Short-circuiting the quotation phase in the selection process of an air handling unit

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Abstract

Engineering consultants in the building industry usually lack a decent tool to fiddle around with all the necessary parameters regarding the selection of an air handling unit (ahu), and that in a timely manner. Today they ask a supplier for a quote, which could take a week until reception and there's not much space to fiddle around with parameters. If such a tool could become reality, then the quality and convenience of the engineering of all related technical installations would be greatly improved, with the bonus of an important gain of time.

Keywords: air handling unit; bim; ahu selection software; and combinations

1 The building information modeling (bim) connection

For an ahu supplier/manufacturer it is a great advantage and of an uttermost importance to be involved in a building project as early in the process as possible, and sometimes the engineering starts based on a designed bim model.
Based on the study of the designed bim model, heat losses, heat gains and the needed amount of fresh air are calculated and the desired ahu air supply conditions are chosen. Then a desired airflow for the ahu is being calculated.
The engineering consultant will also work on the ductwork and will be able to calculate a pressure drop for the projected ductwork and end elements in combination with the foreseen airflow, these measures are mandatory in the selection process of the ahu.
Maybe there are also fresh air conditions, for winter and summer, presented in the bim model and it might even be that, in case of an ahu with heat recuperation, that the air conditions of return air could be calculated through the bim model. Also indoor or outdoor placement is mandatory to know.

The above mentioned parameters are the minimum inputs needed to select an ahu.

Based on these parameters a plugin in the bim software could be initialised, which in term initialises a (cloud) application to automatically select an ahu almost instantly, which will be promptly described below. This (cloud) selection software generates a bim object for the ahu and this object could be incorporated in the bim model for the whole building, maybe this incorporation could once also be automated through the bim plugin.

2 How to automate ahu selection?

2.1 Base constraints for ahu selection

In the case of a comfort application the ErP-directive and the price are the two main limiting base factors, the others being the requested output figures.
The lower the price of the ahu, the less possible the ahu is conform ErP.
The ErP-directive (2018) describes a projected internal specific fan power of maximum 1250 $W/m^3/s$ and a projected heat recovery efficiency of, in case of a twin coil, 68%, and in case of a plate heat exchanger or heat recovery wheel 73%.

In the case of a process application the constraints are mostly defined by the working limits of the selected fans in a given casing and the price of the unit.
In most cases counts: the smaller the casing, the lower its price, as the casing is a decisive factor when calculating a price for whole ahu.

2.2 Methods to automatically select an ahu

In order to be able to automatically calculate an ahu, something must be said about the inputs and outputs of the intended software and where I'm heading to, based on the section above about bim, is that the inputs are the data from the supplier/manufacturer dll's and the desired (partial) output of the ahu coming from the bim model (the parameters described above), and the output should be a full ahu description, being a bim object and maybe an accompanying technical datasheet.

In the first instance all the possible casings and components combinations should be calculated complying to the above base constraints and the desired ahu output. There's a great deal involved for heuristics to limit the amount of combinations, below in the case study I'll dive deeper into this subject.
Heuristics being nothing more than if-else statements in the source code, defined by prac-

tical knowledge about casing and components constraints.

At a later point in time and if combinations demand too much time to be computed, a learner could be introduced, and it might seem that machine learning is applicable, because the data is categorized, but hidden behind supplier dll's (fans, coils, ...) and these must be seen as a black box. Because of this categorisation a learning algorithm is highly suited for this application. But this is an area not yet fully understood by me.

All the needed computations could be easily done by a graphics processing unit (gpu) as a decent gpu these days could compute more than a thousand processes in parallel and one combination could be seen as one process. Learning is also done by one or more gpu's. The usage of a gpu for general computation is known as gpgpu computing.

3 A case study for the ahu selection software

Here starts a more technical approach to the parameters and computations the software should take care off:

3.1 Example input parameters

Below follows a minimal listing of the input parameters for this example:

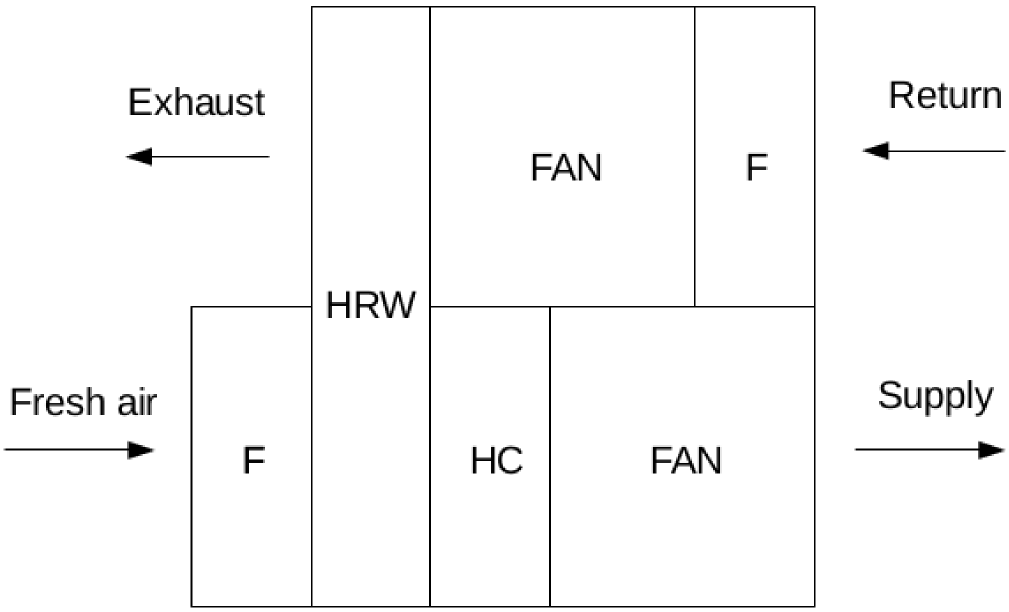
- Fresh air condition in winter e.g. -10°C/90%
- Heat recovery wheel compliant to ErP Return air conditions are mandatory e.g. 20°C/50%
- Supply condition e.g. 24°C

There also exist binary options like prepainted fins, an adsorption heat recovery wheel, SS AISI 304 filter frames, ... but these are not part of the combinations and could rather easily be computed serially in each parallel computation.

We intend to bring only heat with this example unit, but a heating coil is not described here because the software is able to figure out that the supply air condition isn't met and silently adding a heating coil is justified.

Filters and a fan also aren't described as these are mandatory in ahu selection. A filter is needed to protect the inner components from dust and other unwanted particles. A fan is obviously needed to take care for an air flow and to provide an external (to the ahu) pressure.

3.2 Example ahu



The (simplified) ahu consists of:

- Supply air:
  - A filter section (F)
  - The heat recovery wheel (HRW)
  - A heating coil section (HC)
  - The fan section (FAN)
- Return air:
  - A filter section (F)
  - The fan section (FAN)
  - The heat recovery wheel (HRW)

And a casing off course ...

3.3 Counting the combinations

To try to figure out that computation of combinations is feasible, we'll count them for every component in our example. We make a summary of what the possible combinations are for the whole ahu. These numbers are based on practical knowledge of selection software and are different for each supplier/manufacturer, but could be seen as an average.

- Casing: Ideally the casing dimensions are a square for supply and return together (concentrated around the wheel), in reality that's not always feasible and the wheel can be a little bit wider than the supply and return casing in this example where return is on top of supply.
  To dimension these casings we make use of the air velocity in each casing. For our count we take 3 casing dimensions with an air velocity ranging from 1,8 m/s to 2,5 m/s which is a heuristic because we know those values are based on practice and should result in an ErP compliant ahu. (CT = 3)
  The higher the air velocity, the smaller the casing, the lower the price.

- Filters: 3 different suppliers (SF = 3), 2 possible filter types (TF = 2), each with a different price setting and a different pressure drop.

- Heat recovery wheel: 2 different suppliers (SHR = 2)
  For the diameter of the wheel heuristics can be added like the minimal efficiency and the maximal pressure drop, in order to calculate the cheapest ErP compliant solution, let's take 3 possible wheel diameters in to account (DRH = 3)
  The greatest fin spacing which is ErP compliant should be chosen, because that wheel has the lowest pressure drop and the lowest price. The computation for this fin spacing is a serial computation per wheel diameter and so we don't count fin spacing as a combination.
  No type of wheel (condensation, adsorption, ...) is given as an input, so the cheapest solution is chosen which is the condensation wheel.

- Heating coil: There's only 1 supplier
  3 types of coils exist (3012, 4016, 2510), but 2510 is only used in DX applications, we use heated water (TC = 2)
  Reasoning about fin spacing is equal to fin spacing in the heat recovery wheel, so no extra combinations
  The water regime, maximal water pressure drop, prepainted fins, ... also don't give extra combinations, these are inputs (not needed to count combinations here) and binary options.

- Fan: There are 2 suppliers (SFA = 2)
  Several types of fans exist, but through heuristics we can limit the amount of possible candidates to e.g. 4 (TFA = 4), the fan with the highest efficiency is chosen in most cases. Here are also binary options like a request for EC-fans, ...

$$
\begin{aligned}
Total\ combinations\ supply &= CT \times SF \times TF \times SHR \times DRH \times TC \times SFA \times TFA && (1)\\
&= 3 \times 3 \times 2 \times 2 \times 3 \times 2 \times 2 \times 4 && (2)\\
&= 1728 && (3)
\end{aligned}
$$

$$
\begin{aligned}
Total\ combinations\ return &= SF \times TF \times SFA \times TFA && (4)\\
&= 3 \times 2 \times \times 2 \times 4 && (5)\\
&= 48 && (6)
\end{aligned}
$$

$$
Total\ combinations = 1728 + 48 = 1776 \qquad (7)
$$

There's an addition (serial computation) for the total of all combinations, because the most optimal solution for the supply unit will also be decisive for the return unit, and so the calculation for return air awaits the calculation for supply air i.e. to choose the casing of both casings.

These combinations of 1728 and 48 can be computed in parallel, a gpu is ideal in this situation. If a gpu has 1000 parallel processes [1] and computing 1 combination takes approximately 30 seconds [2], then you have to wait a minute to compute the combinations of supply air and an extra half a minute to compute the combinations of return air, totaling a minute and a half. Be aware that you also need time to assemble your initial input parameters and you also need time to create the bim object and perhaps to print the technical datasheet. But a total selection and printing of this example ahu could take less than 5 minutes.

There are also situations that an extra cooling coil is needed, then the calculation of the combinations takes twice the time, as TC is 2 for this extra coil.

4 Conclusion

It shouldn't be impossible to create software which computes all combinations, and includes the possible heuristics, specific to the selection of an air handling unit, as waiting nothing more than a few minutes is the case in the above example of a simple ahu. Also giving engineering consultants this tool so they are able to engineer the ahu to perfection, while integrating the resulting bim object in their bim model, is one of the possibilities. I think this conclusion is like kicking in an open door, so last days I was wondering why it doesn't yet exist as software. Early introduction of a product in a design and engineer process gives a tremendous advantage against the competition.

Notes

The subjected paper is nothing more than a concise introduction to this matter as I wasn't able to do profound research [3] on this topic with the surplus of no ability to fiddle around with bim software.

References

[1] `https://www.quora.com/How-many-cores-in-a-standard-gpu`

[2] Exact measures are missing for such a gpu in combination with the yet non-existent code for such computations foreseen for gpgpu, so a realistic delays profile for all the ahu components combinations computation is also non-existent.

[3] More references couldn't be added, I wasn't able to read papers nor books about these subjects. Most information came from almost random searching on the internet and practical usage of ahu selection software from 3 different manufacturers.