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3.4 THE CHEREDNIK ALGEBRA

Let us now return to the algebra \mathcal{A} of operators on U generated by $\mathcal{D}(U)$ and W . This algebra contains the Dunkl operators

$$D_y := \partial_y + \sum_{s \in \Sigma} c_s \frac{(\alpha_s, y)}{\alpha_s} (s - 1).$$

LEMMA 3.10. *The following relations hold:*

$$\begin{aligned} [x_i, x_j] &= [D_{x_i}, D_{x_j}] = 0, \quad \forall 1 \leq i, j \leq n \\ [D_{x_i}, x_j] &= \delta_{i,j} + \sum_{s \in \Sigma} c_s \frac{(x_i, \alpha_s)(x_j, \alpha_s)}{(\alpha_s, \alpha_s)} s, \quad \forall 1 \leq i, j \leq n \end{aligned}$$

$$wxw^{-1} = w(x), \quad wD_yw^{-1} = D_{w(y)}, \quad \forall w \in W, x \in \mathfrak{h}^*, y \in \mathfrak{h}.$$

Proof. The proof is an easy computation, except for the relations $[D_{x_i}, D_{x_j}] = 0$, which follow from Theorem 2.6. \square

This lemma motivates the following definition.

DEFINITION 3.11 (see e.g. [EG]). The *Cherednik algebra* H_c is an associative algebra with generators $x_i, y_i, i = 1, \dots, n$, and $w \in W$, with defining relations

$$\begin{aligned} [x_i, x_j] &= [y_i, y_j] = 0, \quad \forall 1 \leq i, j \leq n \\ [y_i, x_j] &= \delta_{i,j} + \sum_{s \in \Sigma} c_s \frac{(x_i, \alpha_s)(x_j, \alpha_s)}{(\alpha_s, \alpha_s)} s, \quad \forall 1 \leq i, j \leq n \end{aligned}$$

$$wxw^{-1} = w(x), \quad wyw^{-1} = w(y), \quad w \cdot w' = ww', \quad \forall w, w' \in W, x \in \mathfrak{h}^*, y \in \mathfrak{h}.$$

This algebra was introduced by Cherednik as a rational limit of his double affine Hecke algebra defined in [Ch]. Notice that if $c = 0$ then $H_0 = \mathcal{D}(\mathfrak{h}) \rtimes \mathbf{C}[W]$.

Lemma 3.10 implies that the algebra H_c is equipped with a homomorphism $\phi: H_c \rightarrow \mathcal{A}$, given by $w \rightarrow w, x_i \rightarrow x_i, y_i \rightarrow D_{x_i}$.

Cherednik proved the following theorem.

THEOREM 3.12 (Poincaré-Birkhoff-Witt theorem). *The multiplication map*

$$\mu: \mathbf{C}[\mathfrak{h}] \otimes \mathbf{C}[\mathfrak{h}^*] \otimes \mathbf{C}[W] \rightarrow H_c$$

given by $\mu(f(x) \otimes g(y) \otimes w) = f(x)g(y)w$ is an isomorphism of vector spaces.

Proof. It is easy to see that the map μ is surjective. Thus, we only have to show that it is injective. In other words, we need to show that monomials $x_1^{i_1} \dots x_n^{i_n} y_1^{j_1} \dots y_n^{j_n} w$ are linearly independent in H_c . To do this, it suffices to show that the images of these monomials under the homomorphism ϕ , i.e. $x_1^{i_1} \dots x_n^{i_n} D_{x_1}^{j_1} \dots D_{x_n}^{j_n} w$, are linearly independent.

Given an element $A \in \mathcal{A}$, writing $A = \sum_{w \in W} P_w w$ with $P_w \in \mathcal{D}(U)$ we define the order of A , $\text{ord}A$, as the maximum of the orders of the P_w 's. Notice that $\text{ord}AB \leq \text{ord}A + \text{ord}B$. We now remark that for any sequence of non negative indices (i_1, \dots, i_n) ,

$$D_{x_1}^{i_1} \dots D_{x_n}^{i_n} = \partial_{x_1}^{i_1} \dots \partial_{x_n}^{i_n} + l.o.t.$$

Indeed this is true for D_{x_i} . We proceed by induction on $r = i_1 + \dots + i_n$. We can clearly assume $i_1 > 0$, so by induction,

$$D_{x_1}^{i_1} \dots D_{x_n}^{i_n} = (\partial_{x_1} + l.o.t.)(\partial_{x_1}^{i_1-1} \dots \partial_{x_n}^{i_n} + l.o.t.) = \partial_{x_1}^{i_1} \dots \partial_{x_n}^{i_n} + l.o.t.$$

From this we deduce that for any pair of multiindices $I = (i_1, \dots, i_n)$, $J = (j_1, \dots, j_n)$, $w \in W$, setting $x_I = x_1^{i_1} \dots x_n^{i_n}$, $D_J = D_{x_1}^{j_1} \dots D_{x_n}^{j_n}$, $\partial_J = \partial_{x_1}^{j_1} \dots \partial_{x_n}^{j_n}$, we have

$$x_I D_J w = x_I \partial_J w + l.o.t.$$

Using this and the linear independence of the elements $x_I \partial_J w$, it is immediate to conclude that the elements $x_I D_J w$ are linearly independent, proving our claim. \square

REMARK 1. We see that the homomorphism ϕ identifies H_c with the subalgebra of \mathcal{A} generated by $\mathbf{C}[\mathfrak{h}]$, the Dunkl operators D_y , $y \in \mathfrak{h}$ and W .

REMARK 2. Another way to state the PBW theorem is the following. Let F^\bullet be a filtration on H_c defined by $\deg(x_i) = \deg(y_i) = 1$, $\deg(w) = 0$. Then we have a natural surjective mapping from $\mathbf{C}[\mathfrak{h} \times \mathfrak{h}^*] \rtimes W$ to the associated graded algebra $\text{gr}(H_c)$. The PBW theorem claims that this map is in fact an isomorphism.

3.5 THE SPHERICAL SUBALGEBRA

Let us now introduce the idempotent

$$e = \frac{1}{W} \sum_{w \in W} w \in \mathbf{C}[W].$$