited from `scrbook` and the `kao`-specific ones. Options passed to the class modifies its default behaviour; beware though that some options may lead to unexpected results...



## 16.1 **KOMA** Options

The `kaobook` class is based on `scrbook`, therefore it understands all of the options you would normally pass to that class. If you have a lot of patience, you can read the KOMA-Script guide.[1] Actually, the reading of such guide is suggested as it is very instructive.

Every KOMA-Script option you pass to the class when you load it is automatically activated. In addition, in `kaobook` some options have modified default values. For instance, the font size is 9.5pt and the paragraphs are separated by space,[2] not marked by indentation.

1: The guide can be downloaded from https://ctan.org/pkg/koma-script?lang=en.

2: To be precise, they are separated by half a line worth of space: the `parskip` value is "half".

## 16.2 **kao** Options

In the future I plan to add more options to set the paragraph formatting (justified or ragged) and the position of the margins (inner or outer in twoside mode, left or right in oneside mode).[3]

3: As of now, paragraphs are justified, formatted with `\singlespacing` (from the `setspace` package) and `\frenchspacing`.

I take this opportunity to renew the call for help: everyone is encouraged to add features or reimplement existing ones, and to send me the results. You can find the GitHub repository at https://github.com/fmarotta/kaobook.

**To Do**

Implement the `justified` and `margin` options. To be consistent with the KOMA-Script style, they should accept a simple switch as a parameter, where the simple switch should be `true` or `false`, or one of the other standard values for simple switches supported by KOMA-Script. See the KOMA-Script documentation for further information.

The above box is an example of a `kaobox`, which will be discussed more thoroughly in Chapter 21 (Mathematics and Boxes) on page 77. Throughout the book I shall use these boxes to remarks what still needs to be done.

## 16.3 Other Things Worth Knowing

A bunch of packages are already loaded in the class because they are needed for the implementation. These include:

- etoolbox
- calc
- xifthen
- xkeyval
- xparse

- xstring

Many more packages are loaded, but they will be discussed in due time. Here, we will mention only one more set of packages, needed to change the paragraph formatting (recall that in the future there will be options to change this). In particular, the packages we load are:

- ragged2e
- setspace
- hyphenat
- microtype
- needspace
- xspace
- xcolor (with options `usenames,dvipsnames`)

Some of the above packages do not concern paragraph formatting, but we nevertheless grouped them with the others. By default, the main text is justified and formatted with singlespacing and frenchspacing; the margin text is the same, except that the font is a bit smaller.

As a last warning, please be aware that the `cleveref` package is not compatible with `kaobook`. You should use the commands discussed in Section 19.3 instead.

## 16.4 Document Structure

We provide optional arguments to the `\title` and `\author` commands so that you can insert short, plain text versions of this fields, which can be used, typically in the half-title or somewhere else in the front matter, through the commands `\@plaintitle` and `\@plainauthor`, respectively. The PDF properties `pdftitle` and `pdfauthor` are automatically set by hyperref to the plain values if present, otherwise to the normal values.[4]

4: We think that this is an important point so we remark it here. If you compile the document with pdflatex, the PDF metadata will be altered so that they match the plain title and author you have specified; if you did not specify them, the metadata will be set to the normal title and author.

There are defined two page layouts, `margin` and `wide`, and two page styles, `plain` and `fancy`. The layout basically concern the width of the margins, while the style refers to headers and footer; these issues will be discussed in Chapter 20 (Page Design) on page 71.[5]

5: For now, suffice it to say that pages with the `margin` layout have wide margins, while with the `wide` layout the margins are absent. In `plain` pages the headers and footer are suppressed, while in `fancy` pages there is a header.

The commands `\frontmatter`, `\mainmatter`, and `\backmatter` have been redefined in order to automatically change page layout and style for these sections of the book. The front matter uses the `margin` layout and the `plain` page style. In the mainmatter the margins are wide and the headings are fancy. In the appendix the style and the layout do not change; however we use `\bookmarksetup{startatroot}` so that the bookmarks of the chapters are on the root level (without this, they would be under the preceding part). In the backmatter the margins shrink again and we also reset the bookmarks root.

# Margin Stuff 17

Sidenotes are a distinctive feature of all 1.5-column-layout books. Indeed, having wide margins means that some material can be displayed there. We use margins for all kind of stuff: sidenotes, marginnotes, small tables of contents, citations, and, why not?, special boxes and environments.



## 17.1 Sidenotes

Sidenotes are like footnotes, except that they go in the margin, where they are more readable. To insert a sidenote, just use the command `\sidenote{Text of the note}`. You can specify a mark[O] with `\sidenote[mark]{Text}`, but you can also specify an offset, which moves the sidenote upwards or downwards, so that the full syntax is:

O: This sidenote has a special mark, a big O!

```
\sidenote[mark][offset]{Text}
```

If you use an offset, you always have to add the brackets for the mark, but they can be empty.[1]

1: If you want to know more about the usage of the `\sidenote` command, read the documentation of the `sidenotes` package.

In `kaobook` we copied a feature from the `snotez` package: the possibility to specify a multiple of `\baselineskip` as an offset. For example, if you want to enter a sidenote with the normal mark and move it upwards one line, type:

```
\sidenote[][*-1]{Text of the sidenote.}
```

As we said, sidenotes are handled through the `sidenotes` package, which in turn relies on the `marginnote` package.

## 17.2 Marginnotes

This command is very similar to the previous one. You can create a marginnote with `\marginnote[offset]{Text}`, where the offset argument can be left out, or it can be a multiple of `\baselineskip`, *e.g.*

While the command for margin notes comes from the `marginnote` package, it has been redefined in order to change the position of the optional offset argument, which now precedes the text of the note, whereas in the original version it was at the end. We have also added the possibility to use a multiple of `\baselineskip` as offset. These things were made only to make everything more consistent, so that you have to remember less things!

```
\marginnote[-12pt]{Text} or \marginnote[*-3]{Text}
```

**To Do**

A small thing that needs to be done is to renew the `\sidenote` command so that it takes only one optional argument, the offset. The special mark argument can go somewhere else. In other words, we want the syntax of `\sidenote` to resemble that of `\marginnote`.

We load the packages `marginnote`, `marginfix` and `placeins`. Since `sidenotes` uses `marginnote`, what we said for marginnotes is also valid for sidenotes. Side- and margin- notes are shifted slightly upwards (`\renewcommand{\marginnotevadjust}{3pt}`) in order to align them to the bottom of the line of text where the note is issued. Importantly, both sidenotes and marginnotes are defined as floating if the optional argument (*i. e.* the vertical offset) is left blank, but if the offset is specified they are not floating. Recall that floats cannot be nested, so in some rare cases you may encounter errors about lost floats; in those cases, remember that sidenotes and marginnotes are floats. To solve the problem, it may be possible to transform them into non-floating elements by specifying an offset of 0pt.

## 17.3 Footnotes

Even though they are not displayed in the margin, we will discuss about footnotes here, since sidenotes are mainly intended to be a replacement of them. Footnotes force the reader to constantly move from one area of the page to the other. Arguably, marginnotes solve this issue, so you should not use footnotes. Nevertheless, for completeness, we have left the standard command `\footnote`, just in case you want to put a footnote once in a while.*

## 17.4 Margintoc

Since we are talking about margins, we introduce here the `\margintoc` command, which allows one to put small table of contents in the margin. Like other commands we have discussed, `\margintoc` accepts a parameter for the vertical offset, like so: `\margintoc[offset]`.

The command can be used in any point of the document, but we think it makes sense to use it just at the beginning of chapters or parts. In this document I make use of a KOMA-Script feature and put it in the chapter preamble, with the following code:

The font used in the margintoc is the same as the one for the chapter entries in the main table of contents at the beginning of the document.

```
\setchapterpreamble[u]{\margintoc}
\chapter{Chapter title}
```

As the space in the margin is a valuable resource, there is the possibility to print a shorter version of the title in the margin toc. Thus, there are in total three possible versions for the title of a section (or subsection): the one for the main text, the one for the main table of contents, and the one for the margintoc. These versions can be specified at the same time when the section is created in the source TeXfile:

```
\section[alternative-title-for-toc]{title-as-written-in-text}[
    alternative-title-for-margintoc]
```

By default, the margintoc includes sections and subsections. If you only want to show sections, add

```
\setcounter{margintocdepth}{\sectiontocdepth}
```

somewhere in your preamble.

## 17.5 Marginlisting

On some occasions it may happen that you have a very short piece of code that doesn't look good in the body of the text because it breaks the flow of narration: for that occasions, you can use a `marginlisting`. The support for this feature is still limited, especially for the captions, but you can try the following code:

**Listing 17.1:** An example of a margin listing.

```
print("Hello World!")
```

```
\begin{marginlisting}
 \caption{My caption}
 \begin{lstlisting}[language=Python,style=kaolstplain]
 ... code ...
 \end{lstlisting}
\end{marginlisting}
```

* And this is how they look like. Notice that in the PDF file there is a back reference to the text; pretty cool, uh?

Since we are here, let me spend a few words about listsings. Thanks to contributions from Kazuhiko Sakaguchi, kaobook now supports both `listings` and `minted`. Just pass the option `listing=listings` or `listing=minted` when you load the `kaobook` class, and the appropriate pacakge will be loaded.

Not only textual stuff can be displayed in the margin, but also figures. Those will be the focus of the next chapter.

# 18 Figures and Tables

## 18.1 Normal Figures and Tables



Figures and tables can be inserted just like in any standard LaTeX document. The `graphicx` package is already loaded and configured in such a way that the figure width is equal to the textwidth and the height is adjusted in order to maintain the original aspect ratio. As you may have imagined, the captions will be positioned…well, in the margins. This is achieved with the help of the `floatrow` package.

Here is a picture of Mona Lisa (Figure 18.1), as an example. The captions are formatted as the margin- and the side-notes; If you want to change something about captions you can use the command `\captsetup` from the `caption` package. Remember that if you want to reference a figure, the label must come *after* the caption!

While the format of the caption is managed by `caption`, its position is handled by the `floatrow` package. Achieving this result has been quite hard, but now I am pretty satisfied. In two-side mode, the captions are printed in the correct margin.

Tables can be inserted just as easily as figures, as exemplified by the following code:

**Listing 18.1:** Caption of a listing.

```
\begin{table}
\begin{tabular}{ c c c c }
    \toprule
    col1 & col2 & col3 & col 4 \\
    \midrule
    \multirow{3}{4em}{Multiple row} & cell2 & cell3 & cell4\\ &
    cell5 & cell6 & cell7 \\ &
    cell8 & cell9 & cell10 \\
    \multirow{3}{4em}{Multiple row} & cell2 & cell3 & cell4 \\ &
    cell5 & cell6 & cell7 \\ &
    cell8 & cell9 & cell10 \\
    \bottomrule
```

The credits for the image above the chapter title go to: Bushra Feroz, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=68724647

```
\end{tabular}
\end{table}
```

which results in the useless Table Table 18.1.

Table 18.1: A useless table.

| col1 | col2 | col3 | col 4 |
|---|---|---|---|
| Multiple row | cell2 | cell3 | cell4 |
| | cell5 | cell6 | cell7 |
| | cell8 | cell9 | cell10 |
| Multiple row | cell2 | cell3 | cell4 |
| | cell5 | cell6 | cell7 |
| | cell8 | cell9 | cell10 |

I don’t have much else to say, so I will just insert some blind text. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

Figure 18.1: It's Mona Lisa again. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

## 18.2 Margin Figures and Tables

Marginfigures can be inserted with the environment **marginfigure**. In this case, the whole picture is confined to the margin and the caption is below it. Figure 15.1 is obtained with something like this:

**Listing 18.2:** Another caption.

```
\begin{marginfigure}
    \includegraphics{monalisa}
    \caption[The Mona Lisa]{The Mona Lisa.}
    \labfig{marginmonalisa}
\end{marginfigure}
```

There is also the **margintable** environment, of which Table 18.2 is an example. Notice how you can place the caption above the table by just placing the **\caption** command before beginning the **tabular** environment. Usually, figure captions are below, while table captions are above. This rule is also respected for normal figures and tables: the captions are always on the side, but for figure they are aligned to the bottom, while for tables to the top.

**Table 18.2:** Another useless table.

| col1 | col2 | col3 |
|---|---|---|
| Multiple row | cell2 | cell3 |
| | cell5 | cell6 |
| | cell8 | cell9 |

Marginfigures and tables can be positioned with an optional offset command, like so:

```
\begin{marginfigure}[offset]
    \includegraphics{seaside}
\end{marginfigure}
```

Offset ca be either a measure or a multiple of **\baselineskip**, much like with **\sidenote**, **\marginnote** and **\margintoc**. If you are wondering how I inserted this orange bubble, have a look at the **todo** package.

Improve this part.

## 18.3 Wide Figures and Tables

With the environments **figure*** and **table*** you can insert figures which span the whole page width. For example, here are a wide figure and a wide table.

**Figure 18.2:** A wide seaside, and a wide caption. Credits: By Bushra Feroz, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=68724647

**Table 18.3:** A wide table with invented data about three people living in the UK. Note that wide figures and tables are centered and their caption also extends into the margin.

| Name | Surname | Job | Salary | Age | Height | Country |
|---|---|---|---|---|---|---|
| Alice | Red | Writer | 4.000 £ | 34 | 167 cm | England |
| Bob | White | Bartender | 2.000 £ | 24 | 180 cm | Scotland |
| Drake | Green | Scientist | 4.000 £ | 26 | 175 cm | Wales |

It is the user's responsibility to adjust the width of the table, if necessary, until it is aesthetically pleasing. The previous table was obtained with the following code:

**Listing 18.3:** How to typeset a wide table

```
\begin{table*}[h!]
    \caption{A wide table with invented data about three people
    living in the UK. Note that wide figures and tables are
    centered and their caption also extends into the margin.}
    \begin{tabular}{p{2.0cm} p{2.0cm} p{2.0cm} p{2.0cm} p{2.0cm}
    p{2.0cm} p{1.5cm}}
        \toprule
        Name    & Surname   & Job       & Salary          & Age
      & Height    & Country \\
        \midrule
        Alice   & Red       & Writer    & 4.000 \pounds    & 34
      & 167 cm     & England \\
        Bob     & White     & Bartender & 2.000 \pounds    & 24
      & 180 cm     & Scotland \\
        Drake   & Green     & Scientist & 4.000 \pounds    & 26
      & 175 cm     & Wales \\
        \bottomrule
    \end{tabular}
\end{table*}
```

The `floatrow` package provides the "H" specifier to instruct LaTeXto position the figure (or table) in precisely the same position it occupies in the source code. However, this specifier does not work with wide figures or tables: you should use "h!" instead, like so: `\begin{figure*}[h!]`.

You may have noticed the full width image at the very beginning of this chapter: that, however, is set up in an entirely different way, which you'll read about in Chapter 20 on page 71.

`kaobook` also supports paginated tables (have a look at the `longtable` package). The `longtable`[1] environment behaves a bit differently from `table`, in that `longtable` encompasses both `table` and `tabular`, so that you can write, *e.g.*,

1: Interestingly, `longtable`s may require up to four rounds of compilation before they are typeset correctly.

**Listing 18.4:** Example of a longtable

```
\begin{longtable}{|l c c|}
    \hline
    One & Two & Three \\
    Left & Center & Center \\
    \hline
    \caption{Caption of the longtable.}
\end{longtable}
```

to obtain the following table:

| | | |
|---|---|---|
| One | Two | Three |
| Left | Center | Center |

**Table 18.4:** Caption of the longtable.

The caption of a `longtable` is always positioned below the table, and it has the same width as the text (it doesn't extend into the margin). However, sometimes you may need a `longtable` that is so wide that it trespass into the margins; in those cases, you may want to also increase the width of the caption. To do so, you'll have to write two additional commands, one before and one after the `longtable`:

**Listing 18.5:** Increasing the width of the caption of a `longtable`.

```
\floatsetup[longtable]{margins=centering,LTcapwidth=table} % Add this line before the longtable to increase the caption width
\begin{longtable}{lp{8cm}p{5cm}p{2cm}}
...
\end{longtable}
\floatsetup[longtable]{margins=raggedright,LTcapwidth=\textwidth} % Add this line after the longtable to revert the previous change
```

Having seen figures and tables, it is now time to tackle hyperreferences.

# 19 References

## 19.1 Citations

To cite someone [Visscher2008, James2013] is very simple: just use the \sidecite command. It does not have an offset argument yet, but it probably will in the future. This command supports multiple entries, as you can see, and by default it prints the reference on the margin as well as adding it to the bibliography at the end of the document. Note that the citations have nothing to do with the text,[James2013] but they are completely random as they only serve the purpose to illustrate the feature.

Visscher2008, James2013

James2013

For this setup I wrote a separate package, kaobiblio, which you can find in the styles directory and include in your main tex file. This package accepts all the options that you can pass to biblatex, and actually it passes them to biblatex under the hood. Moreover, it also defines some commands, like \sidecite, and environments that can be used within a kao book.[1]

1: For this reason you should always use kaobiblio instead of biblatex, but the syntax and the options are exactly the same.

If you want to use bibtex instead of biblatex, pass the option backend=bibtex to kaobiblio. kaobiblio also supports two options that are not shared with biblatex: addspace and linkeverything, both of which are boolean options, meaning that they can take either “true” or “false” as a value. If you pass addspace=true when loading kaobiblio, a space will be automatically added before the citation marks. If you pass linkeverything=true, the author’s name in the authoryear-* and authortitle-* styles will be a hyperlink like the year.[2]

2: The fact that the author name is not a hyperlink bothers more than one biblatex user. There are strong arguments *against* hyperlinking the author name, but in my personal opinion, linking the author’s name does not result in any problems in most practical cases.

As you have seen, the \sidecite command will print a citation in the margin. However, this command would be useless without a way to customise the format of the citation, so the kaobook provides also the \formatmargincitation command. By “renewing” that command, you can choose which items will be printed in the margins. The best way to understand how it works is to see the actual definition of this command.

```
\newcommand{\formatmargincitation}[1]{%
    \parencite{#1}: \citeauthor*{#1} (\citeyear{#1}), \citetitle{#1}%
}
```

Thus, the \formatmargincitation accepts one parameter, which is the citation key, and prints the parencite followed by a colon, then the author, then the year (in brackets), and finally the title.[Battle2014] Now, suppose that you wish the margin citation to display the year and the author, followed by the title, and finally a fixed arbitrary string; you would add to your document:

Battle2014

```
\renewcommand{\formatmargincitation}[1]{%
    \citeyear{#1}, \citeauthor*{#1}: \citetitle{#1}; very interesting!%
}
```

The above code results in citations that look like the following.[Zou2005] Of course, changing the format is most useful when you also change the default bibliography style. For instance, if you want to use the “philosophy-modern” style for your bibliography, you might have something like this in the preamble:

Zou2005

```
\usepackage[style=philosophy-modern]{styles/kaobiblio}
\renewcommand{\formatmargincitation}[1]{%
    \sdcite{#1}%
}
\addbibresource{main.bib}
```

The commands like `\citeyear`, `\parencite` and `\sdcite` are just examples. A full reference of the available commands can be found in this cheatsheet, under the “Citations” section.

Finally, to compile a document containing citations, you need to use an external tool, which for this class is biber. You need to run the following (assuming that your tex file is called main.tex):

```
$ pdflatex main
$ biber main
$ pdflatex main
```

## 19.2 Glossaries and Indices

The `kaobook` class loads the packages `glossaries` and `imakeidx`, with which you can add glossaries and indices to your book. For instance, I previously defined some glossary entries and now I am going to use them, like this: computer. `glossaries` also allows you to use acronyms, like the following: this is the full version, Frame per Second (FPS), and this is the short one FPS. These entries will appear in the glossary in the backmatter.

Unless you use Overleaf or some other fancy IDE for LaTeX, you need to run an external command from your terminal in order to compile a document with a glossary. In particular, the commands required are:[3]

3: These are the commands you would run in a UNIX system, but see also Section 19.4 (A Final Note on Compilation); I have no idea about how it works in Windows.

```
$ pdflatex main
$ makeglossaries main
$ pdflatex main
```

Note that you need not run `makeglossaries` every time you compile your document, but only when you change the glossary entries.

To create an index, you need to insert the command `\index{subject}` whenever you are talking about “subject” in the text. For instance, at the start of this paragraph I would write `index{index}`, and an entry would be added to the Index in the backmatter. Check it out!

In theory, you would need to run an external command for the index as well, but luckily the package we suggested, `imakeidx`, can compile the index automatically.

A nomenclature is just a special kind of index; you can find one at the end of this book. To insert a nomenclature, we use the package `nomencl` and add the terms with the command `\nomenclature`. We put then a `\printnomenclature` where we want it to appear.

Also with this package we need to run an external command to compile the document, otherwise the nomenclature will not appear:

```
$ pdflatex main
$ makeindex main.nlo -s nomencl.ist -o main.nls
$ pdflatex main
```

These packages are all loaded in packages.sty, one of the files that come with this class. However, the configuration of the elements is best done in the main.tex file, since each book will have different entries and styles.

This brief section was by no means a complete reference on the subject, therefore you should consult the documentation of the above package to gain a full understanding of how they work.

Note that the `nomencl` package caused problems when the document was compiled, so, to make a long story short, I had to prevent `scrhack` to load the hack-file for `nomencl`. When compiling the document on Overleaf, however, this problem seem to vanish.

## 19.3 Hyperreferences

Together with this class we provide a handy package to help you referencing the same elements always in the same way, for consistency across the book. First, you can label each element with a specific command. For instance, should you want to label a chapter, you would put `\labch{chapter-title}` right after the `\chapter` directive. This is just a convenience, because `\labch` is actually just an alias to `\label{ch:chapter-title}`, so it spares you the writing of "ch:". We defined similar commands for many typically labeled elements, including:

- Page: `\labpage`
- Part: `\labpart`
- Chapter: `\labch`
- Section: `\labsec`
- Figure: `\labfig`
- Table: `\labtab`
- Definition: `\labdef`
- Assumption: `\labassum`
- Theorem: `\labthm`
- Proposition: `\labprop`
- Lemma: `\lablemma`
- Remark: `\labremark`
- Example: `\labexample`
- Exercise: `\labexercise`

Of course, we have similar commands for referencing those elements. However, since the style of the reference should depend on the context, we provide different commands to reference the same thing. For instance, in some occasions you may want to reference the chapter by name, but other times you want to reference it only by number. In general, there are four reference style, which we call plain, vario, name, and full.

The plain style references only by number. It is accessed, for chapters, with `\refch{chapter-title}` (for other elements, the syntax is analogous). Such a reference results in: Chapter 19.

The vario and name styles rest upon the `varioref` package. Their syntax is `\vrefch{chapter-title}` and `\nrefch{chapter-title}`, and they result in: Chapter 19 on page 65, for the vario style, and: Chapter 19 (References), for the name style. As you can see, the page is referenced in `varioref` style.

The full style references everything. You can use it with `\frefch{chapter-title}` and it looks like this: Chapter 19 (References) on page 65.

Of course, all the other elements have similar commands (*e.g.* for parts you would use `\vrefpart{part-title}` or something like that). However, not all elements implement all the four styles. The commands provided should be enough, but if you want to see what is available or to add the missing ones, have a look at the attached package.

In order to have access to all these features, the `kaorefs` should be loaded in the preamble of your document. It should be loaded last, or at least after `babel` (or `polyglossia`) and `plaintheorems` (or `mdftheorems`). Options can be passed to it like to any other package; in particular, it is possible to specify the language of the captions. For instance, if you specify "italian" as an option, instead of "Chapter" it will be printed "Capitolo", the Italian analog. If you know other languages, you are welcome to contribute the translations of these captions! Feel free to contact the author of the class for further details.

The `kaorefs` package also include `cleveref`, so it is possible to use `\cref` in addition to all the previously described referencing commands.

## 19.4 A Final Note on Compilation

Probably the easiest way to compile a latex document is with the `latexmk` script, as it can take care of everything, if properly configured, from the bibliography to the glossary. The command to issue, in general, is:

```
latexmk [latexmk_options] [filename ...]
```

`latexmk` can be extensively configured (see https://mg.readthedocs.io/latexmk.html). For convenience, I print here an example configuration that would cover all the steps described above.

```
# By default compile only the file called ’main.tex’
@default_files = (’main.tex’);

# Compile the glossary and acronyms list (package ’glossaries’)
add_cus_dep( ’acn’, ’acr’, 0, ’makeglossaries’ );
add_cus_dep( ’glo’, ’gls’, 0, ’makeglossaries’ );
$clean_ext .= ” acr acn alg glo gls glg”;
sub makeglossaries {
   my ($base_name, $path) = fileparse( $_[0] );
   pushd $path;
   my $return = system ”makeglossaries”, $base_name;
   popd;
   return $return;
}

# Compile the nomenclature (package ’nomencl’)
add_cus_dep( ’nlo’, ’nls’, 0, ’makenlo2nls’ );
sub makenlo2nls {
    system( ”makeindex -s nomencl.ist -o \”$_[0].nls\” \”$_[0].nlo\”” );
}
```

However, if you’d rather not use an external package and want to do everything manually, here are some tips.[4]

4: As the author only uses Linux and compiles everything from the command line, he doesn’t know how the compilation works in Windows or Mac. The tips, therefore, refer to the usage with Linux from the command line.

#### Compiling the examples in the kaobook repository

To compile the examples, and in particular the documentation, that are in the `examples` directory of the kaobook repository on GitHub, do as follows. **`cd`** into the root directory of the repository, and run `pdflatex -output-directory examples/documentation main.tex`. With this trick, you can compile the documentation using the class files pertaining to the repository (and not, say, those in your texmf tree). The “-output-directory” option works with the other LaTeX-related commands such as biber and makeglossaries.

A note of warning: sometimes LaTeX needs more than one run to get the correct position of each element; this is true in particular for the positioning of floating elements like figures, tables, and margin notes. Occasionally, LaTeX can need up to four re-runs, so If the alignment of margin elements looks odd, or if they bleed into the main text, try running pdflatex one more time.

# Design and Additional Features

# 20 Page Design



## 20.1 Headings

So far, in this document I used two different styles for the chapter headings: one has the chapter name, a rule and, in the margin, the chapter number; the other has an image at the top of the page, and the chapter title is printed in a box (like for this chapter). There is one additional style, which I used only in the Chapter **??** (**??**); there, the chapter title is enclosed in two horizontal rules, and the chapter number (or letter, in the case of the appendix) is above it.[1]

1: To be honest, I do not think that mixing heading styles like this is a wise choice, but in this document I did it only to show you how they look.

Every book is unique, so it makes sense to have different styles from which to choose. Actually, it would be awesome if whenever a `kao`-user designs a new heading style, he or she added it to the three styles already present, so that it will be available for new users and new books.

The choice of the style is made simple by the `\setchapterstyle` command. It accepts one option, the name of the style, which can be: “plain”, “kao”, “bar”, or “lines”.[2] If instead you want the image style, you have to use the command `\setchapterimage`, which accepts the path to the image as argument; you can also provide an optional parameter in square brackets to specify the height of the image. `\setchapterimage` automatically sets the chapter style to “bar” for that chapter (and also for subsequent chapters).

2: Plain is the default LaTeX title style; the other ones are self explanatory.

Let us make some examples. In this book, I begin a normal chapter with the lines:

```
1 \setchapterstyle{kao}
2 \setchapterpreamble[u]{\margintoc}
3 \chapter{Title of the Chapter}
4 \labch{title}
```

In Line 1 I choose the style for the title to be “kao”. Then, I specify that I want the margin toc. The rest is ordinary administration in LaTeX, except that I use my own `\labch` to label the chapter. Actually, the `\setchapterpreamble` is a standard KOMA-Script one, so I invite you to read about it in the KOMA documentation. Once the chapter style is set, it holds until you change it.[3] Whenever I want to start a chapter with an image, I simply write:

3: The `\margintoc` has to be specified at every chapter. Perhaps in the future this may change; it all depends on how this feature will be welcomed by the users, so keep in touch with me if you have preferences!

```
1 \setchapterimage[7cm]{path/to/image.png} % Optionally specify the
      height
2 \setchapterpreamble[u]{\margintoc}
3 \chapter{Catchy Title} % No need to set a chapter style
4 \labch{catchy}
```

If you prefer, you can also specify the style at the beginning of the main document, and that style will hold until you change it again.

## 20.2 Headers & Footers

Headers and footers in KOMA-Script are handled by the `scrlayer-scrpage` package. There are two basic style: "scrheadings" and "plain.scrheadings". The former is used for normal pages, whereas the latter is used in title pages (those where a new chapter starts, for instance) and, at least in this book, in the front matter. At any rate, the style can be changed with the `\pagestyle` command, *e.g.* `\pagestyle{plain.scrheadings}`.

In both styles, the footer is completely empty. In plain.scrheadings, also the header is absent (otherwise it wouldn't be so plain...), but in the normal style the design is reminiscent of the "kao" style for chapter titles.

## 20.3 **twoside** mode

**To Do**

The `twoside` class option is still unstable and may lead to unexpected behaviours. Great strides have been done since the first version of `kaobook`, but some work still needs to be done. As always, any help will be greatly appreciated.

By passing the `twoside` option to the `kaobook`, the style of left and right pages will be different, similarly to a printed book. In digital books, having a symmetrical layout for left and right pages is less important, and you may be tempted to use the `twoside=false` option. However, keep in mind that in "oneside" mode the `\uppertitleback` and `\lowertitleback` commands are not available.[4] If you want to have the upper/lower titleback in a one-side document, just add manually the contents that you'd put using the upper/lower titleback commands.

4: Another useful thing to keep in mind is that, when `twoside=true`, an extra white page will be added to the frontmatter.

## 20.4 Table of Contents

Another important part of a book is the table of contents. By default, in `kaobook` there is an entry for everything: list of figures, list of tables, bibliographies, and even the table of contents itself. Not everybody might like this, so we will provide a description of the changes you need to do in order to enable or disable each of these entries. In the following Table 20.1, each item corresponds to a possible entry in the TOC, and its description is the command you need to provide to have such entry. These commands are specified in the attached style package,[5] so if you don't want the entries, just comment the corresponding lines.

5: In the same file, you can also choose the titles of these entries.

Of course, some packages, like those for glossaries and indices, will try to add their own entries. In such cases, you have to follow the instructions specific to that package. Here, since we have talked about glossaries and notations in Chapter 19, we will briefly see how to configure them.

In a later section, we will see how you can define your own floating environment, and endow it with an entry in the TOC.

For the `glossaries` package, use the "toc" option when you load it: `\usepackage[toc]{glossaries}`. For `nomencl`, pass the "intoc" option at the moment of loading the package. Both `glossaries` and `nomencl` are loaded in the attached "packages" package.

| Entry | Command to Activate |
|---|---|
| Table of Contents | `\setuptoc{toc}{totoc}` |
| List of Figs/Tabs | `\PassOptionsToClass{toc=listof}{\@baseclass}` |
| Bibliography | `\PassOptionsToClass{toc=bibliography}{\@baseclass}` |

**Table 20.1:** Commands to add a particular entry to the table of contents.

Additional configuration of the table of contents can be performed through the packages `etoc`, which is loaded because it is needed for the margintocs, or the more traditional `tocbase`. Read the respective documentations if you want to be able to change the default TOC style.[6]

6: (And please, send me a copy of what you have done, I'm so curious!)

## 20.5 Paper Size

Recent versions of Kaobook support paper sizes different from the default A4. It is possible to pass the name of the paper as an option to the class, as we are accustomed for any other LaTeX class. For example, the class option `b5paper` would set the paper size to the B5 format.

We also support the paper sizes specified in this web page and some additional sizes requested by the users, with the option names specified in Table 20.2.

**Table 20.2:** Some non-standard paper sizes supported by kaobook.

| Dimension | Option name |
|---|---|
| 12.0cm x 19.0cm | smallpocketpaper |
| 13.5cm x 21.5cm | pocketpaper |
| 14.8cm x 21.0cm | a5paper |
| 15.5cm x 22.0cm | juvenilepaper |
| 17.0cm x 17.0cm | smallphotopaper |
| 21.0cm x 15.0cm | appendixpaper |
| 17.0cm x 22.0cm | cookpaper |
| 19.0cm x 27.0cm | illustratedpaper |
| 17.0cm x 17.0cm | photopaper |
| 16.0cm x 24.0cm | f24paper |

For instance, to use the "smallpocketpaper" add the correct description at the beginning of the documentclass instruction:

```
\documentclass[
        smallpocketpaper,
        fontsize=10pt,
        twoside=false,
        %open=any,
        secnumdepth=1,
]{kaobook}
```

Sometimes it is convenient to adopt a landscape view; `kaobook` provides two additional options, `a4paperlandscape` and `169paperlandscape`, which set the page in landscape mode with width-to-height ratios of, respectively, 1.414 and 16:9.

## 20.6 Page Layout

Besides the page style, you can also change the width of the content of a page. This is particularly useful for pages dedicated to part titles, where having the 1.5-column layout might be a little awkward, or for pages where you only put figures, where it is important to exploit all the available space.

In practice, there are two layouts: "wide" and "margin". The former suppresses the margins and allocates the full page for contents, while the latter is the layout used in most of the pages of this book, including this one. The wide layout is also used automatically in the front and back matters.

Sometimes it is desirable to increase the width for just one or a few paragraphs; the `widepar` environment does that: wrap your paragraphs in this environment, and they will occupy the full width of the page.

To change page layout, use the `\pagelayout` command. For example, when I start a new part, I write:

```
\pagelayout{wide}
\addpart{Title of the New Part}
\pagelayout{margin}
```

Beyond these two basic layouts, it is also possible to finely tune the page layout by redefining the `\marginlayout` command. This command is called internally by the higher-level `\pagelayout`, and it is responsible for setting the width of the margins and of the text. The default definition is:

```
\newcommand{\marginlayout}{%
    \newgeometry{
        top=27.4mm,             % height of the top margin
        bottom=27.4mm,          % height of the bottom margin
        inner=24.8mm,           % width of the inner margin
        textwidth=107mm,        % width of the text
        marginparsep=8.2mm,     % width between text and margin
        marginparwidth=49.4mm,  % width of the margin
    }%
}
```

so if you want to, say, decrease the width of the margin while increasing the width of the text, you could write in the preamble of your document something like:

```
\renewcommand{\marginlayout}{%
    \newgeometry{
        top=27.4mm,             % height of the top margin
        bottom=27.4mm,          % height of the bottom margin
        inner=24.8mm,           % width of the inner margin
        textwidth=117mm,        % width of the text
        marginparsep=8.2mm,     % width between text and margin
        marginparwidth=39.4mm,  % width of the margin
    }%
}
```

where the text width has been increased by 10mm and the margin width has been decreased by 10mm.

## 20.7 Numbers & Counters

In this short section we shall see how dispositions, sidenotes and figures are numbered in the `kaobook` class.

By default, dispositions are numbered up to the section in `kaobook` and up to the subsection in `kaohandt`. This can be changed by passing the option `secnumdepth` to`kaobook` or `kaohandt` (e.g. 1 corresponds to section and 2 corresponds to subsections).

The sidenotes counter is the same across all the document, but if you want it to reset at each chapter, just uncomment the line

`\counterwithin*{sidenote}{chapter}`

in the `styles/style.sty` package provided by this class.

Figure and Table numbering is also per-chapter; to change that, use something like:

`\renewcommand{\thefigure}{\arabic{section}.\arabic{figure}}`

## 20.8 White Space

One of the things that I find most hard in LaTeX is to finely tune the white space around objects. There are not fixed rules, each object needs its own adjustment. Here we shall see how some spaces are defined at the moment in this class.

Attention! This section may be incomplete.

### Space around sidenotes and citations marks

There should be no space before or after sidenotes and citation marks, like so:

sidenote[7]sidenote
citation[**James2013**]citation

7: This paragraph can be used to diagnose any problems: if you see whitespace around sidenotes or citation marks, probably a % sign is missing somewhere in the definitions of the class macros.

Space around figures and tables

```
\renewcommand\FBaskip{.4\topskip}
\renewcommand\FBbskip{\FBaskip}
```

Space around captions

```
\captionsetup{
    aboveskip=6pt,
    belowskip=6pt
}
```

Space around displays (*e.g.* equations)

```
\setlength\abovedisplayskip{6pt plus 2pt minus 4pt}
\setlength\belowdisplayskip{6pt plus 2pt minus 4pt}
\abovedisplayskip 10\p@ \@plus2\p@ \@minus5\p@
\abovedisplayshortskip \z@ \@plus3\p@
\belowdisplayskip \abovedisplayskip
\belowdisplayshortskip 6\p@ \@plus3\p@ \@minus3\p@
```

# Mathematics and Boxes 21



## 21.1 Theorems

Despite most people complain at the sight of a book full of equations, mathematics is an important part of many books. Here, we shall illustrate some of the possibilities. We believe that theorems, definitions, remarks and examples should be emphasised with a shaded background; however, the colour should not be to heavy on the eyes, so we have chosen a sort of light yellow.[1]

1: The boxes are all of the same colour here, because we did not want our document to look like Harlequin.

**Definition 21.1.1** *Let $(X, d)$ be a metric space. A subset $U \subset X$ is an open set if, for any $x \in U$ there exists $r > 0$ such that $B(x, r) \subset U$. We call the topology associated to d the set $\tau_d$ of all the open subsets of $(X, d)$.*

Definition 21.1.1 is very important. I am not joking, but I have inserted this phrase only to show how to reference definitions. The following statement is repeated over and over in different environments.

**Theorem 21.1.1** *A finite intersection of open sets of (X, d) is an open set of (X, d), i.e $\tau_d$ is closed under finite intersections. Any union of open sets of (X, d) is an open set of (X, d).*

**Proposition 21.1.2** *A finite intersection of open sets of (X, d) is an open set of (X, d), i.e $\tau_d$ is closed under finite intersections. Any union of open sets of (X, d) is an open set of (X, d).*

You can even insert footnotes inside the theorem environments; they will be displayed at the bottom of the box.

**Lemma 21.1.3** *A finite intersection[a] of open sets of (X, d) is an open set of (X, d), i.e $\tau_d$ is closed under finite intersections. Any union of open sets of (X, d) is an open set of (X, d).*

[a] I'm a footnote

You can safely ignore the content of the theorems...I assume that if you are interested in having theorems in your book, you already know something about the classical way to add them. These example should just showcase all the things you can do within this class.

**Corollary 21.1.4** (Finite Intersection, Countable Union) *A finite intersection of open sets of (X, d) is an open set of (X, d), i.e $\tau_d$ is closed under finite intersections. Any union of open sets of (X, d) is an open set of (X, d).*

*Proof.* The proof is left to the reader as a trivial exercise. Hint: Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language. $\square$

**Definition 21.1.2** *Let $(X, d)$ be a metric space. A subset $U \subset X$ is an open set if, for any $x \in U$ there exists $r > 0$ such that $B(x, r) \subset U$. We call the topology associated to d the set $\tau_d$ of all the open subsets of $(X, d)$.*

Here is a random equation, just because we can:

$$x = a_0 + \cfrac{1}{a_1 + \cfrac{1}{a_2 + \cfrac{1}{a_3 + \cfrac{1}{a_4}}}}$$

**Example 21.1.1** Let $(X, d)$ be a metric space. A subset $U \subset X$ is an open set if, for any $x \in U$ there exists $r > 0$ such that $B(x, r) \subset U$. We call the topology associated to d the set $\tau_d$ of all the open subsets of $(X, d)$.

**Remark 21.1.1** Let $(X, d)$ be a metric space. A subset $U \subset X$ is an open set if, for any $x \in U$ there exists $r > 0$ such that $B(x, r) \subset U$. We call the topology associated to d the set $\tau_d$ of all the open subsets of $(X, d)$.

As you may have noticed, definitions, example and remarks have independent counters; theorems, propositions, lemmas and corollaries share the same counter.

**Remark 21.1.2** Here is how an integral looks like inline: $\int_a^b x^2 dx$, and here is the same integral displayed in its own paragraph:

$$\int_a^b x^2 dx$$

There is also an environment for exercises.

**Exercise 21.1.1** Prove (or disprove) the Riemann hypothesis.

We provide one package for the theorem styles: kaotheorems.sty, to which you can pass the `framed` option you do want coloured boxes around theorems, like in this document.[2] You may want to edit this files according to your taste and the general style of the book. However, there is an option to customise the background colour of the boxes if you use the `framed` option: when you load this package, you can pass it the `background=mycolour` option (replace "mycolour" with the actual colour, for instance, "red!35!white"). This will change the colour of all the boxes, but it is also possible to override the default colour only for some elements. For instance, the `propositionbackground=mycolour` option will change the colour for propositions only. There are similar options for theorem, definition, lemma, corollary, remark, and example.

2: The styles without `framed` are not showed, but actually the only difference is that they don't have the yellow boxes.

## 21.2 Boxes & Custom Environments [3]

3: Notice that in the table of contents and in the header, the name of this section is "Boxes & Environments"; we achieved this with the optional argument of the `section` command.

Say you want to insert a special section, an optional content or just something you want to emphasise. We think that nothing works better than a box in these cases. We used `mdframed` to construct the ones shown below. You can create and modify such environments by editing the provided file kao.sty.

**Title of the box**

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

If you set up a counter, you can even create your own numbered environment.

**Comment 21.2.1**

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

## 21.3 Experiments

It is possible to wrap marginnotes inside boxes, too. Audacious readers are encouraged to try their own experiments and let me know the outcomes.

**title of margin note**

Margin note inside a kaobox.
(Actually, kaobox inside a marginnote!)

I believe that many other special things are possible with the kaobook class. During its development, I struggled to keep it as flexible as possible, so that new features could be added without too great an effort. Therefore, I hope that you can find the optimal way to express yourselves in writing a book, report or thesis with this class, and I am eager to see the outcomes of any experiment that you may try.

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# Alphabetical Index